

# *Projects in Big Data Software and Applications*

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# Seismic Data Analysis and Ground Motion Visualization

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**This project explore an alternative solution for seismic data management, which includes to migrate data from a relational database to a non-relational database, populate and manage seismic data in a clustered and distributed database environment, process and analyze the seismic data in Jupyter Notebook that can be potentially used as a simple work flow orchestration tool. Furthermore, we explore a fun visualization method, which is to visualize ground motion with a seismic event in the form of heat map on an interactive web page.**

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**Keywords:** Seismology, Antelope, MongoDB, Ground Motion Visualization, I523/E599

<https://github.com/cloudmesh/classes/blob/master/docs/source/format/report/report.pdf>

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## 1. INTRODUCTION

The science of seismology is awash in data. In the past 20 years the quantity of data available for the typical seismology research project has grown by at least three orders of magnitude. Our field is well fed by Incorporated Research Institutions for Seismology (IRIS [1]) that has done a fantastic job of building and maintaining an accessible archive of these data. The problem this project addresses, in fact, would not exist were it not for the ready availability of this sea of data from IRIS. The fundamental community problem this project addresses is that while the available data has grown by many orders of magnitude there have been no major software innovations for processing this ocean of data. All the standard software tools used by the research community are founding on computing concepts that were leading edge ideas twenty (Antelope [2]) to thirty (Seismic Analysis Code) years or more ago. The key premise of this proposal is that this creaky infrastructure is seriously limiting scientific advances in seismology and has imposed a throttle on scientific advances from Earthscope. The seismology community is like a group of young children given access to the Library of Congress. We can only read and use a tiny fraction of the information in this vast pile of new data.

A second principle is that the project proposed here is the engineering part of a strategic research project to address two elements needed to build a more scalable advanced processing system for seismology: (1) a meta-data handling system for data processing that is flexible, extensible, and capable of storing the full range ancillary parameters that define a data processing flow, and (2) a scalable, approachable system for implementing algorithms in the modern world of high performance computing

characterized by massively parallel systems.

## 2. SOLUTION

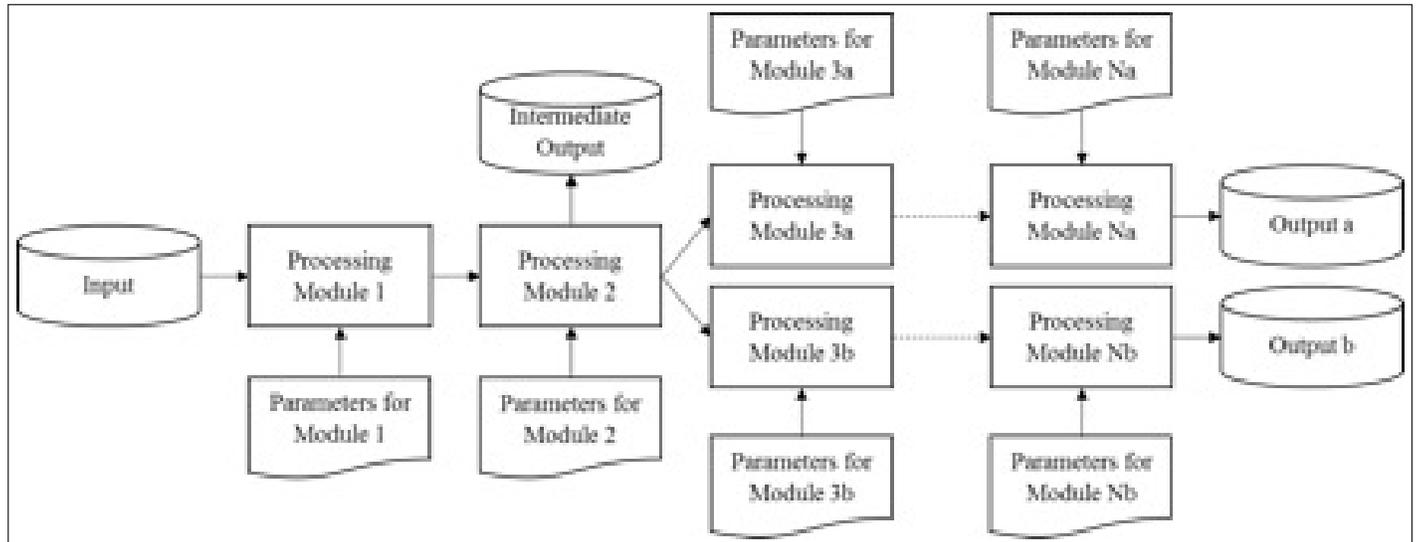
The focus of this project is to consider the efficacy of two technologies for improving passive array data processing: The seismic data processing flow in Figure 1 is a typical example of an embarrassingly parallel problem. The reason is that with this data flow model each seismogram or group (ensemble) of seismogram is processed by the same chain of algorithms each defined by the same set of control parameters. This type of problem is known to be well suited to the concept of Map-Reduce as implemented in software packages like Hadoop and Spark.

The work flow commonly begins with the input of raw data and ends with the output of processed results. The processing modules represent one component of processing such as deconvolution, velocity analysis and migration. Each processing module is independent, because the input and output conform a predefined format. Therefore, the intermediate result of each module could be saved and retrieved later. Most systems provide a means to fork into multiple work flows.

We propose to use a NoSQL database as the framework to handle all meta-data related to a collection of seismogram. The idea is to use a common NoSQL database to manage not just conventional header information, but also input parameters for all processes and log information from each processing module.

### 2.1. Seismic Data

The seismic data includes meta-data and wave form. The meta-data contains the information related a seismic event like geo-location, magnitude, time, duration, etc. The wave form is a



**Fig. 1.** Generic work flow for processing of seismic reflection data

digital signal which is comprised of a discrete value at each sampling point. As we said earlier, because the standard software used in seismology community. The data set is stored and managed separately. The meta-data is stored and managed by Antelope and wave form are stored on the file system. The data set we used is downloadable at USArray, IRIS [3]. The data downloaded from IRIS are encrypted as structured binary files called Standard for the Exchange of Earthquake Data (SEED), which is a data format intended primarily for the archival and exchange of seismological time series data and related metadata [4].

## 2.2. Data Migration

To extend the flexibility of the seismic data management and the data scalability, we replace Antelope with MongoDB, an open-source non-relational database [5], to store and manage not only the meta-data but also the wave form files.

To extract, transfer and load the seismic data from Antelope and file system to MongoDB, a data transfer tool is developed. The tool uses the Antelope Python API to extract the meta-data from Antelope. It also uses a seismological data processing library to read and decrypt the SEED file from the file system and extract the time series from them. In order to store all the data into MongoDB, MongoDB Python API is used to access MongoDB and pickle (Python object serialization module) is used to serialize the wave form data and populate in MongoDB.

After the data migration, we deploy sharding [6] for MongoDB to have a better data scalability and automatic backup.

## 2.3. Data Visualization

We choose transportable array wave visualization to visualize ground motion. Ground motion visualization is a visualization of real data showing how seismic waves sweep across the USArray network of seismic stations [7]. The Transportable Array is a high-quality broadband seismographs and atmospheric sensors network forming a grid pattern [8]. By associating the ground placement with circles in different colors, we can visualize the real-time ground motion monitored by these seismographs in the Transportable Array. For example, we represent a grey circle as a seismograph at rest, a red circle as a seismograph moving

up and a blue one as moving down. The gradient of the color represents how much it moves up or down. To visualize the transportable array wave, we feed the circle grid with the seismic data the seismograph/monitor observed in a continuous fashion.

## 3. SOFTWARE

Here is a list of language/software/tool/library components described as following.

### 3.1. Language

Python is the programming language to perform data analysis in this project. Javascript and HTML are the languages used for data visualization.

Pyenv is a simple Python Version Management tool to easily switch between multiple versions of Python [9]. Virtualenv a tool to create isolated Python environments [10]. pip is a package management system used to install and manage software packages written in Python [11]. We use the above three tools to manage the Python versions, virtual environments and Python software packages in this project.

Jupyter Notebook is an open-source web application to create and share documents that contain live code, equations, visualizations and explanatory text [12]. We use Jupyter Notebook as a work flow orchestration container of this project. We put most of the code, functions, data analysis, visualizations and explanatory text in the notebook.

### 3.2. Database

Antelope is an integrated collection of programs for data collection and seismic data analysis, and typically runs at the central processing site [2]. The raw data downloaded from USArray will be loaded into Antelope. Because Antelope only supports CentOS/RedHat, we use CentOS 7 as the default operating system for this project. In order to read meta-data from Antelope, we use Antelope Python API to extract data from Antelope.

MongoDB is an open-source, document database designed for ease of development and scaling [13]. We use MongoDB as a framework not only to handle all meta-data related to a collection of seismogram but also to store all the wave form files

in GridFS to provide data scalability. GridFS is for storing files larger than 16 MB [14]. To store the meta-data we read from Antelope, we use PyMongo [15] to access MongoDB and pickle to serialize the wave form data before we write it into GridFS.

### 3.3. DevOps

Cloudmesh client is a lightweight client interface of accessing heterogeneous clouds, clusters, and workstations right from the users computer [16]. It provides an API, a commandline client and a commandline shell. Cloudmesh client has several key features including security management, virtual instances management. We use Cloudmesh client shell to deploy our cluster on the cloud.

Ansible is a radically simple IT automation platform that makes your applications and systems easier to deploy [17]. By using the Ansible playbook provided by Ansible example [18], we are able to setup a sharded MongoDB cluster in a short time.

### 3.4. Libraries

ObsPy is an open-source project dedicated to provide a Python framework for processing seismological data, providing parsers for common file formats, clients to access data centers and seismological signal processing routines which allow the manipulation of seismological time series [19]. For the data analysis part, we use ObsPy to parse the wave form file (MiniSEED) and manipulate the seismological time series.

Matplotlib is a Python 2D plotting library which produces publication quality figures in a variety of hardcopy formats and interactive environments across platforms [20]. We use it to plot histogram to help us to find the median of the amplitude.

D3JS is a JavaScript library for manipulating documents based on data and it helps to bring data to life using HTML, SVG, and CSS [21]. D3JS is used in data visualization part along with HTML, Javascript and CSS.

Mapbox GL JS is a JavaScript library that renders interactive maps from vector tiles and Mapbox styles using WebGL [22]. Leaflet is the leading open-source JavaScript library for mobile-friendly interactive maps [23]. We use Mapbox to render an interactive map on web page as a base map and use Leaflet to render heat map with seismic data as each heat point on top of base map to visualize the ground motion.

## 4. INFRASTRUCTURE SETUP

We setup the infrastructure in this section, which includes cluster installment on Chameleon cloud, database installment and configuration, and processing environment setup.

### 4.1. Chameleon Cloud

Chameleon cloud is a large-scale platform providing Infrastructure as a service (IaaS) to the open research community in deeply programmable cloud services, design, and core technologies funded by the National Science Foundation (NSF) [24]. Chameleon cloud provides multiple ways of access. One way is the bare-metal deployment through either web interface or command line [25]. Another way is OpenStack KVM virtualization technology with OpenStack web interface [26]. OpenStack is a cloud operating system that controls large pools of compute, storage, and networking resources throughout a datacenter, all managed through a dashboard that gives administrators control while empowering their users to provision resources through a web interface [27]. Chameleon cloud opens the OpenStack REST Interfaces over secure HTTP connections.

### 4.2. Cluster Installment

To setup the virtual cluster on Chameleon cloud, we use Cloudmesh client toolkit. Cloudmesh client toolkit uses the OpenStack REST Interfaces to access the virtual machines on Chameleon cloud. We first prepare the Cloudmesh setup by modifying the YAML file it generates. Cloudmesh demands our username and password to access Chameleon. The configuration also includes setting the default cloud, which is Chameleon cloud, setting the default virtual machine flavor and image to instantiate, creating an SSH key pair and adding it to Cloudmesh, setting a security group (firewall setting). Since the public images Chameleon provides are not configured with a default root password, the SSH key is the only key to log in to virtual instances.

After the configuration, we upload the SSH public key to Chameleon cloud along with the security group setting. To define and launch the virtual instances, we use the Cloudmesh *cluster define* and *cluster allocate* command.

### 4.3. Cluster Installment Benchmark

To automate cluster installment, we implement a shell script to automatically deploy arbitrary number of instances within a cluster on Chameleon cloud. Figure 2 is the benchmark result that we run locally to scale instance numbers from 1 to 8 on Chameleon cloud. As we can tell from the figure, the time to create is almost exponential. That's because within the setup phase of the deployment. The time to setup Cloudmesh is constant (add key, security group, upload key and security group setting). However, when allocating the actual instances, it not only requires a long of communication but also waits a long time for each instance to be assigned a floating IP from Chameleon cloud. When we scale the instance number, the communication delay and floating IP assign wait become the overhead that increases exponentially.

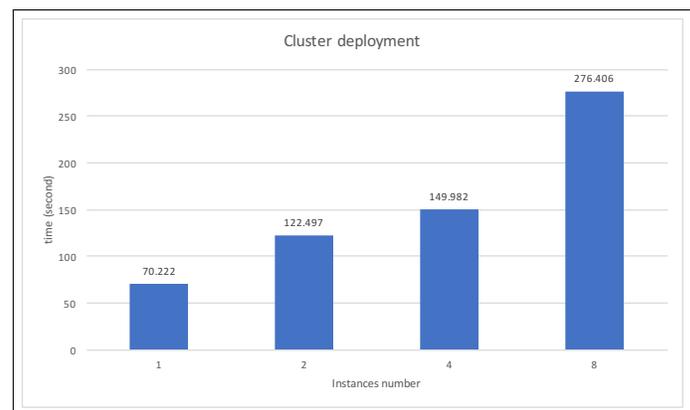


Fig. 2. Cluster Instance Number Scaling

### 4.4. Antelope Installment

Since we only need one node to contain the original data, we install Antelope on one node, which is used as head node within the cluster. Because Antelope is not an open-source software, the installation is manual only. After a manual registration process on the Antelope website, a download link of the installation ISO will be sent to us. Through the link, we download the install ISO with *wget* command directly onto one of the virtual instances on the cloud. Next, we mount the ISO to the file system and install

it following the installment instructions. Free non-commercial license is needed to activate it after installment. To obtain one, we send the license request along with the required information to Brtt.inc [28]. They return an license along with activation instructions within a few business days. Once we upload the license to the installment directory as instructed, Antelope is ready to use.

#### 4.5. MongoDB Sharding Installment

To have a MongoDB sharding deployed, the fastest way is to use Ansible, which seamlessly unites workflow orchestration with configuration management, provisioning, and application deployment in one easy-to-use and deploy platform [17]. Using [18], we are able to deploy a sharded, production-ready MongoDB cluster within several minutes. First, we need to install Ansible on the head node. Then we need to make sure head node can log in to other nodes without password. To do that, a SSH key pair must be generated and add the content of the public key to authorized keys on all nodes within the .ssh directory. This process can be quite annoying but luckily we have Cloudmesh client. The Cloudmesh command, *cluster cross\_ssh*, will automate this procedure. When the cluster is ready, we execute the Ansible playbook we clone from [18]. After some time, we have a sharded MongoDB cluster configured and ready to use. Figure 3 illustrates the deployment model for a MongoDB cluster deployed by Ansible.

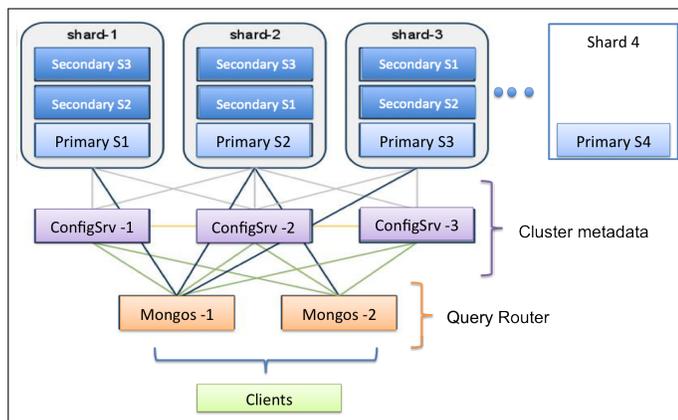


Fig. 3. Sharded MongoDB Architecture [18]

This deployment model focuses on deploying three shard servers, each having a replica set, with the backup replica servers serving as the other two shard primaries. The configuration servers are co-located with the shards. The mongos servers are best deployed on separate servers. This is the minimum recommended configuration for a production-grade MongoDB deployment. Please note that the playbooks are capable of deploying N node clusters, not limited to three. Also, all the processes are secured using key files. Also, a manual deployment solution is included in the notebook, through comparing with Ansible solution, it is painful and slow.

#### 4.6. Data Migration

Data migration tool is used after sharded MongoDB cluster is created and booted. We use shell script to automate the data migration process. Since, this tool is only a one-time job, no parallelism is implemented to boost the speed. Since it's single thread, it takes long time if the migrate data is large. As the

details described before, the tool uses Antelope Python API to read and PyMongo to write. We design and update the exist database schema to fully utilize the flexible schema the non-relational database provides. Each table in Antelope is more or less the same as a collection in MongoDB.

#### 4.7. Processing Environment Setup

Because Jupyter Notebook is able to have a mixture of codes, functions, data analysis, visualizations and explanatory text in one notebook, we use Jupyter Notebook to orchestrate our work. To have the Python environment ready on the cluster, we create an isolated Jupyter ipython kernel with Pyenv and Virtualenv with *pip* [29]. At last, we install the supporting libraries PyMongo and ObsPy in the same Python environment.

Now we start Jupyter Notebook in background on the head node. But because Jupyter Notebook is running in the virtual cluster and can only be access through a local browser, we need to use SSH tunneling as a proxy to access the notebook remotely, as for on our laptop. In this way, we still use SSH port 22 to access Jupyter Notebook to avoid modifying the security group setting in Cloudmesh client.

### 5. SEISMIC DATA ANALYSIS

We process and analyze the raw seismic data, then transform it for better visualization.

#### 5.1. Seismic Event Selection

The *origin* collection in MongoDB contains the origin information of the seismic events including latitude, longitude, depth, time, etc. With PyMongo, we read the origin collection from MongoDB and select a seismic event from it which occurred at 2009-04-07 04:23:00 UTC at latitude  $46^{\circ}2'56.4''N$ , longitude  $51^{\circ}32'52.8''E$ , where located at north Caspian Sea and with depth 31 kilometer. Then we read the wave form data from MongoDB.

#### 5.2. Seismic Data Processing

Next, we process the wave form data that we want to visualize. First of all, by cross checking the arrival collection and sites collection, we get all US sites' latitude, longitude which successfully monitor this event. Since we want to depict the vertical motion of the ground, we only use the BHZ trace in the wave form data. BHZ trace represent the vertical movement of ground motion. After filtering out the noise in BHZ trace data, we combine the amplitude data with its related site information where the seismic data is recorded.

We apply two simple digital signal processing methods on the seismic data, filtering and decimation. The reason to filter the digital signal is to reduce the data size. We apply a low-pass filter to remove the high-pass signals. Same reason to decimate the seismic data, we want to have less data on this event to visualize. In this case, we decimate the seismic data in the factor of 4 by throwing away three quarter of the total samples.

#### 5.3. Seismic Data Analysis

We still need more information to help us visualize the raw wave form data. We use heat map to visualize the seismic data. A heat map is a graphical representation of data in which values are represented by colors [30]. The reason why we choose it will be discussed later. But how can we associate the ground motion with the heat map?

In order to demonstrate the distribution of the seismic data, we plot the histogram of the seismic event we select using Matplotlib as in Figure 4. As we can tell from the distribution, most amplitude is around zero. However, to better identify the exact number on positive amplitude and negative amplitude, we use the percentile function in Numpy library to get the 15% percentile and 85% percentile of amplitude data. We next use the 15% percentile amplitude data as the maximum negative amplitude and 85% percentile as the maximum positive amplitude. Since the data distribution is not symmetric, we choose 50% percentile rather than zero amplitude as our "zero" amplitude.

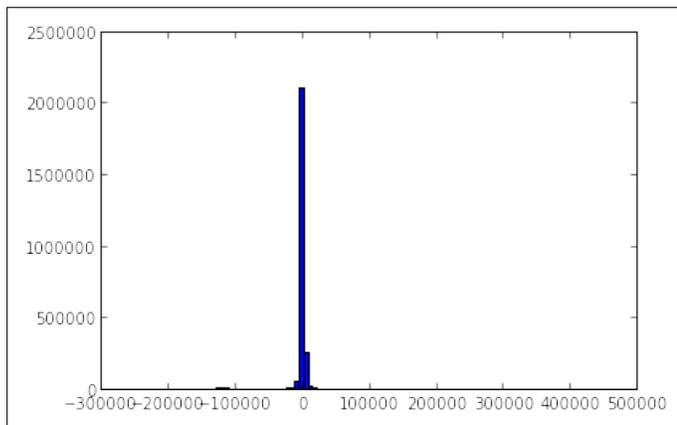


Fig. 4. Seismic data histogram of the seismic event we select

We choose the sample rate of the seismic data as 10, which means that the time interval of reading every two successive data is 0.1s. In heat map, the key property is the density value, which represents the density of the dots in the map. By treating the amplitude as density value, we are able to visualize the amplitude variance at each site. We combine the density value with the latitude and longitude of each site where the data is monitored to generate a 3-element tuple as a element of a data sample. So for each data sample we read, we get 450 tuples (because there are 450 sites monitored this event in US). These 450 tuples make up a 'frame' in our visualization. In addition, we divide these 450 tuples into 3 groups. The first group consists of all tuples that their density represents the positive amplitude, the second group consists of all tuples that their density represents the negative amplitude and the last group consists of all tuples that their density represents that the station didn't receive seismic data or the amplitude is zero.

Finally, we encapsulate the tuples generated above as list variables within Javascript files. Because the data was so large that if we write them to only one file, it cost so much time to load the file and may cause web kernel crash in some browsers. Hence, we divide the data to 4 variables among 4 separate files. All we need to do in web page with Javascript is to load these files and read them successively.

## 6. GROUND MOTION VISUALIZATION

After we have the processed seismological data (time series data) ready, we implement a transportable array wave visualization on web page in HTML and Javascript with D3, Mapbox and Leaflet libraries.

### 6.1. Heat Map Implementation

In the web page, we select heat map as our visualization method. The reason why we choose heat map is that the heat map provides some very good properties like radius, blur and gradient. Especially gradient, with the density value, we can easily map the amplitude of the seismic wave to density and show how much the ground moves up and down by changing the gradient of that heat point. Also, because heat map can have multiple heat layers, we can utilize this feature to show different types of ground motion. We use the red dots to represent the positive amplitude, the blue the negative, and the grey the zero. In this way, we have a clear contrast on the heat map on different ground motions.

First of all, we plot a base map of the North American continent with Mapbox. We partition all the time series into three groups: positive amplitude, zero amplitude and negative amplitude. Using Leaflet, we generate a layer of heat map for each group and plot on top of the base map. Within the heat map, the geo-location of each heat point is calculated by the latitude and longitude of the seismographs. For each heat point, we populate the time series data one by one from the beginning to the end at the same pace. The time series data at each heat point is plotted into colored circle in different colors and sizes based on which group. We use the gradient of the color and the size of the circle to represent the amplitude of the ground motion for each heat point. The darker the color is, the more positive/negative the amplitude is.

Javascript provides several ways to animate. What we use is a function in D3 called *SetInterval*. We populate one data sample (frame) of data to the heat map in a continuous fashion in each interval of time and plot. The time interval is modifiable, hence, we use this to adjust the animation speed. Then in the next time interval, we clear the previous layers and populate the next frame of data to the heat layer and plot. In this way, we are able to visualize the seismic data as the ground motion.

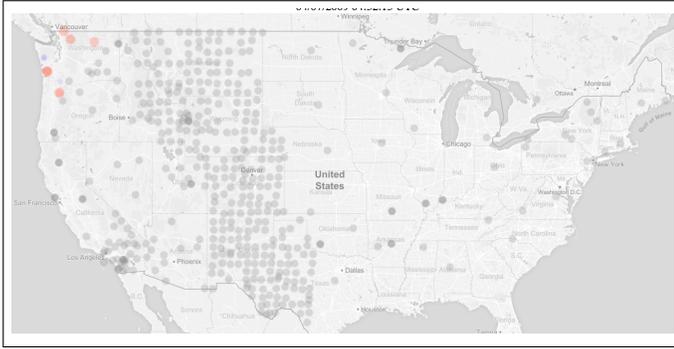
Furthermore, we add several interactive features to the web page. Different colors can be associated with positive/negative amplitude. Animation speed is adjustable as well.

### 6.2. Ground Motion Visualization

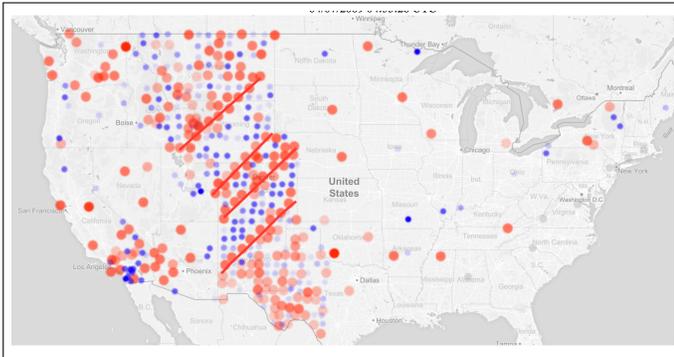
Figure 5 is a screenshot of the moment when this seismic event just reach USA, which is first monitored by sites in Washington State. In Figure 6, it is the screenshot of the moment when the seismic wave reaches the Caribbean Sea. We emphasize the seismic wave by drawing red lines on the figure. As we can tell, the seismic wave travels from northwest to southeast on the surface of earth. We can tell that the seismic wave is clearly distinguishable in the visualization.

## 7. FUTURE WORK

In this project, the deployment is a pain. One of the reason is the registration process of Antelope. Bypassing this, we can automate all the deployment process with Ansible. Second pain is the data migration. Considering the large amount of data, a parallel version of data migration tool can be implemented to boost this process. The third improvement can be done is data processing. In a larger scope, the data processing part can be paralleled by using big data frameworks such as Hadoop or Spark. Finally, the last improvement is data visualization. This part is inspired by USArray GMV Project at IRIS. Maybe there is a better way to visualize the ground motion. But as for this



**Fig. 5.** The seismic event reach USA



**Fig. 6.** The seismic wave during the seismic event

project, a few more features can be added to the web page such as play/pause, forward/backward, etc.

## 8. SUMMARY

In this project, we deploy a virtual cluster on Chameleon cloud with Cloudmesh client toolkit. We install Antelope on the head node of our cluster and set a sharded MongoDB cluster to replace the relational database with non-relational database to help manage and store the meta-data and wave form file we downloaded from IRIS. By using the Ansible example on deploying a product-ready Sharded MongoDB, we achieve a much better performance than doing it manually. With the data migration tool we implemented, we are able to extract, transfer and load the data in Antelope to MongoDB. We observe that the non-relational database is capable to manage the meta-data and even wave form data in a scalable and distributed fashion. With the sharding, we provide fault tolerance, overall high throughput and high data availability. MongoDB is not an alternative to Antelope. It is much flexible in data management and storage. However, we also see that MongoDB is merely a database. On the other hand, Antelope is a mature seismological framework with many other features. But thanks to the open-source community, ObsPy is very handy and helpful in seismological data processing. Furthermore, we deploy an isolated Python environment for seismic data processing with ObsPy. By using Jupyter Notebook, we experience the ease of putting the code, functions, data analysis, visualizations and explanatory text at one place. This is helpful to organize the research and orchestrate the work flow of the research. At last, we visualize the ground motion with a seismic event we select in the form of heat map in an interactive web page.

## ACKNOWLEDGEMENTS

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S17-IO-3004/report/report.pdf not submitted

S17-IO-3009/report/report.pdf not submitted

# Remotely Deploying, Visualizing and Controlling a Robot Swarm with ROS and Cloudmesh

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Working with robot swarms has emerged as an important area of robotics research. Since the cost of deploying physical robot swarms could prove time-consuming and cost-prohibitive to research departments, the field needs a convenient, cost-efficient method of educating the next generation of experts. Hence, we explore the feasibility of simulating such swarms while harnessing remotely-located, distributed computing environments to conduct such simulations. In particular, our interest lies in using and re-using cloud computing resources to simulate large-scale robot swarms. Therefore, we produced the proof-of-concept deployment model described in the following pages, which creates a two-robot virtual swarm on multiple clouds to which we have access. Importantly, deployment occurs with minimal user intervention, opening up the research field to STEM students and undergraduate freshmen, as well as PhD students. Users can observe the robots' behavior through a streamed visual simulation. We demonstrate that users can start up the behavior of a robot through a single command, allowing us to benchmark the activity streams of the swarm in the cloud. The project uses open source software throughout, including the Open Source Robotics Foundation's (OSRF) Robot Operating System to define, create and control the virtual robots. The OSRF's *Gazebo* program provides the visualization of the simulation. *Cloudmesh* simplifies interaction with the various clouds we use.

**Keywords:** Cloud, I524, ROS, Gazebo, Robot, Swarm

Report: <https://github.com/cloudmesh/sp17-i524/tree/master/project/S17-IO-3010/report/report.pdf>

Code: <https://github.com/cloudmesh/cloudmesh.ros>

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## 1. INTRODUCTION

With the evolution of robotics and its increased influence in society we anticipate the need to deal with robot swarms. Thus, we need to educate the next generation of scientists by offering the ability to simulate a multiple and diverse sets of robot swarms. Simulation mitigates operational risk prior to real-world deployment even as it allows researchers to interact with swarms while conducting actions and observing the swarm's responses to its environment. Furthermore, simulation on a cluster of remotely-located computers allows users to conduct such research in a cost-effective manner on platforms with computational capabilities far in excess of those provided by a single workstation. The question we ask, would it be possible to simulate tens of thousands of robots in a cloud environment?

However, deployment of an interconnected swarm of virtual robots in a cloud imposes additional requirements on the scientist researching such swarms. Although researchers can choose from a multitude of cloud providers currently, provisioning and configuring multiple computers presents a time and resource challenge versus a single-host setup. In addition, network se-

curity measures, such as ssh keys and port access, impede ROS' intra-cluster communication capabilities. Since these aspects typically remain out of reach for entry-level educational communities such as college freshmen or non-technical STEM students, our project attempts to lower the barrier of managing such a *virtual swarm* to a level accessible by individual researchers as well as freshmen and STEM students. In order to address the unique requirements of a networked, remotely-located swarm, we develop a multi-platform system to automate the creation and deployment of the virtual swarm, with access to numerous clouds enabled by *cloudmesh* [? ].

## 2. VIRTUAL ROBOT SWARM COMPONENTS

### 2.1. Robot Operating System (ROS) [1]

The Open Source Robotics Foundation's middleware product *Robot Operating System*, or ROS, provides a framework for writing operating systems for robots. ROS offers "a collection of tools, libraries, and conventions [meant to] simplify the task of creating complex and robust robot behavior across a wide variety of robotic platforms" [3]. The Open Source Robotics

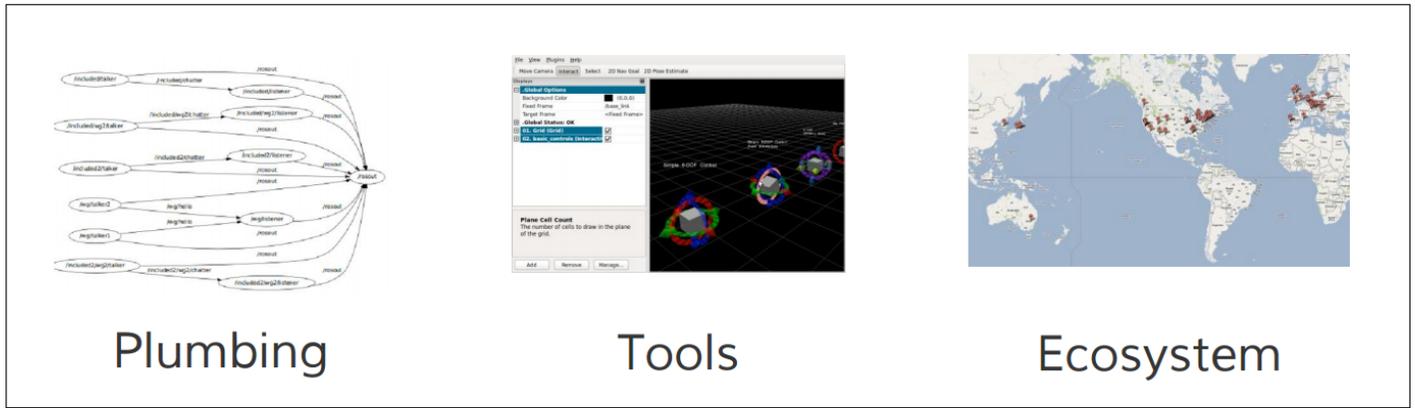


Fig. 1. A Conceptualization of What ROS, the Robot Operating System, Offers to Roboticians [2]

Foundation, hereinafter OSRF or the Foundation, attempts to meet the aforementioned objective by implementing ROS as a modular system. That is, ROS offers a core set of features, such as inter-process communication, that work with or without pre-existing, self-contained components for other tasks.

Figure 1 depicts the three parts of the ROS universe: a) the plumbing, ROS' communications infrastructure; b) the tools, such as ROS' visualization capabilities or its hardware drivers; and c) ROS' ecosystem, which represents ROS' core developers and maintainers, its contributors and its user base.

The modules or packages, which are analogous to packages in Linux repositories or libraries in other software distributions such as *R*, provide solutions for numerous robot-related tasks and challenges. General categories include a) drivers, such as sensor and actuator interfaces; b) platforms, for steering and image processing, etc.; c) algorithms, for task planning and obstacle avoidance; and, d) user interfaces, such as tele-operation and sensor data display. [4]

### 2.1.1. Communications Infrastructure

**General** OSRF maintains three distinct communication methods for ROS: a) *message passing*; b) *services*; and, c) *actions*. Each method utilizes ROS' standard communication type, the *message* [5]. Messages, in turn, adhere to ROS' *interface description language*, or IDL. The IDL dictates that messages should be in the form of a data structure comprised of typed fields [6]. Finally, *.msg* files store the structure of messages published by various nodes so that ROS' internal systems can generate source code automatically. The virtual swarm and the talker/listener robots utilize ROS' message passing capabilities in project's this implementation.

**Message Passing** ROS implements a publish-subscribe anonymous message passing system for inter-process communication, hereinafter pubsub, as its most-basic solution for roboticians. A pubsub system consists of two complementary pieces: a) a device, node or process, hereinafter node, publishing messages, i.e., information, to a *topic*; and b) another node *listening to* and ingesting the information from the associated topic. Designating topics to which a node should subscribe and topics to which a node should publish falls to the robotician. ROS' *rostopic* command line tool conveniently "display[s] a list of active topics, the publishers and subscribers of a specific topic, the publishing rate of a topic, the bandwidth of a topic, and messages published to a topic" [7].

Pubsub's method of operation analogizes to terrestrial ra-

dio. In the analogy, the radio station represents the publishing node, the radio receiver maps to the subscribing node and the frequency on which one transmits and the other receives represents the topic. Unlike terrestrial radio, though, ROS provides a lookup mechanism versus "flipping through the dial."

The OSRF touts the pubsub communications paradigm as the ideal method primarily due to its anonymity and its requirement to communicate using its message format. With respect to the first point, the nodes involved in bilateral or multilateral conversations need only know the topic on which to publish or subscribe in order to communicate. As a result, nodes can be replaced, substituted or upgraded without changing a single line of code or reconfiguring the software in any manner. The subscriber node can even be deleted entirely without affecting any aspect of the robot except those nodes that depend on the deleted node.

In addition, ROS' pubsub requires well-defined interfaces between nodes in order to succeed. For instance, if a node publishes a message without a crucial piece information a subscribing node requires or in an unexpected format, the message would be useless. Alternatively, it would be pointless for an audio processing node to subscribe to a node publishing lidar data. Therefore, a message's structure must be well-defined and available for reference as needed in order to ensure compatibility between publisher and subscriber nodes. As a result, ROS has a modular communication system. That is, a subscriber node may use all or only parts of a publishing node's message. Further, the subscribing node can combine the data with information from another node before publishing the combined information to a different topic altogether for a third node's use. At the same time, a fourth and fifth node could subscribe to the original topic for each node's respective purpose.

Finally, ROS' pubsub can natively replay messages by saving them as files. Since a subscriber node processes messages received irrespective of the message's source, publishing a saved message from a subscriber node at a later time works just as well as an actual topic feed. One use of asynchronous messaging: postmortem analysis and debugging.

### 2.2. Gazebo

The Foundation also supports *Gazebo*, ROS' 3D virtual simulation software. "Gazebo...simulate[s] populations of robots in complex indoor and outdoor environments. [It] offers physics simulation at a much higher degree of fidelity [than gaming engines], a suite of sensors, and interfaces for both users and



or CC. A 100Gbps connection runs between the two centers. Project development primarily occurred on three-node clusters created as needed using Chameleon Cloud's *m1.medium* flavor of Ubuntu 16.04. Deployment testing also utilized the *m1.small*, *m1.xlarge* and *m1.xxlarge* flavors CC provides.

**Table 1.** Deployment Resources

Chameleon Cloud Flavor Specifications			
Flavor	vCPU	RAM	Hard Drive
m1.small	1	2	20
m1.medium	2	4	40
m1.large	4	8	80
m1.xlarge	8	16	160

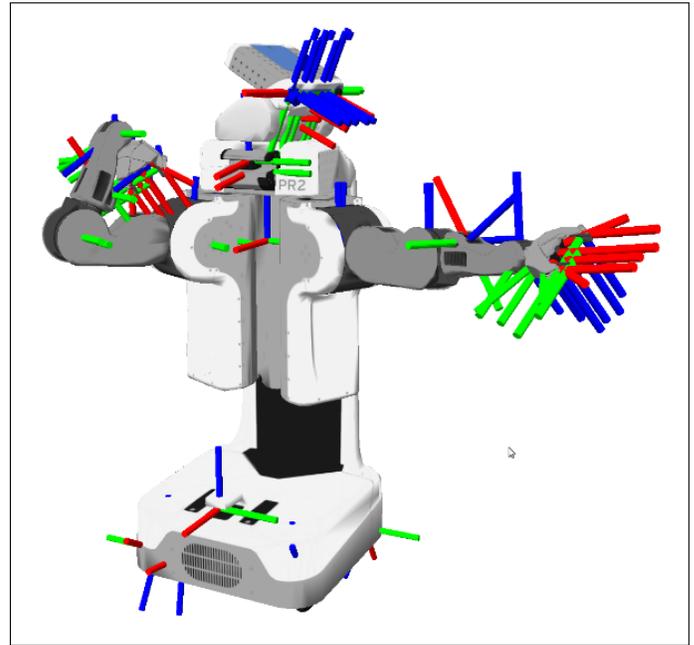
*vCPU*: count of virtual CPUs; RAM units: MB; Hard Drive units: GB

## 2.6. Robots and Worlds with ROS

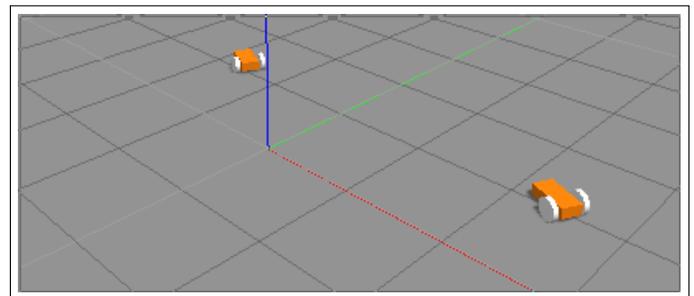
A ROS robot may be extremely simple, such as the pre-built talker and listener robots supplied in the ROS distribution, or as complex as the roboticist desires. If users desire to visualize the robot, s/he must define his / her ROS robot in *Universal Robot Description Format*. A ROS robot's specifications reside in a series of files with *xacro* extensions, referred to as URDF files. These files, which borrow XML's syntax structure, can include specifications for the basic shapes of the robot and its appendages (if applicable), e.g., rectangular box, cylinder, etc. with attached wheels; various kinds of joints, such as ones that rotate around an axis or extend along an axis; types and numbers of sensors; number of joints in an appendage; colors of the robot(s); etc., etc. In addition, any file in the robot description stack may reference an external file to complete the description of the robot. This capability allows the user to re-use code by incorporating previously-completed robot features into a new robot. Finally, simulations include a world file to provide the setting, or environment, in which the robot simulation occurs. As with the URDF files, the world file can be simple, like the *empty\_world* file included in the ROS distribution or extremely complex.

Finally, a simulation package will include one or more *launch* files. These files coordinate the disparate aspects of the entire simulation package in a manner similar to that of Ansible's playbook file. According to the OSRF, best practices for robot simulation dictate that the main launch file consist of little more than calls to other launch files in the package [18]. Continuing with the playbook analogy, the launch files called from the main launch file would correspond to the roles defined in Ansible. This functionality significantly increases ROS' usability since managing even relatively straightforward robots, simulated or real, can prove unwieldy. For instance, this project, a proof-of-concept project, utilizes a *.world* file, four URDF files and four launch files in addition to the pre-compiled talker and listener robots.

This project uses two straightforward differential drive robots sourced from an online tutorial entitled *Simulating Robot Models in ROS (part 1)* [19]



**Fig. 3.** Example of a Complex Simulated Robot



**Fig. 4.** Example of Two Simpler Robots

### 3. VIRTUAL ROBOT SWARM PROJECT IMPLEMENTATION

#### 3.1. VR Swarm task

Although the swarm accomplishes the seemingly-trivial task of driving in circles, the real accomplishment rests in proving the feasibility of automating the deployment of multiple controllable virtual robots on a remote cluster of computers and then visualizing them on a local computer.

#### 3.2. Deployment

Achieving the aforementioned task requires coordinating a modestly-complex mix of shell commands, cloudmesh commands, Ansible commands and ROS / Gazebo commands. A shell script provides the automation for the shell, cloudmesh and ROS commands, while Ansible's *playbook* functionality handles the Ansible-focused portion. Only the initial step, retrieving and sourcing the shell script that begins the deployment process, requires user intervention. However, if the user wants to listen to the talker robot (*talker.py* and *listener.py*), s/he needs to follow the steps described in the README file.

**wget...begin - Retrieve the Initialization Bash Script** Deployment begins when the user retrieves the initialization file, named *begin*, from the project's Github repository. The user then starts the execution sequence by sourcing the file with the command

```
> ./begin
```

from the directory where the *begin* bash script resides.

**begin bash script** The bash script calls three cloudmesh\_client commands:

1. > cm cluster define -n rosA1 -c 3
2. > cm cluster allocate
3. > cm cluster cross\_ssh

The script creates and prepares a three-node cluster named *rosA1*. We then use two additional Cloudmesh commands:

1. > cm cluster nodes
2. > cm vm ip show

to capture the public and private ip addresses of the cluster, as well as the host names.

The ip addresses and names are written to separate files for distinct purposes. The host names and private ip addresses are used to create a file to append to each cluster node's *known\_hosts* file. The private ip addresses also end up in a different file that serves as the basis for a custom Ansible inventory file.

The private ip addresses, termed static ips by Chameleon, must be used because ROS nodes communicate by binding to any available port. That is, ROS does not specify the port beforehand, and it does not consider whether or not the firewall blocks the port for security purposes. As a result, intra-cluster communication requires access to every port, i.e., the firewall cannot close any port on any computer running ROS when that computer needs to communicate with another computer in the cluster. Obviously, this presents a major security concern, especially on shared resources. Refer to the *Deployment Obstacles* section below for the workaround used with this project.

As its penultimate step, the *begin* script places all the necessary files for the demonstration on the correct cluster nodes. The ROS robot files and the Ansible files go onto the main node, while the script places a copy of the *known\_hosts* addendum onto each cluster node. In addition, the script uses the *wget*

command to copy the bash script for the next step in the process onto the main node.

The final lines of the file initiate the next step in the process, running the *beginAgain* script on the master node, and perform a few administrative duties.

**beginAgain bash script** This script handles the software installation and initialization of the robots. It first establishes the veracity of the main node and the other nodes by connecting to each one in turn via ssh connection. If these steps do not occur before Ansible runs, the software installations never occur because Ansible hangs mid-process. Ansible installs all the necessary software on each cluster node. It installs Linux's *tree* package because the author prefers to use it to view directory structures; the ROS package; the *roshash* package; the *rosinstall* package; and, the *catkin\_tools* package. Ansible also creates a new *known\_hosts* file for each computer node.

Upon completing the installation, the file's instructions initialize the robot workspace. The *catkin\_tools* package accomplishes this on behalf of ROS. *catkin\_tools* represents an evolution of ROS' built-in *catkin* family of commands. Initializing the robot workspace essentially involves the addition of numerous hidden helper files, which assist in building the robot package. Creating the robot package, referred to as *building* the package, involves a series of automated *CMake* commands.

With the robot package built, the script copies another script from github. This small script starts ROS' *talker* robot, a simple robot included as part of ROS' tutorial packages. It relies upon Linux's *byobu* program to set up usable working environment if the user chooses to start the listener robot on the third cluster node.

Finally, execution of the last few lines of the script occurs. These lines start ROS, start the two robots, create a simulated world for the robots and then issue a command for the robots to drive in circles. Gazebo's simulation of the robots and their world come back through the ssh connection to the end user so s/he can see the simulation in real time.

**talkListen bash script** The *talkListen* script sets up a multiplexed terminal environment on the second node and starts ROS' talker robot, which ROS' maintainers include as a pre-built package with the distribution. It relies upon Linux's *byobu* terminal multiplexing program. Using a series of *> byobu -tmux ...* commands, it creates a terminal screen with three panels. ROS's *rosmaster* program starts in panel 1, while the talker program/robot/node starts in Panel 2. The final panel, panel 0, connects to the third node in the cluster in anticipation of the user starting the listener program (also included in the ROS distribution).

#### 3.3. Deployment Performance

In general, completing the deployment process took around 500 seconds, or eight minutes and 20 seconds. Much of that time, around five minutes, consisted of installing ROS on the cluster nodes. Since Ansible completes each individual step of a playbook on each cluster node simultaneously, users should be able to provision a 5-, 10- or 100-node cluster as quickly as the three-node cluster used in this project, barring network communication bottlenecks, etc.

The total amount of time needed increased when using a higher-spec Chameleon Cloud flavor, as shown in the nearby table. However, the first portion of the process, handled by the *begin* script consistently takes about 130 seconds, irrespective of the node's vCPU/RAM/HD combination.

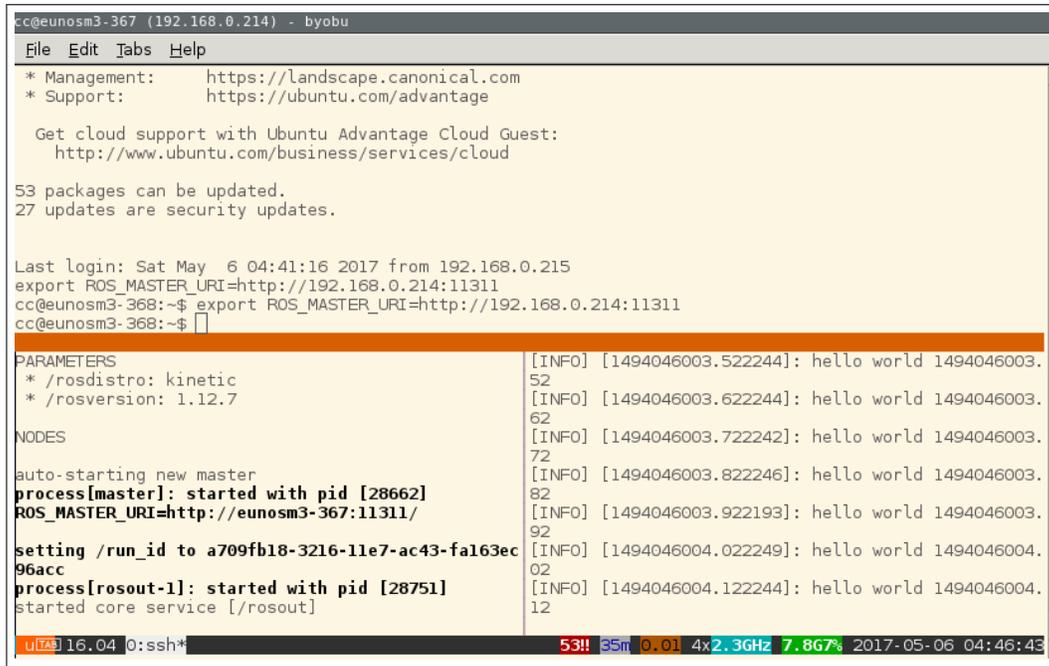


Fig. 5. The Multiplexed Talk-Listen Terminal

Furthermore, deployment failures seem to occur about 50% of the time, independent of the CC flavor chosen. Anecdotally, then, vCPU/RAM/HD combinations do not seem to be the first suspect to investigate with respect to failed deployments.

Table 2. Virtual Swarm Deployment Times

Flavor	Time Needed to Deploy (mean; seconds)			Notes
	Part 1	Part 2	Total	
m1.small	144	441	555	4/6 attempts succeeded
m1.medium	129	358	487	2/6 attempts succeeded
m1.large	134	401	534	3/6 attempts succeeded
m1.xlarge	—	—	—	no successes

Part 1: Consists of *begin* shell script  
 Part 2: Consists of *beginAgain* shell script, which includes the Ansible playbook and installation of ROS

### 3.4. Deployment Obstacles

**Intra-Node Communication** In order to maintain security and enable intra-cluster communication, two of the three computer nodes must have their public ip addresses removed, i.e., disassociated, using Chameleon’s browser-based graphical user interface (GUI), Horizon. Then, and only then, the ports can be opened by applying the *ros* security group to the two nodes in question (the private nodes). Since the third node, the main node, still has a public-facing ip address, the other two nodes can be accessed via an ssh connection (*ssh’ing*) to the main node and then *ssh’ing* to one of the private nodes.

**Deployment Problems** Even if a script or a user completes each step correctly to set up a controllable virtual swarm on remotely-located resources, problems still occur that cause deployment

failures. Usually, the issues can be resolved with manual intervention, so the deployment can be completed.

**Adding the ROS Repository Key** The deployment often went awry during the Ansible script step that retrieves the repository key for the ROS repo. When the key retrieval would fail, the ROS software installation would also fail. Obviously, if the main node lacks ROS, the simulation will not launch either. As a workaround, the script adds the repository to each machine with the *deb [trusted=yes] ...* syntax. Using this method obviates the need for the repo key. Although it works, applying it to repos in general creates unnecessary security risks. Therefore, the workaround should be used sparingly.

**Starting the Robot Simulation** Errors while starting the simulation occurred much more frequently during the development process than the key repo problem. In fact, approximately 50% of tested deployments failed, almost always at the final step when launching the simulation.

ROS prints error messages in red to the console, so they stand out. The most common error: *[gazebo\_gui-3] process has died* . Sometimes, an almost identical error occurs, *[gazebo-2] process has died* , while other times the launch program cannot find parts of the robot model. The latter error consists of one or both of the following: *Error [parser.cc:581] Unable to find uri[model://ground\_plane and / or Error [parser.cc:581] Unable to find uri[model://sun* . Unlike the previously-described error, this one requires manual intervention. The user needs to enter the following commands at the terminal prompt:

1. > killall roscore
2. > killall rosmaster
3. > killall gzclient
4. > killall gzserver
5. > **source** ~/.bashrc
6. > ./beginAgain

Somewhat maddeningly, this process often needs to be completed twice before the simulation will start successfully. If the simulation still will not start, refer to the instructions in the *Initializing the Swarm Manually* section.

### 3.5. Initializing the Swarm Manually

If needed the user can manually start the simulation with the commands listed below. You will need three terminals for the three commands, so ssh into the main node three times from three separate consoles or use *byobu* to split the terminal into three panes. The command

```
> roslaunch mybot_gazebo mybot_world.launch
starts the simulation. Entering
rostopic pub /robot1/cmd_vel geometry_msgs/Twist '{linear: {
x: 0.2, y: 0.0, z: 0.0}, angular: {x: 0.0, y: 0.0, z: 0.1}}'
in a free terminal will command the first robot to begin turning
in a circle. Likewise,
rostopic pub /robot1/cmd_vel geometry_msgs/Twist '{linear: {
x: 0.2, y: 0.0, z: 0.0}, angular: {x: 0.0, y: 0.0, z: 0.1}}'
moves the second robot. Alternatively, one can delete the cluster
and run the deployment script again.
```

## 4. VR SWARM PROJECT CONCLUSIONS

Automating the deployment of a virtual robot swarm on a cluster of remotely accessed computers should allow roboticists to more easily explore the benefits of collecting data from multiple sources at the same time over a give geogrpahy and timeframe. The virtual swarm presented in this paper provides framework for obtaining those benefits. It also highlights the challenges presented with an automated deployment, including a) network communication issues like obtaining the ROS repo key for each cluster node; b) compute resource security concerns since ROS nodes bind to any available port; c) the exacting nature of the interplay between the host OS, ROS and Gazebo as shown by the high number of deployment failures despite seemingly-duplicate processes and resources. The process developed for this project could perhaps benefit from the use of different tools and would undoubtedly benefit from a much-deeper understanding of how ROS functions.

The logical next step in the automation development process would seem to be projecting a differential drive robot started on one of the secondary nodes into the world created by ROS on the main node. The literature the technical feasibility of the task, although the implementation may prove more difficult than expected.

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**Matthew Lawson** received his BSBA, Finance in 1999 from the University of Tennessee, Knoxville. His research interests include data analysis, visualization and behavioral finance.

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# Charge Detection Mass Spectrometry

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project-001, September 21, 2017

A Charge Detection Mass Spectrometry research application, developed at Indiana University by the Martin F. Jarrold research group, is used to indicate the performance and simplicity benefits of using Cloudmesh and Ansible Galaxy to deploy and run big data software on one or more virtual machines in the cloud. This proprietary research application was initially installed and run by hand on local servers and remote Supercomputers. The research application performed well on these powerful systems; however, the manual process of deploying and running the application turned out to be inefficient and too cumbersome for the domain scientists. Therefore, Cloudmesh and Ansible Galaxy were leveraged in order to automate the deployment of virtual clusters and execution of this research application in the cloud. This modification abstracted away the need for explicit human interaction while maintaining an efficient, reproducible and scalable Charge Detection Mass Spectrometry research workflow.

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**Keywords:** Chemistry, Cloud, Hadoop Streaming, HPC, I524, Parallel Computing

Report: <https://github.com/cloudmesh/sp17-i524/blob/master/project/S17-IO-3011/report/report.pdf>

Code: <https://github.com/cloudmesh/cloudmesh.cdms>

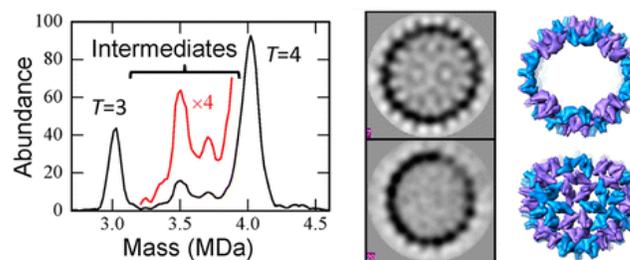
## 1. INTRODUCTION

### 1.1. Research Background

The Martin F. Jarrold research group at Indiana University studies Charge Detection Mass Spectrometry (CDMS) [1]. Their general day-to-day workflow consists of conducting many scientific experiments using a Mass Spectrometer. This expensive scientific instrument creates raw frequency data at a rate of four (4) MB/s throughout the duration of each experiment. The research group has developed a Fast Fourier based application written in Fortran to process this raw frequency data. The Fortran application generates human interpretable output, which assists the domain scientists in understanding the substances analyzed in the aforementioned experiments. The outputted results contain detailed mass information of the many ions discovered, which is used to solve important research topics such as the measurement and classification of the Hepatitis B virus. The mass and the abundance of the ions discovered by the application can be plotted to determine *Intermediates* that exist between definitive peaks in the plot, shown in Figure 1. This mass information can also be used to generate two and three-dimensional graphical representations of the ions, which help the domains scientists visualize the underlying structure of the Hepatitis B virus, shown in Figure 1.

### 1.2. General Problem

The Martin F. Jarrold research group has the ability to generate a lot of raw data, all of which needs to be processed by their For-



**Fig. 1.** The chart to the left displays an accurate measurement of the Hepatitis B virus (HBV) created by the research group [2]. This detailed mass information is used to create the images shown in the middle and to the right, which show 2-D and 3-D models of ions within the HBV. [2]

tran application, as shown in Figure 2. A typical day conducting research consists of eight (8) to ten (10) one (1) hour experiments with each experiment generating raw frequency data at a rate of four (4) MB/s. Therefore, a single day of experiments has the ability to generate up to one hundred and forty four (144) GB of data. The research group must be able to process this data in a similar amount of time as the time required to generate the raw data. If their collection of compute resources is not powerful enough, they will quickly become inundated with piles and piles of raw data. This day-to-day research workflow typically strains the research group's local compute resources. Further-



**Fig. 2.** The Martin F. Jarrold research group’s pipeline is shown above. This pipeline includes a one (1) hour experiment, which creates approximately seven thousand (7,000) two (2) MB raw frequency files. Each of these files need to be transferred to the remote compute resource(s) and processed with a Fortran application to generate four (4) human interpretable output files.

more, the research group frequently makes algorithmic changes to the CDMS research application. When a significant change occurs, the research group must conduct a bulk reprocessing of months or even years worth of raw data. When a bulk reprocess is required, the limited compute resources available to the group become a significant limitation to the efficiency of their research. Additionally, when the application is run on remote systems, the raw input data must be transferred to the remote systems and the resulting output must be aggregated and then plotted in order to visualize and interpret the results. The process of moving data around by hand is time consuming and the process to aggregating results is tedious.

### 1.3. General Solution

The research group is composed of domain scientists who do not necessarily have backgrounds in Computer Science [3]. Therefore, a simple (i.e. automated) and reproducible solution must be developed in order to satisfy their day-to-day research workflow and their bulk reprocessing requirements.

#### 1.3.1. Cloud Computing

Leveraging virtual clusters in the cloud to conduct their CDMS analysis increases their available compute power while simultaneously removing the need to explicitly manage a collection of compute resources. Furthermore, the ability to dynamically scale up or down the number of virtual machines aligns well with the evolving compute needs of the research group. The software tools Cloudmesh Client and Ansible Galaxy are at the foundation of this cloud computing solution [4, 5]. These two software tools collectively provide the ability to abstract away the technological details of the deployment and installation of virtual clusters in the cloud as well as automate the execution of the CDMS research application. These general modifications to their research workflow will ensure scalability, simplicity and reproducibility. These improvements allow the domain scientists in the Martin F. Jarrold research group to spend the majority of their time, effort and money on their research and not on the technological challenges of running the CDMS application.

## 2. ARCHITECTURE

The underlying architecture of this cloud computing research workflow is explicitly designed to facilitate automation. Cloudmesh and Ansible Galaxy are software tools that enable the creation of a virtual cluster, facilitate the deployment of software/data and automate the execution of the CDMS research application.

### 2.1. Software

#### 2.1.1. Cloudmesh Client Toolkit

The Cloudmesh Client Toolkit provides an application programming interface (API), which allows users to simply manage a set of cloud resources (i.e. virtual machines, virtual clusters and etc.) [5]. The Cloudmesh Client Toolkit abstracts away the technological details of managing cloud computing resources.

#### 2.1.2. Ansible Galaxy

Ansible is an information technology automation service designed for software deployment and execution [6]. Ansible Galaxy is an Ansible community, which “provides pre-packaged units of work known to Ansible as roles” [4]. Ansible Galaxy’s pre-packaged units of work are essentially shared solutions to common automation tasks. This is a representation of the open source style of the Ansible Galaxy community. Ansible Galaxy promotes fast development since the wheel does not need to be reinvented for the automation of common tasks.

#### 2.1.3. CDMS Application

The Martin F. Jarrold Group has written a Fast Fourier based application written in Fortran in order to conduct their CDMS research. This application is composed of approximately fifteen thousand (15,000) lines of Fortran code. Depending on the input, about 60% to 70% of the total compute time is spent within the external Intel Math Kernel Library (MKL) conducting the required Fast Fourier Transformations (FFT) [7].

#### 2.1.4. Intel

The CDMS source code is compiled with the Intel compiler [8]. The CDMS application relies on the Math Kernel Library (MKL) to leverage efficient Fast Fourier Computations [7]. The application also leverages the Intel OpenMP parallel framework in order to divide the work amongst available CPU’s [9]. Therefore, the Intel software is a fundamental piece of the architecture, which provides the compiler, MKL, and OpenMP functionality.

#### 2.1.5. Hadoop

Apache Hadoop “is a framework that allows for the distributed processing of large data sets across clusters of computers using simple programming models” [10]. Therefore, Hadoop must be installed at the foundation of each virtual machine in the cloud in order to leverage multiple virtual machines during the CDMS processing phase of the workflow shown in Figure 2.

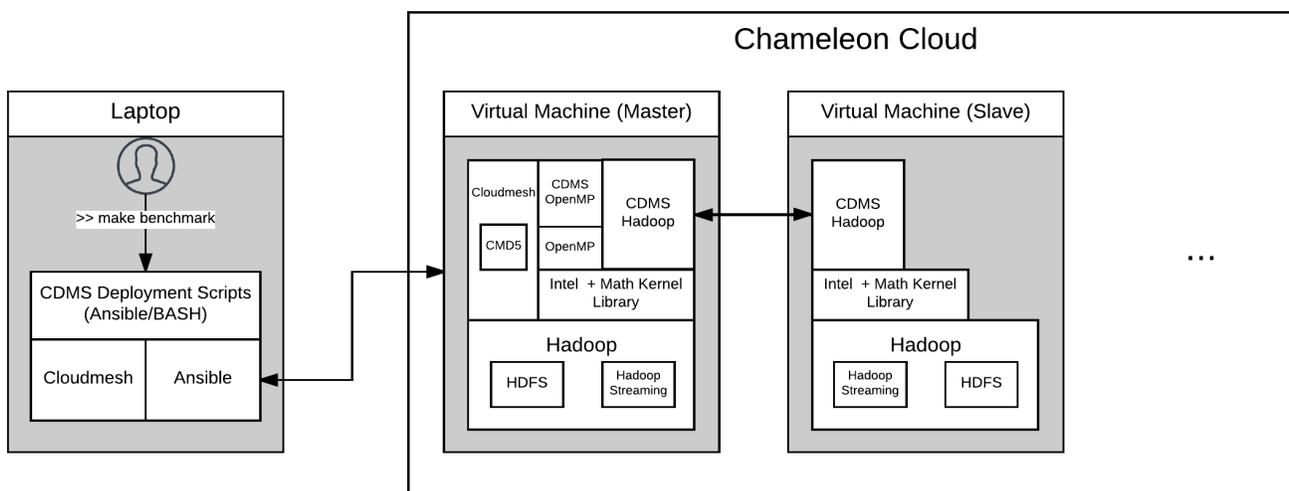
### 2.2. Data

The CDMS application requires a set of raw two (2) MB files as input. In order to develop and test the efficiency of the deployment, a small dataset was used to generate all of the performance results. This small test dataset, composed of two hundred (200) files has a total size of four hundred (400) MB and is a representative sample. A typical dataset for the research group is approximately fourteen (14) GB in size. In a single day, up to ten (10) datasets are created and need to be processed.

## 3. LICENSING

### 3.1. CDMS Deployment Scripts

The source code (i.e. Bash, Ansible, Python) presented here is licensed under the Apache License, Version 2.0 [11].



**Fig. 3.** The figure above provides a visual representation of the underlying architecture required for the Charge Detection Mass Spectrometry Cloud Computing workflow. The necessary software (i.e. Cloudmesh, Ansible, Hadoop, Intel, and etc.) and compute resources (i.e. Laptop and Virtual Machines) are explicitly shown above.

### 3.2. CDMS Application

The Martin F. Jarrold Group research group owns all of the rights to the Fortran Source code and data [1]. All distribution of the application and data must be consented by the research group.

### 3.3. Intel

The Intel software requires a license in order to complete the installation [12]. A student license is obtainable for free with an *EDU* email address; however, the leveraging the Indiana University Intel license server would provide a more complete and reproducible solution. In order to use the Indiana University Intel license server, the Virtual Machines must reside in the Indiana University IP address space. This can be achieved by connecting each virtual machine to Indiana University's Virtual Private Network (i.e. VPN) [13]. In order to connect to the VPN, one must connect via DUO Authentication (i.e. use a phone or token to validate) [14]. Given the complexity and reliability concerns with connecting to Indiana University's VPN simultaneously on multiple virtual machines, the Intel software is activated with the free Intel student license in order to promote simplicity and reproducibility.

#### 3.3.1. Student License Limitations

The CDMS Deployment Scripts that were developed for this project leverage a free Intel student license to compile and link the CDMS application. While anyone can use this student license, it is registered to the author of this paper. This student license is *System Locked* and therefore can be installed on at most five (5) virtual machines. Once this threshold has been passed, the Intel software (i.e. compiler, MKL and OpenMP) can no longer be activated. This limitation somewhat inhibits the reproducibility and scalability of the research workflow. If a license registration error occurs during the Intel build phase of the deployment of the software, please contact the author of this paper. The author has the ability to uninstall the license from the currently registered hosts using Intel's Registration Center [15].

## 4. PARALLELIZATION

The Charge Detection Mass Spectrometry input data is split into many two (2) MB files. Conveniently, the data within each file is entirely independent to the data in the other input files. Therefore, the input data files can be processed simultaneously (i.e. in parallel). Parallel processing may not seem important when working on our sample dataset composed of two hundred (200) files; however, when a large collection of data requires reprocessing, parallel processing becomes critical to the efficiency of the Martin F. Jarrold research group.

### 4.1. OpenMP

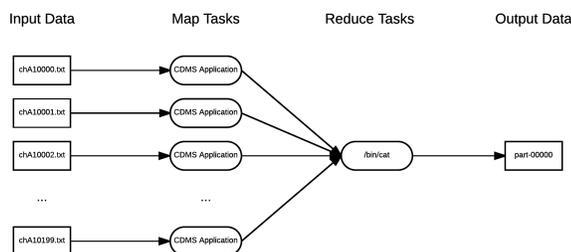
OpenMP is a shared memory parallelization framework that is specified with simple compiler directives [9]. The shared memory parallelization structure limits the scalability of the application to a single node or virtual machine. This is in contrast to distributed memory parallelization, such as Message Passing Interface (MPI) or Hadoop, which enables multi-node parallelization [10, 16]. The original developers of the CDMS application decided to leverage OpenMP parallelization in order to exploit the natural data independency and improve overall performance of the application. However, this design choice limited the parallelization (i.e. scalability) to a single node or virtual machine.

### 4.2. Hadoop

In order to improve the overall performance and scalability, a distributed processing framework such as Hadoop must be integrated into the foundation of the CDMS application. Such an enhancement would allow for parallelization across multiple virtual machines. As discussed in Section 2.1.3, the source code is composed of fifteen thousand (15,000) lines of legacy Fortran code that interfaces with the Intel Math Kernel Library. In order to leverage the Hadoop MapReduce framework, the source code would need to be rewritten in a compatible programming language such as Java or Python.

#### 4.2.1. Hadoop Streaming

Hadoop Streaming provides an alternative to rewriting the application in a compatible programming language. Hadoop Streaming allows one to “create and run Map/Reduce jobs with any executable or script as the mapper and/or the reducer” [17]. In Hadoop Streaming, “the mapper and the reducer are executables that read the input from stdin (line by line) and emit the output to stdout” [17]. The CDMS application is designed to read and write data to local files on disk; therefore, source code modifications were required in order to ensure the application read from stdin and wrote to stdout. The overall structure of the application and its data, which is naturally split into many relatively small files, allowed for a straightforward transformation from OpenMP parallelization Hadoop Streaming parallelization, as shown in Figure 4. Altering the way in which data was inputted to and outputted from the CDMS application was the only modification that was required in order to integrate Hadoop Streaming parallelization.



**Fig. 4.** The diagram shown above indicates the MapReduce style analysis of the CDMS Hadoop Streaming version of the application. Each two (2) MB input file is processed independently by the CDMS application and the results are aggregated with a single *cat* reduce task.

## 5. GETTING STARTED

The CDMS Deployment Scripts were specifically designed to promote simplicity and reproducibility. The following subsections describe how to use the CDMS Deployment Scripts to install and run the CDMS application in the cloud with as little as one simple command.

### 5.1. Requirements

In order to execute the CDMS Deployment Scripts, one must have the Cloudmesh Client installed and configured on their local system. This includes having a valid `~/.cloudmesh/cloudmesh.yaml` configuration file, registering Chameleon as the default cloud, registering a profile, uploading a ssh key and uploading a secgroup.

### 5.2. Fetch Code

The CDMS Deployment Scripts are hosted using GitHub [18]. A single repository contains the required Ansible and Bash scripts used to launch the CDMS research workflow [19]. See the following Bash commands:

```
>> git clone [REPOSITORY]
>> cd sp17-i524/project/S17-IO-3011/code
```

### 5.3. Benchmark

A single command will deploy the Hadoop virtual cluster, install the required software, run the three versions (i.e. Serial, OpenMP and Hadoop Streaming) of the CDMS application, aggregate the results, create plots of the output and delete the Hadoop virtual cluster. Timing information for each of these stages is printed to the screen once the benchmark has completed. The performance of this benchmark is plotted and explained in Section 7. See the following Bash command:

```
>> make benchmark
```

By default the benchmark will be run on a virtual cluster containing a single virtual machine. You can modify the maximum number of virtual machines to be used in the benchmark by passing in an optional argument to the *benchmark* Makefile option. The example shown below will run the entire benchmark with one, two and three virtual machines. See the following Bash command:

```
>> make benchmark num_nodes=3
```

### 5.4. Additional Commands

In case one would like to break up the aforementioned benchmark into individual pieces, there are separate Bash commands available. See the following Bash commands:

```
>> make deploy [num_nodes=n]
>> make install
>> make run
>> make view
>> make delete
>> make clean
```

#### 5.4.1. Deploy

The *deploy* Makefile option leverages Cloudmesh Client to deploy a Hadoop virtual cluster in the Chameleon Cloud [20]. By default one (1) virtual machines will be created with the *deploy* option. The specific number of virtual machines deployed can be configured by passing in `num_nodes=n`, where `n` is the number of virtual machines requested to be deployed in the virtual cluster.

#### 5.4.2. Install

The *install* Makefile option installs necessary software (i.e. Intel Compiler, Intel MKL, Python, Pip, Cloudmesh, Git, Charge Detection Mass Spectrometry application, and etc.) on the master and slave virtual machines of the active virtual cluster.

#### 5.4.3. Run

The *run* Makefile option runs the serial, OpenMP, and Hadoop Streaming versions of the CDMS application on the active virtual cluster using the small test dataset containing two hundred (200) input files.

#### 5.4.4. View

The *view* Makefile option aggregates the output data from the virtual machines in the active cluster, plots the results using Python’s `matplotlib` and transfers a subset of the plots to the local system in order to visually validate the accuracy of the application [21].

#### 5.4.5. Delete

The *delete* Makefile option deletes all of the virtual machines associated with active virtual cluster.

#### 5.4.6. Clean

The *clean* Makefile option removes all of the local output files, if any exist.

## 6. COMPUTE RESOURCES

The CDMS OpenMP parallel version application was tested on multiple compute resources, as explained in Section 7. Each resource has unique architectural qualities that impact the performance, scalability and degree of parallelism. While the degree of parallelism (i.e. number of CPUs) may not be indicative of application performance, it certainly provides a baseline understanding of some architectural differences amongst the four (4) available systems.

### 6.1. Windows HPC Server

The Martin F. Jarrold's local Windows HPC Server has eight (8) CPUs; therefore, the Charge Detection Mass Spectrometry OpenMP version application can process up to eight (8) input files in parallel.

### 6.2. Karst

Indiana University's Linux Supercomputer, named Karst, has sixteen (16) CPUs per node; therefore, the Charge Detection Mass Spectrometry application can process up to sixteen (16) input files in parallel [22].

### 6.3. Big Red II

Indiana University's Linux Supercomputer, named Big Red II, has thirty-two (32) CPUs per node; therefore, the Charge Detection Mass Spectrometry OpenMP application can process up to thirty-two (32) input files in parallel [23].

### 6.4. Chameleon Cloud

The Cloudmesh Client allows one to specify different flavors of virtual machines to be deployed in the Chameleon Cloud [5, 20]. These flavors come in various sizes (i.e. Memory, vCPUs, and etc.). As shown in Table 1, these flavors can be used strategically to specify the number of virtual CPUs allocated to each virtual machine. As an example, the Chameleon Cloud m1.xlarge flavor provides eight (8) vCPUs. This allows the Charge Detection Mass Spectrometry OpenMP application to process up to eight (8) input files in parallel. Additionally, the virtual machines deployed in the Chameleon Cloud are running version 14.04 of the Ubuntu operating system.

**Chameleon Cloud Virtual Machine Flavors**

# Flavor	# of vCPUs
m1.medium	2
m1.large	4
m1.xlarge	8

**Table 1.** The table above indicates the number of virtual CPUs allocated to the various virtual machine flavors in the Chameleon Cloud [20]. The number of vCPUs indicates the maximum degree of parallelism for the CDMS application.

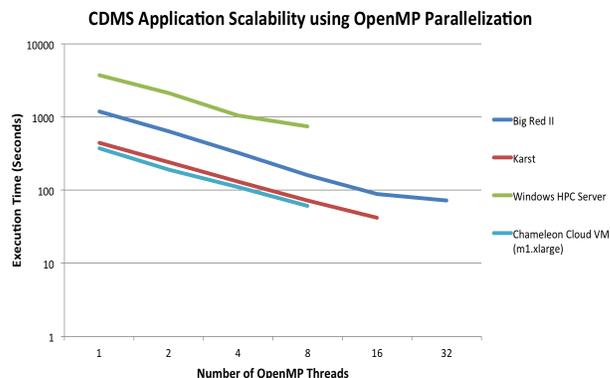
## 7. PERFORMANCE RESULTS

The following subsections describe the performance of the OpenMP and Hadoop Streaming versions of the application. These performance results only include the time-to-solution of the application processing the two hundred (200) input files. Performance results including the entire deployment, installation and execution will be explained in Section 7.3.

### 7.1. OpenMP Scalability

As discussed in Section 4.1, the application was initially parallelized using OpenMP. This version of the application attempts to utilize the computational power available on a single node or virtual machine. Figure 5 compares the time-to-solution performance of the OpenMP version of the application on the available compute resources (i.e. local servers, Supercomputers and clouds) introduced in Section 6. As expected the time-to-solution (i.e. execution time) of the CDMS OpenMP version of the application decreases as amount of compute resources increase, as shown in Figure 5. For instance, on Karst the application running with sixteen (16) OpenMP threads completes in 9.4% of the time required for the application running with one (1) OpenMP thread.

The application performs most efficiently on Karst when using sixteen (16) CPUs (i.e. OpenMP threads). However, when the application is run using one (1), two (2), four (4) or eight (8) CPUs, the best performance exists on the Chameleon Cloud, as shown in Figure 5. Specifically, the application performs 18% faster on a single Chameleon Cloud virtual machine when compared to running the application on eight (8) CPUs of Karst.

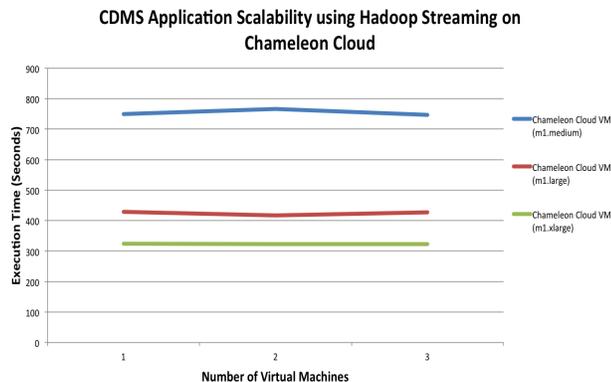


**Fig. 5.** The figure above shows the scalability (i.e. reduction in time-to-solution) as the number of OpenMP threads increase on local servers, Supercomputers and Clouds.

### 7.2. Hadoop Streaming Scalability

Unfortunately, the performance results for the Hadoop Streaming version of the CDMS application are not as promising as the performance results for the OpenMP version of the application. The Hadoop Streaming application does not exhibit the desired scalability. Since the application is essentially a map only Hadoop application, the performance (i.e. total runtime) of the application should decrease linearly as the number of virtual machines increase. However, the performance results shown in Figure 6 indicate that the execution time remains relatively consistent when one (1), two (2) or three (3) virtual machines are

used to process the two hundred (200) raw input files. Interestingly, the performance of the application significantly increases as the flavor of the virtual machine changes from smaller (i.e. less vCPUs) to larger (i.e. more vCPUs). Figure 6 shows that the Hadoop Streaming version of the application run on a m1.xlarge flavor requires only 43% of the execution time as the same application run on a m1.medium flavor.



**Fig. 6.** The image above shows the scalability (i.e. reduction in time-to-solution) of the Charge Detection Mass Spectrometry Hadoop Streaming version of the application in a Chameleon Cloud virtual cluster. The performance information includes timing results for three (3) different virtual machine flavors.

### 7.3. Benchmark Scalability

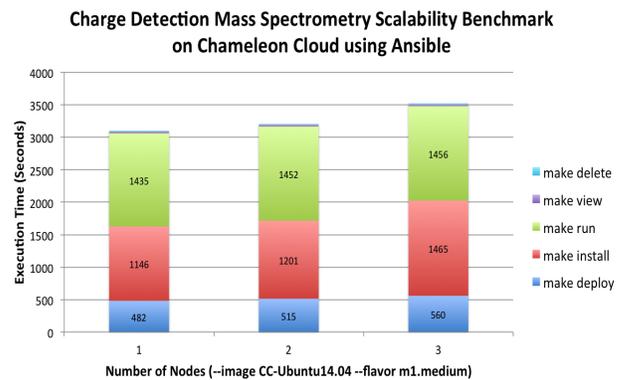
The benchmark including the deployment of the virtual cluster, installation of the required software, execution the serial/OpenMP/Hadoop Streaming versions of the CDMS application and the aggregation of the results was tested using one (1), two (2) and three (3) virtual machines in the Chameleon Cloud. Interestingly, this benchmark required increasing time as the number of virtual machines increased, as shown in Figure 7. This performance information indicates that the deployment overhead outweighs the potential benefits of leveraging multiple virtual machines. The lack of scalability shown in the Hadoop Streaming version of the application and the small dataset are major factors, which contribute to the overall performance results. Specifically, if the Hadoop Streaming version of the application exhibited linear scalability and the dataset was significantly larger, the overhead incurred would not be as impactful as shown in Figure 7.

## 8. FUTURE WORK

Future work includes analyzing the performance of the CDMS Hadoop Streaming application to understand the poor scalability when running on a virtual cluster containing multiple virtual machines. Once the scalability issue has been fixed, larger flavors and more virtual machines will be utilized in order to increase the performance of the Hadoop Streaming application.

Future work includes figuring out how to leverage Indiana University's Intel license server. This will increase reproducibility by allowing the Intel Compiler and Intel MKL to be installed on an unlimited number of virtual machines.

Future work includes dispersing the raw input data across multiple virtual machines and running an instance of the CDMS OpenMP version of the application on each virtual machine and



**Fig. 7.** The figure above indicates the time-to-solution for a full benchmark of the deployment of one (1), two (2) and three (3) virtual machines in the Chameleon Cloud. This benchmark includes deploying the virtual machines, installing all of the software, running the serial, OpenMP and Hadoop Streaming versions of the application and aggregating/plotting the results.

then aggregating the results. This modification will increase scalability for the shared memory parallelization.

Future work includes integrating Message Passing Interface (MPI) as the parallelization structure of the application rather than OpenMP or Hadoop Streaming [16]. This will allow for a dramatic increase in the scalability of the application.

## 9. CONCLUSION

The use of the Cloudmesh Client and Ansible Galaxy software to automate the execution of the Charge Detection Mass Spectrometry research application in the cloud improved the simplicity, efficiency and reproducibility. The automation allows the Martin F. Jarrold research group to focus on the details of their specific research rather than on the details of managing the software subsystems, executing the application and managing the input/output data. This automated cloud computing solution benefits the Martin F. Jarrold research group with respect to both simplicity and performance of the application. Streamlining the research workflow will inevitably result in an increase in productivity for the research group. An increase in research productivity may also result in an increase in grant funding and/or an increase in publications for the Indiana University research group.

The performance of the CDMS OpenMP version of the application performed favorably on a single Chameleon Cloud virtual machine when compared with a single node of the Indiana University High Performance Computing clusters (e.g. Karst and Big Red II). This unexpected result has sparked future work in optimizing the OpenMP version of the application for the Chameleon Cloud. However, the overhead included with deploying the virtual cluster and installing the necessary software causes the overall time-to-solution to increase dramatically.

The Hadoop Streaming version of the CDMS application did not exhibit optimal performance on a Chameleon Cloud virtual cluster. If the execution time reduced when more virtual machines were used, then this version of the application would become a viable solution for the research group's need to bulk reprocess raw input data. The Hadoop streaming version of the CDMS application is a step in the right direction; however, additional work must be done to ensure scalability across

multiple virtual machines.

## 10. EXECUTION PLAN

The following subsections act as a timeline regarding how the project was divided up in order to complete all of the work by the desired deadline. The project execution plan is simply a guide and was followed diligently; however, some items were pushed slightly forwards or backwards as technological challenges were faced.

### 10.1. March 6, 2017 - March 12, 2017

This week I installed Cloudmesh on my local machine, created my first virtual machine on the Chameleon Cloud and tested Ansible Galaxy on remote systems such as one or more Chameleon Cloud virtual machine. I also wrote the project proposal, which eventually became this project report.

### 10.2. March 13, 2017 - March 19, 2017

This week I tested the deployment of the Intel Compiler on one or more Chameleon Cloud virtual machine using Cloudmesh and Ansible Galaxy. Given that I was out of town for Spring Break, I did not expect significant progress to be made during this week.

### 10.3. March 19, 2017 - March 26, 2017

This week I attempted to configure the Intel Compiler and Math Kernel Library to use the Indiana University Intel license server. Using this license server required connecting to Indiana University's Virtual Private Network (VPN) and using Two-Step Login (Duo) from the command line.

### 10.4. March 27, 2017 - April 2, 2017

This week I deployed the Charge Detection Mass Spectrometry research application along with the required input data on one or more Chameleon Cloud virtual machines using Cloudmesh and Ansible Galaxy.

### 10.5. April 3, 2017 - April 9, 2017

This week I modified the source code of the OpenMP parallel Charge Detection Mass Spectrometry research application to leverage Hadoop Streaming.

### 10.6. April 10, 2017 - April 16, 2017

This week I benchmarked the Charge Detection Mass Spectrometry research workflow on the Chameleon Cloud. This included varying the number and size of the virtual machines. I also wrote Python scripts to aggregate and plot the CDMS application's output from one or more virtual machines and locally visualize the results.

### 10.7. April 17, 2017 - April 23, 2017

This week I ensured the reproducibility of my source code as well as wrote and revised the final version of this report.

## ACKNOWLEDGEMENTS

The authors would like to thank the School of Informatics and Computing for providing the Big Data Software and Projects (INFO-I524) course [24]. This project would not have been possible without the technical support & edification from Gregor von Laszewski and his distinguished colleagues.

## AUTHOR BIOGRAPHIES



**Scott McClary** received his BSc (Computer Science) and Minor (Mathematics) in May 2016 from Indiana University and will receive his MSc (Computer Science) in May 2017 from Indiana University. His research interests are within scientific application performance analysis on large-scale HPC systems. He will begin working as a Software Engineer with General Electric Digital in San Ramon, CA in July 2017.

## WORK BREAKDOWN

The work on this project was distributed as follows between the authors:

**Scott McClary.** He completed all of the work for this project including researching, deploying, testing and benchmarking the Charge Detection Mass Spectrometry research application as well as composing this paper.

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# Automated Sharded MongoDB Deployment and Benchmarking for Big Data Analysis

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Using Python, Ansible, Bash Shell, and Cloudmesh Client a fully automated process is created for deploying a configurable MongoDB sharded cluster on Chameleon, FutureSystems, and Jetstream cloud computing environments. A user runs a single Python program which configures and deploys the environment based on parameters specified for numbers of Config Server Replicas, Mongos Instances, Shards, and Shard Replication. The process installs either MongoDB version 3.4 or 3.2 as requested by the user. Additionally, functionality exists to run benchmarking tests for each deployment, capturing statistics in a file as input for python visualization programs, the results of which are displayed in this report. These reports depict the impact of MongoDB version and degrees of sharding and replication on performance. Key performance findings regarding version, sharding, and replication are abstracted from this analysis. As background, technologies and concepts key to the deployment and benchmarking, such as MongoDB, Python, Ansible, Cloudmesh Client, and OpenStack are examined.

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**Keywords:** MongoDB, Cloud Computing, Ansible, Python, Cloudmesh Client, OpenStack, I524

Report: <https://github.com/cloudmesh/sp17-i524/tree/master/project/S17-IO-3012/report/report.pdf>

Code: <https://github.com/cloudmesh/sp17-i524/tree/master/project/S17-IO-3012/code>

## 1. INTRODUCTION

As the final project for I524, Big Data Software and Projects, Spring 2017, a Python program invoking Bash shell scripts, Ansible playbooks, and Cloudmesh Client commands has been created to fully automate a configurable deployment of a MongoDB sharded cluster on various clouds. Chameleon Cloud, FutureSystems, and Jetstream are the currently supported cloud environments. The scripts have been developed and tested on an Ubuntu 16.04 LTS (Xenial Xerus) Virtual Machine running in Virtual Box. Using the Python cmd command line interface, the program project.py accepts parameters for deployment cloud, MongoDB version, Config Server replication, number of Mongos instances, number of Data Shards, and Shard replication.

Also via project.py, automated benchmarking tests can be run. Tests were performed with various sharding and replication configurations to assess their impact on performance. Additionally, tests were run against MongoDB versions 3.4 and 3.2 to uncover any performance differences between these version. Performance results are captured and graphed using Python's matplotlib, the results of which are displayed and analyzed in this report.

## 2. INFRASTRUCTURE

Three clouds were selected for deployment: Chameleon Cloud, FutureSystems (also referred to as Kilo in some sections of this document), and Jetstream. In our automated deployment and benchmarking process, the cloud name is passed as a parameter to the deploy function of the main project.py script and a customized version of MongoDB is deployed to the selected cloud.

### 2.1. OpenStack

Chameleon Cloud, FutureSystems and Jetstream all utilize OpenStack. OpenStack is a free, open source cloud computing platform, primarily deployed as IaaS [1]. OpenStack was created in 2010 as joint project between NASA and Rackspace that is currently managed by the OpenStack Foundation [1]. Open Stack is open source software released under the Apache 2.0 license [2].

Open Stack has various components, also known by code names [1]. Examples of OpenStack components (and code names) are Compute (Nova), Networking (Neutron), Block Storage (Cinder), Identity (Keystone), Image (Glance), Object Storage (Swift), Dashboard (Horizon), Orchestration (Heat), Work-

flow (Mistral), Telemetry (Ceilometer), OpenStack Telemetry (Ceilometer), Database (Trove), Elastic Map Reduce (Sahara), Bare Metal (IroniC), Messaging (Zaqar), Shared File System (Manila), DNS (Designate), Search (Searchlight), and Key Manager (Barbican) [1].

## 2.2. Chameleon Cloud

Chameleon is funded by the National Science Foundation and provides computing resources to the open research community. The Chameleon testbed is hosted at the Texas Advanced Computing Center and the University of Chicago. Chameleon provides resources to facilitate research and development in areas such as Infrastructure as a Service, Platform as a Service, and Software as a Service. Chameleon provides both an OpenStack Cloud and Bare Metal High Performance Computing Resources [3].

## 2.3. FutureSystems

FutureSystems is a computing environment run by Indiana University that supports educational and research activities [4]. FutureSystems is directed by Geoffrey C. Fox and Gregor von Laszewski, both of Indiana University [4]. For our deployment, we utilize the OpenStack Kilo Cloud, running on the India machine. Because the environment is by default referred to as Kilo in the Cloudmesh documentation and setup file, it is referred to as both FutureSystems and Kilo in subsequent sections of this document and the accompanying diagrams.

## 2.4. Jetstream

Jetstream is a cloud computing environment implemented by many academic and industry partners including the University of Texas at Austin's Texas Advanced Computing Center (TACC), the Computation Institute at the University of Chicago, the University of Arizona, the University of Texas San Antonio, Johns Hopkins University, Penn State University, Cornell University, the University of Arkansas at Pine Bluff, the National Snow and Ice Data Center (NSIDC), the Odum Institute at the University of North Carolina, the University of Hawaii, and Dell [5]. At Indiana University, leadership is provided by the Pervasive Technology Institute with involvement from several members of the School of Informatics and Computing including Beth Plale, Katy Borner, and Volker Brendel [6].

## 2.5. Cloud Hardware Comparison

Table 1 shows a comparison of key computing resources on Chameleon, FutureSystems, and Jetstream cloud environments.

**Table 1. Cloud Hardware Specification Comparison [7] [8] [9]**

	FutureSystems	Chameleon	Jetstream
CPU	Xeon E5-2670	Xeon X5550	Haswell E-2680
cores	1024	1008	7680
speed	2.66GHz	2.3GHz	2.5GHz
RAM	3072GB	5376GB	40TBr
storage	335TB	1.5PB	2 TB

## 3. PYTHON/CMD

Python is utilized in two portions of the automated process. First, the main script, `project.py`, is a Python program that utilizes the `cmd` module to provide a simple command line interface [10] accepting parameters for deployment configuration. `project.py` also provides other functionality such as cluster deletion, benchmarking, benchmarking summarization and reporting, and data distribution reporting. Second, several visualization programs for benchmarking analysis are written in Python, utilizing the `matplotlib` and `pandas` modules.

## 4. ANSIBLE

Ansible is open source software typically use to automate software provisioning and configuration management. Ansible uses Playbooks specified in YAML file format to accomplish this goal. Ansible runs on Linux/Unix and requires Python [11].

In our deployment, virtual machines are created using Cloudmesh Client cluster commands. Once they are created, all direct cloud interaction for the MongoDB software installation and environment customization and setup is performance via Ansible playbooks.

## 5. CLOUDMESH CLIENT

The Cloudmesh Client toolkit is an open source client interface that standardizes access to various clouds, clusters, and workstations [12]. Cloudmesh Client is a python based application developed by Gregor von Laszewski and others collaborators primarily at Indiana University.

In the deployment, Cloudmesh Client is used to handle most interaction with the Virtual Machines in the clouds. Cloudmesh Client provides functionality in three main areas: Key Management, OpenStack Security, and virtual machine management. For key management, Cloudmesh's key add and upload commands simplify secure interaction with the cloud environments. For OpenStack security, Cloudmesh's secgroup commands allow new security rules to be added and uploaded to the cloud. Virtual machine management is performed with Cloudmesh's cluster functionality, which allows easy creation and deletion of virtual machines and communication between them.

Cloudmesh Client simplifies and standardized interaction with the cloud for these tasks. This allows us to more easily port the deployment to additional clouds that are supported by Cloudmesh. Furthermore, by encapsulating the logic necessary to perform these tasks we are shielded from changes in interfaces made by individual clouds.

## 6. MONGODB

MongoDB is a popular open source, document oriented noSQL database. It stores documents in JSON-like schema-less formats called collections [13]. DBEngines ranks MongoDB as the most popular noSQL store and as the fifth most popular Database Management System overall [14].

### 6.1. Architecture

A sharded cluster in MongoDB has three main components, all of which will be implemented in our deployment:

- Config Servers - hold configurations setting and metadata
- Mongos - a query routing interface between applications and the cluster

- Shards - subsets of data

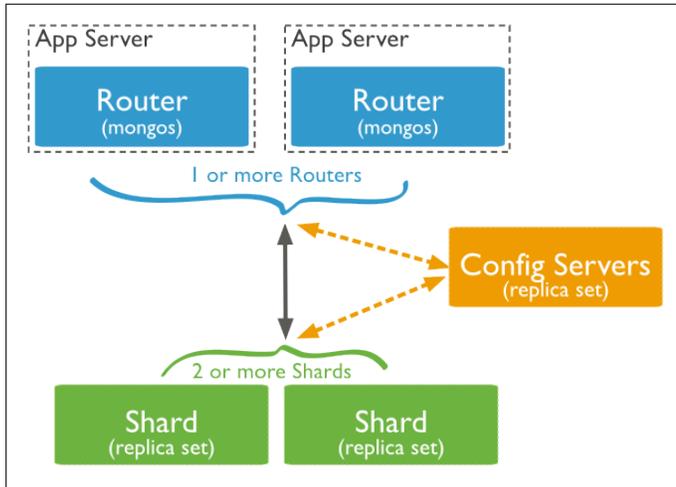


Fig. 1. Sharded MongoDB Architecture [15]

Figure 1 depicts a sharded MongoDB environment with two Mongos instances and two data Shards. The replica sets shown for both Config Servers and Shards may have any number of replicas within the set.

### 6.2. Config Servers

Config Servers stored metadata for sharded MongoDB clusters. This metadata includes information about the state and structure of the data and components of the sharded cluster [16].

Config Servers also contain authentication information. For example, information about the key files used for internal authentication between the nodes is stored in the Config Servers [16].

In production deployments, it is recommended for Config Servers to be deployed in 3 member replica sets [15]. The rationale behind a 3 member set is discussed in more detail in the Replication subsection that follows.

In our deployment and benchmarking automation, the degree of replication in the Config Server Replica Set is by the third parameter to the main project.py script. For example, specifying 1 will create a Replica Set with one Config Servers (not replication), specifying 3 will create a Replica Set with three Config Server, and so on.

### 6.3. Mongos Routers

Mongos is a query routing service used in sharded MongoDB configurations. Queries from applications go through Mongos, which locates the data in the sharded cluster. The Mongos instances accomplish this by reading and caching data from the Config Servers [17].

For applications with high performance or availability requirements multiple Mongos instances may be ideal. In a high volume application, spreading the routing load over multiple Mongos instances can benefit performance. Additionally, multiple Mongos instances may increase availability in the case where a Mongos instance fails [16].

In our deployment and benchmarking automation, the number of Mongos instances is controlled by the fourth parameter to the main project.py script. For example, specifying 1 will create one Mongos instance, specifying 3 will create three Mongos instances, and so on.

### 6.4. Shards

Sharding, or distributing data across machines, is used by MongoDB to support large data sets and provide high throughput [18]. Our deployment and benchmarking will test the performance of various numbers of shards, measuring the performance improvements associated with sharding in MongoDB.

Documents are distributed among the shards using a shard key. A sharded collection must have one, and only one, shard key which must have a supporting index [18]. Since the shard key is critical to performance and efficiency, particular care must be given to shard key selection [19]. In our performance testing a key was chosen that would distribute data relatively evenly across the shards, but was not used in retrieving the data as the more costly retrieval of not using an index provided a better test case.

In our deployment and benchmarking automation, Sharding is controlled by the fifth parameter to the main project.py script. For example, specifying 1 cause only 1 shard to be created, specifying 3 will cause three shards to be created, and so on.

### 6.5. Replication

In databases, replication provides data redundancy leading to greater availability and fault tolerance. Replication in MongoDB is achieved via Replica Sets [20]. Replica Sets were implemented in our deployment for both Config Servers and Shards.

Two key benefits provided by replication are redundancy and fault tolerance. Each Replica in a Replica Set provides another copy of data. Higher redundancy means more nodes can be lost without data being lost. Higher numbers of Replicas in a set also increase fault tolerance, which leads to increased availability. As a general rule, a set will be able to tolerate faults while the majority of its nodes are still available

Table 2. Fault Tolerance by Replica Set Size [21]

Replica Members	Majority Needed	Fault Tolerance
2	1	0
3	2	1
4	3	1
5	3	2
6	4	2
7	4	3
8	5	3

As shown in Table 2, odd numbers of members in a replica set are a better choice for fault tolerance. For example, both a 3 and 4 replica set can only tolerate one member failing while maintaining availability. This is because a majority of the members must be available to maintain availability. In a 3 replica set the majority is 2, so it can tolerate 1 member failing. In a 4 replica set, the majority is 3, so it can still only tolerate 1 member failing. Increases in fault tolerance only occur when the next odd numbered member of a replica set is added [21].

For production systems, a standard deployment is a 3 Replica Set [21]. A 3 replica set provides 3 copies of the data for redundancy and fault tolerance if 1 member of the set were to fail. In a situation where availability was of higher concern, a 5 replica

set would provide 4 copies of the data for redundancy and fault tolerance if 2 members of the set were to fail.

In our automated deployment and benchmarking process, the degree of replication for Shards is controlled by the sixth parameter to the main `project.py` script. For example, specifying 1 for will create a replica set per shard with only one copy of data (essentially no replication, although technically we create a one member replica set), specifying 3 will cause a replica set of with three copies to be created, and so on.

### 6.6. MongoDB Versions

The most current version of MongoDB is version 3.4, which was released on November 29, 2016. Based on an input parameter, our deployment will install either version 3.4 or version 3.2, the prior version of MongoDB. Many enhancements were made for version 3.4 impacting Sharded Clusters, Replica Sets, Aggregation, Indexes, Views, Security, Tools, and Platform Support. The complete list of 3.4 features and enhancements can be found in the Release Notes [22].

In our automated deployment and benchmarking process, the version of MongoDB installed is controlled by the second parameter to the main `project.py` script. Specifying 34 will install version 3.4. Specifying 32 will install 3.2. These versions were selected as they are the two most recent major versions of MongoDB and because they are the only two compatible with Ubuntu 16.04 LTS (Xenial Xerus).

### 6.7. Security

There are two levels of security to consider in a sharded MongoDB deployment: internal and external authentication.

In our deployment the various MongoDB components (config servers, mongos instances, shards, and replicas) all reside on separate Virtual Machines. These machines must be able to communicate with each other. Two steps were necessary to enable this internal authentication. First, the ports (27017, 27018, 27019, 28017) used by MongoDB needed to be opened for communication. This was accomplished by adding appropriate security group rules to the clouds through Cloudmesh client. Second, MongoDB requires the internal authentication to be done by either key files or x.509 certificates [23]. In our deployment, authentication is done by key files. A new key file is automatically created for each deployment and distributed to all of the virtual machines on the selected cloud.

For external authentication, the three users are created. The user `admin` is created with the role of `userAdminAnyDatabase`. `admin` performs administrative functions such as creating the other users. The user `cluster_admin_user` is created with the role `clusterAdmin`. `cluster_admin_user` user performs sharding functions such as sharding the collection and checking its data distribution. `user1` is a standard user with readWrite permissions. `user1` performs the benchmarking tests and other functions not requiring administrative privileges.

## 7. DEPLOYMENT

The automated process fully deploys a sharded MongoDB environment with the Cloud, MongoDB version, number of Config Servers, Mongos Instances, Shards, and degree of Replication specified as input parameters.

### 7.1. Computing Resources

In all cases, virtual machines are deployed with the Ubuntu 16.04 LTS (Xenial Xerus) operating system. On OpenStack the

flavor or the machine determines the amount of computing resources (CPU, memory, storage) allocated to it. In our testing, `m1.medium` was used as the flavor for Chameleon Cloud and FutureSystems, while `m1.small` was used on Jetstream. Jetstream has more resources allocated to each flavor than Chameleon and FutureSystems, which are similar. In order to perform similar tests on each cloud, flavors with identical CPU and memory were selected. Table 3 shows the comparative resources of the flavors used in our testing. While storage is lower on Jetstream, it is sufficient for our tests and should not significantly impact performance.

**Table 3. Computing Resources**

Cloud	Flavor	VCPU	RAM	Size
Chameleon	m1.medium	2	4	40
FutureSystems	m1.medium	2	4	40
Jetstream	m1.small	2	4	20

### 7.2. Deployment Process

Several programs are involved in the deployment. A high level overview of each is provided.

#### 7.2.1. `project.py`

The deployment process is invoked by running the `deploy` function of `project.py`, passing six required parameters: cloud (chameleon, jetstream, or kilo), version (32 or 34 for version 3.2 or 3.4), size of the config server replica set (a number, 1 or greater), number of mongos routers (a number, 1 or greater), number of data shards (a number, 1 or greater), and size of data shard replica sets.

`Project.py` calls a bash script, `deploy.sh`, which runs two bash shell scripts to accomplish the deployment: `cluster.sh` and `ansible.sh`.

#### 7.2.2. `cluster.sh`

`Cluster.sh` does the work of creating the cluster in the specified cloud environment. First, it creates a key file needed for secure access between the nodes, and uses Cloudmesh `secgroup` commands to build and uploads a new security group with the ports necessary for MongoDB (27017, 27018, 27019, and 28017) accessible. Next, it uses Cloudmesh client `cluster` commands to launch the appropriate number of virtual machines in the desired cloud. Then, it builds a file, `inventory.txt`, with sections for each MongoDB component (Config Servers, Mongos Instances, and Shard Replica Sets), allocating the correct number of IP addresses to each. Finally, `cluster.sh` builds a few complex commands that will need to be run later in the process by `ansible`.

#### 7.2.3. `ansible.sh`

After the virtual machines have been created by `cluster.sh`, `ansible.sh` used the `inventory.txt` file to execute Ansible playbooks on the appropriate virtual machines.

1. `install-python.yaml` - Installs Python, if not installed. This script was necessary because the Ubuntu Xenial image on FutureSystems does not have Python installed. Python is required for Ansible.

2. mongo-install32.yaml - Using apt\_key and apt\_repository, installs the packages for version 3.2 of MongoDB on all virtual machines.
3. mongo-install34.yaml - Using apt\_key and apt\_repository, installs the packages for version 3.4 of MongoDB on all virtual machines.
4. add-mongo-key.yaml - Uploads the key file created in cluster.sh to all virtual machines.
5. mongo-config.yaml - On Config Servers only, stops the mongod service and uses a template file to start the mongod process for a Config Server.
6. mongo-config2.yaml - On only one Config Server, uses a template file to initiate the primary Config Server.
7. mongo-mongos.yaml - On Mongos Instances only, stops the mongod service and uses a template file to start the mongos process for a Mongos instance.
8. mongo-users.yaml - On only one Mongos Instance, create several users needed in later steps.
9. mongo-shard.yaml - On Shards only, stops the mongod service and uses a template file to start the mongod process for a Shard.
10. mongo-shard2.yaml - On the primary Shard in each Replica Set, uses a file built in cluster.sh to initiate the Shards.
11. add-shards.yaml - On one Mongos instance, uses a file built in cluster.sh to add all of the Shards.
12. create-sharded-collection.yaml - Uploads several files to one Mongos instance that will be need for benchmarking and shard the collection (benchmarking setup, not included in deployment times).
13. getdata.yaml - Downloads and unarchive the pitches data from an AWS S3 directory. Also, create a smaller version for testing (benchmarking setup, not included in deployment times).

The kill function in project.py will delete and deallocate the last existing cluster on the cloud to clean up after the test is complete.

### 7.3. Deployment Timing

The configuration parameters and cluster and Ansible deployment times are captured in a file for each deployment (benchmarking timings are later captured as well). Total run time for a few interesting configurations are shown in Table 4.

Deployment A shows a simple deployment with only one of each component being created. This deployment may only be suitable for a development or test environment. Deployment A completed in 330 seconds.

Deployment B shows a more complex deployment with production like replication factors for Config Servers and Shards and an additional Mongos instance. This deployment may be suitable for a production environment as it has greater fault tolerance and redundancy. Deployment B took 1059 seconds to deploy.

Deployment C shows a deployment focused on high performance. It has a high number of shards, nine, but no fault tolerance or redundancy. The deployment may be suitable where

performance needs are high and availability is less critical. Deployment C finished in 719 seconds.

**Table 4. Deployment Times on Chameleon Cloud in Seconds**

	Config	Mongos	Shards	Replicas	Seconds
A	1	1	1	1	330
B	3	2	3	3	1059
C	1	1	9	1	719

The total number of virtual machines is highly correlated with deployment time as booting the machines and installing the software, tasks that occur for all nodes, take the most time. The additional steps to configure Config Servers, Mongos Instances, Replicas, and Shards run in relatively similar times, so the specific type of component created has little impact on the deployment time. For example, holding all other deployment variables at 1, a deployment with five Config Servers took 534 seconds, one with five Mongos Instances took 556 seconds, one with five Shards took 607 seconds, and one with a five Shard Replica set took 524 seconds. There is small extra overhead to starting additional data shards, but a strong correlation exists for total nodes to runtime for all configurations. Deployment times for version 3.4 were very similar to version 3.2.

Table 5 shows this empirically, as it takes a very similar time to launch configurations with the same total number of nodes, but extremely different mixed of Config Servers, Mongos Instances, Replicas, and Shards.

The total number of nodes in a deployment can be calculated by the following equation involving the parameters to the deployment script.

$$c + m + (s * r) = \text{total nodes}$$

**Table 5. Deployment Times on Chameleon Cloud in Seconds**

Config Servers	Mongos	Shards	Replicas	Time in Seconds
-c	-m	-s	-r	
5	1	1	1	534
1	5	1	1	556
1	1	5	1	607
1	1	1	5	524

Due to Chameleon Cloud having the most reliable and consistent performance of the three clouds, performance numbers are presented only for selected runs on Chameleon. These numbers are proportionately representative of deployment timings on Jetstream and FutureSystems.

## 8. BENCHMARKING

After the sharded MongoDB instance has been fully deployed, a benchmarking process is run to assess performance of the configuration. This process has also been fully automated. It is invoked by running the benchmark function of project.py and passing either the parameter large (for a full benchmark test) or small for a small test.

### 8.1. Data Set

The data set used in the benchmarking testing and analysis was Major League Baseball PITCHf/x data obtained by using the program Baseball on a Stick (BBOS) [24]. BBOS is a python program created by *willkoky* on github which extracts data from mlb.com and loads it into a MySQL database. While it would be possible to convert this program to populate the MongoDB database directly, collecting all of the data is a time consuming process. Therefore, the data was captured locally to the default MySQL database and then extracted to a CSV file. This file contains 5,508,014 rows and 61 columns. It is 1,588,996,075 bytes in size uncompressed.

### 8.2. Methodology

There are several goals of the benchmarking process. The primary benchmarking goal of the project is to assess the impact of sharding on performance in MongoDB. Since replication was also built into the deployment process, a secondary goal was to assess the impact of replica sets on performance. A third goal is to assess performance of MongoDB version 3.4 versus version 3.2, specifically for various shard configuration. A final objective is to assess the relative performance of the Chameleon, FutureSystems, and Jetstream cloud computing environments.

The benchmarking tests are design to assess performance in three situations: Reads, Writes, and MapReduce operations.

#### 8.2.1. Impact on Reads

To access the impact of different configurations on writes, we use MongoDB's `mongoimport` command. `Mongoimport` is a command line tool capable of loading JSON, CSV, or TSV files [25]. In this case, we load a CSV file to the `pitches` collections in the `mlb` database.

#### 8.2.2. Impact on Writes

To assess the impact of different configurations on reads, we use MongoDB's `find` command. We read the data previously loaded by the `mongoimport` command to the `pitches` collection. The `find` command retrieves documents that meet a specified criteria. In this case, we search for pitches with a speed over 100 mph, a relatively rare event in baseball. To limit the information sent back over the network, we only return a count of these events. 3,632 is the count returned of 5,508,014 total documents. The column we search on does not have an index, as the goal is to test the impact of sharding on a long running query.

#### 8.2.3. Impact on MapReduce

To assess the performance of MongoDB version, sharding, and replication on reads, a simple MapReduce operation was written against the `pitches` table to get the average speed of pitches that were stikes versus those that were not strikes [26] [27].

### 8.3. Benchmarking Process

The benchmarking process is invoked by running the `benchmark` function of the script `project.py` with the `large` parameter. Results for each test are automatically captured in file `benchmark_datetime.csv`. This file included the configuration the test was run under (cloud, MongoDB version, config server replication factor, mongos instances, number of shards, and shard replication factor) along with the run times of the `find`, `mongoimport`, and `MapReduce` commands. After all tests were run, a shell script, `combine_benchdeploy.sh` combines all files into one file, `benchmark_combined.csv`.

The graphical depictions of the test results shown in the next section were created by running python programs to average the run times across the shard, replication, and version configurations shown. For consistency, config server replication and mongos instances were both kept at one for all benchmarking tests. Additionally, replication was kept at one for sharding and version tests and sharding at one for replication tests. This methodologies allows us to isolate the variable we are assessing. All sharding tests were run with one, two, three, five, seven, and nine shards. All replication tests were run with one, two, three, five, and seven replicas.

To setup for the test, a compressed version of file has been stored in an Amazon Web Services S3 directory. This file is pre-staged on a Mongos instance during the deployment (but excluded from the run time) and is loaded it to a collection named `pitches` in MongoDB using `mongoimport` before running the `find` and `MapReduce` commands.

Before the benchmarking process can be run, a sharded collection must be created and sharded. This was also done via Ansible during the deployment in preparation for benchmarking. For reproducibility of benchmarks, the benchmarking process also deletes any data from the `pitches` collection that may have been loaded prior to running `mongoimport`.

The shard key for the `pitches` table is set to `pitchID`. `PitchID` is a unique key to each pitch document. Selecting `pitchID` as the shard key should cause the data to be reasonably evenly distributed among the shards. Data distribution will be analyzed in a subsequent section.

### 8.4. Data Distribution

To explore how data was allocated among the shards, a function called `distribution` was built into `project.py`. This function runs the `getShardDistribution()` command, which reports on how data and documents are distributed among shards [28]. Tables 6 and 7 show the results of tests with one, three, and five shards in version 3.2 and 3.4 of MongoDB. The results clearly show the data is well distributed, although interestingly, in all cases there is some minor skew toward the first shard having the most data. These results clearly show that data distribution is similar in both versions of MongoDB.

**Table 6. Data Distribution among Shards - Version 3.2**

	1	2	3	4	5
1	100				
3	35.84	32.18	31.96		
5	23.04	19.27	19.40	19.38	18.89

**Table 7. Data Distribution among Shards - Version 3.4**

	1	2	3	4	5
1	100				
3	36.23	31.82	35.75		
5	22.26	19.67	19.42	19.37	19.26

## 8.5. Benchmarking Analysis

### 8.5.1. Cloud Analysis

Chameleon Cloud was significantly more stable and reliable than FutureSystems and Jetstream Clouds for our testing. Chameleon yields the fastest and most consistent results with very few errors. Jetstream initially had stability problems that were eventually resolved by the Jetstream support team. Once these issues were resolved, Jetstream performance and stability was very close to Chameleon's. FutureSystem performance was the poorest with respect to run time. Environmental errors were initially frequent, but after allocating new floating IPs test would be completed successfully. JetStream performance was good, but the environment was very unstable. Due to its stability and performance, Chameleon was chosen as the environment to test MongoDB version 3.4 versus 3.2, due to its stability.

### 8.5.2. Impact of Sharding on Reads

Figure 2 depicts the impact on performance of various numbers of shards on a find command in Chameleon, FutureSystems, and Jetstream Clouds. All three clouds show a strong overall decline in run time as the number of shards increases, which shows the positive impact of sharding on performance. For all clouds, reads were over 35 seconds for one shard and less than 10 seconds for five shards. This is a significant gain in performance.

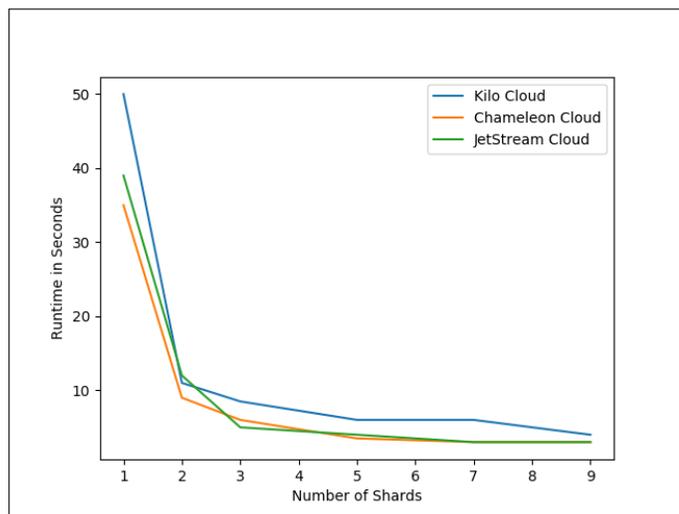


Fig. 2. Find Command - Sharding Test

All three clouds show a particularly large gain in performance when increasing from one shard to two. Run time for two shards is less than one third the run time of one shard. Increases in shards beyond two show much smaller incremental gains.

Performance on Chameleon Cloud and Jetstream is very similar for the find test. Kilo performance is worse, although proportionately better than on the mongoimport test. This is an interesting observation as for both deployment and mongoimport, performance was much better on Chameleon and FutureSystems than Kilo. One difference from the mongoimport test is that much less data is being sent over the network. Network speeds could be a factor in this discrepancy.

Figure 2 can be recreated by running the program `benchmark_shards_find.py` passing the file `benchmark_combined.csv` as a parameter. It plots the average run time for each configuration as shown using matplotlib. This report is run automatically by the report function of `project.py`.

### 8.5.3. Impact of Sharding on Writes

Figure 3 depicts the impact on performance of various numbers of shards on a mongoimport command in the three clouds. For all clouds, run time of the mongoimport command in our tests does not appear to be impacted by the number of shards. Since the same amount of data is written with more computing resources available when there are more shards, we might expect to see a performance gain. However, there are possible explanations for performance not improving. First, the mongoimport command may not write data in parallel. This is not indicated in the documentation, but it seems likely that it reads the file serially. Second, resources on the server the data is written to may not be the bottleneck in the write process. Other resources like the network time seem more likely to be the bottleneck. Since we are always going over the network from the mongos instance to a data shard, regardless of the number of shards, a bottleneck in the network would impact all shard configurations equally.

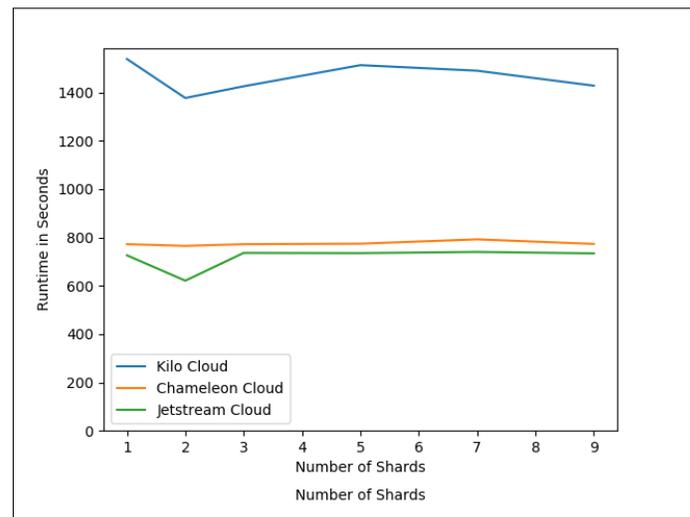


Fig. 3. Mongoimport Command - Sharding Test

While sharding did not benefit a single threaded mongoimport command, it is likely it would benefit other heavy write operations, particularly coming through multiple mongos instances. In a non-sharded environment, this would lead to a heavy load on the single data shard. In a sharded environment, the load on each shard would drop as the number of shards increased.

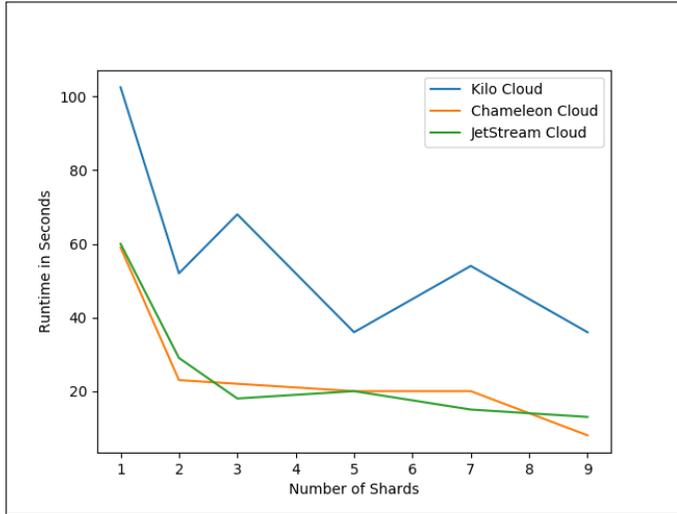
While performance on Chameleon and FutureSystems was very similar for the find command, performance of the mongoimport command was significantly better on Chameleon than on Kilo. We see approximately 50% better performance on both Chameleon and Jetstream Clouds compared to FutureSystems. Jetstream performance is slightly better than Chameleon for the import test.

Figure 3 can be recreated by running the program `benchmark_shards_import.py` passing the file `benchmark_combined.csv` as a parameter. It plots the average run time for each configuration as shown using matplotlib. This report is run automatically by the report function of `project.py`.

### 8.5.4. Impact of Sharding on MapReduce

Figure 4 shows the performance of MapReduce across various sharding configurations on our three clouds. These results are relatively similar to the find results. While results are inconsis-

tent, particularly on FutureSystems, likely due to environmental issues, all clouds show an overall decrease in processing time with addition of shards. Relative to mongoimport performance, performance is more similar across the three clouds for MapReduce.

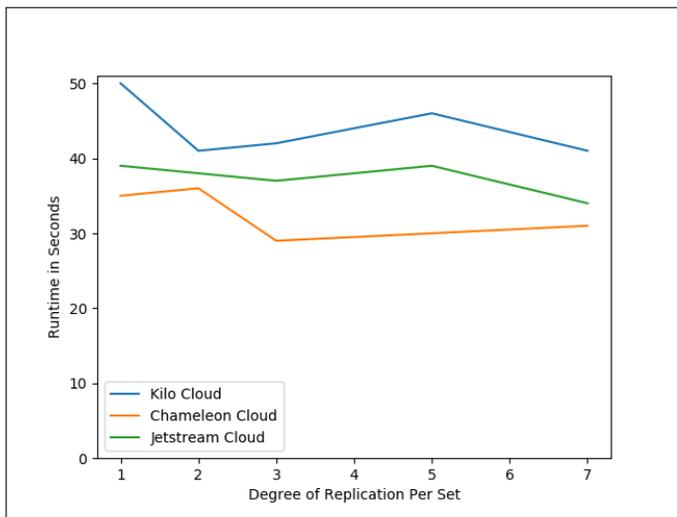


**Fig. 4.** MapReduce - Sharding Test

Figure 4 can be recreated by running the program `benchmark_shards_mapreduce.py` passing the file `benchmark_combined.csv` as a parameter. It plots the average run time for each configuration as shown using matplotlib. This report is run automatically by the report function of `project.py`.

**8.5.5. Impact of Replication on Reads**

Figure 5 depicts the impact on performance of various numbers of replicas on a find command in Chameleon, FutureSystems, and Jetstream Clouds. These results show no correlation between the number of replicas and find performance.

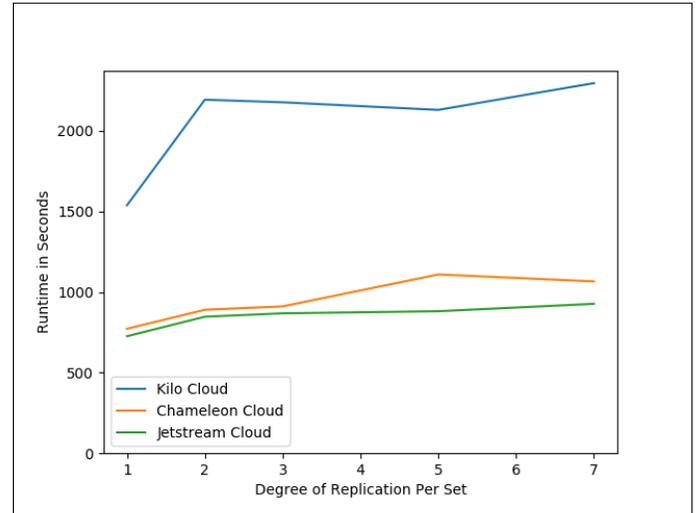


**Fig. 5.** Find Command - Replication Test

Similarly to other tests, performance on Chameleon was best for the majority of the test runs in the find replication test, followed by Jetstream, with FutureSystems performing the worst.

Figure 5 can be recreated by running the program `benchmark_replicas_find.py` passing the file `benchmark_combined.csv` as a parameter. It plots the average run time for each configuration as shown using matplotlib. This report is run automatically by the report function of `project.py`.

**8.5.6. Impact of Replication on Writes**



**Fig. 6.** Mongoimport Command - Replication Test

Figure 6 depicts the impact on performance of various numbers of replicas on a mongoimport command on our three Clouds. The results show poorer write performance as the number of replicas increase. Given that an extra copy of data is written with each increase in the replication factor, this performance hit is expected.

Performance on Jetstream and Chameleon were very close on this test with Chameleon only performing significantly better with four or more replicas. FutureSystems import performance was by far the worst of the three clouds.

Figure 6 can be recreated by running the program `benchmark_shards_import.py` passing the file `benchmark_combined.csv` as a parameter. It plots the average run time for each configuration as shown using matplotlib. This report is run automatically by the report function of `project.py`.

**8.5.7. Impact of Replication on MapReduce**

As shown in Figure 7, replication appears to have no impact on MapReduce operations. While there are variations in FutureSystems and Jetstream performance for different numbers of replicas, they do not follow a consistent pattern and appear to be caused by environmental issues. This is an interesting result as increased levels of replication came with a performance penalty for the find command, which also reads data.

As with several other tests, Chameleon MapReduce performance was the best, followed by Jetstream, with FutureSystems again being the worst.

Figure 7 can be recreated by running the program `benchmark_shards_import.py` passing the file `benchmark_combined.csv` as a parameter. It plots the average run time for each configuration as shown using matplotlib. This report is run automatically by the report function of `project.py`.

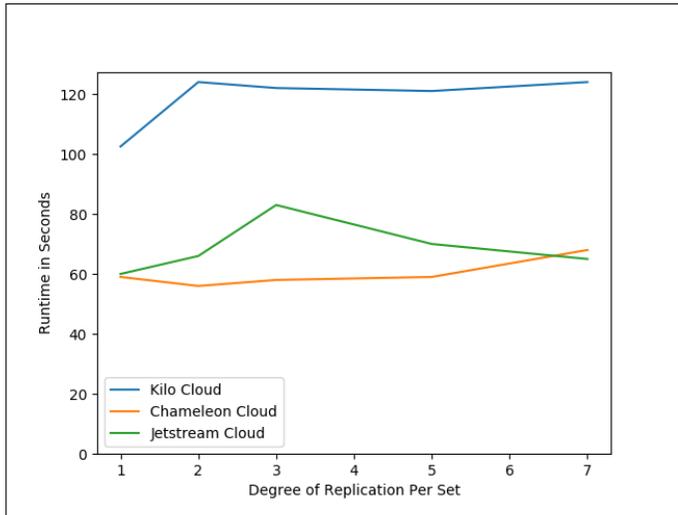


Fig. 7. MapReduce - Replication Test

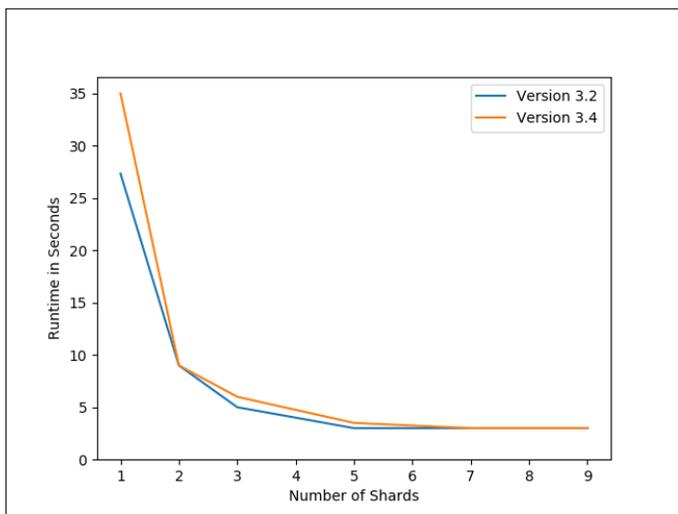


Fig. 8. Find Command - Version 3.2 vs 3.4

**8.5.8. Impact of Version and Sharding on Reads**

Figure 8 shows the MongoDB version 3.4 and 3.2 find performance on Chameleon Cloud. Results are very close, with version 3.2 having the best performance for one shard and performance being similar for all other sharding levels.

Figure 8 can be recreated by running the program `benchmark_version_find.py` passing the file `benchmark_combined.csv` as a parameter. It plots the average run time for each configuration as shown using `matplotlib`. This report is run automatically by the `report` function of `project.py`.

**8.5.9. Impact of Version and Sharding on Writes**

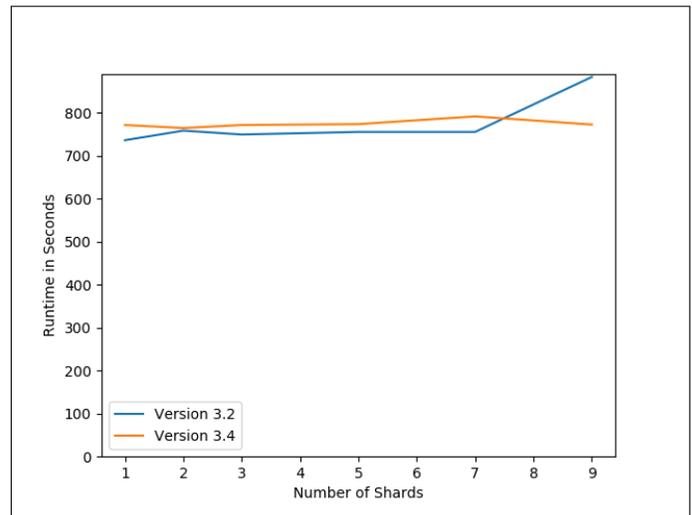


Fig. 9. Mongoimport Command - Version 3.2 vs 3.4

Figure 9 shows the MongoDB version 3.4 and 3.2 mongoimport performance on Chameleon Cloud. Runtimes are similar for each version. Version 3.2 is slightly faster at the lowest sharding levels and Version 3.4 is slightly faster at the highest sharding level. Given the mixed results and close run times, neither version shows a significant advantage for write operations.

Figure 9 can be recreated by running the program `benchmark_version_find.py` passing the file `benchmark_combined.csv` as a parameter. It plots the average run time for each configuration as shown using `matplotlib`. This report is run automatically by the `report` function of `project.py`.

**8.5.10. Impact of Version and Sharding on MapReduce**

Figure 10 shows the MongoDB version 3.4 and 3.2 mongoimport performance on Chameleon Cloud. Runtimes are similar for each version and with each version being faster at some shard level, which appears to be random. Given the mixed results and close run times, neither version shows a significant advantage for MapReduce operations.

Figure 10 can be recreated by running the program `benchmark_version_find.py` passing the file `benchmark_combined.csv` as a parameter. It plots the average run time for each configuration as shown using `matplotlib`. This report is run automatically by the `report` function of `project.py`.

**9. SUMMARY**

We have created, tested, and demonstrated a fully automated program to configure and deploy a sharded MongoDB cluster to three cloud environments: Chameleon, Jetstream, and

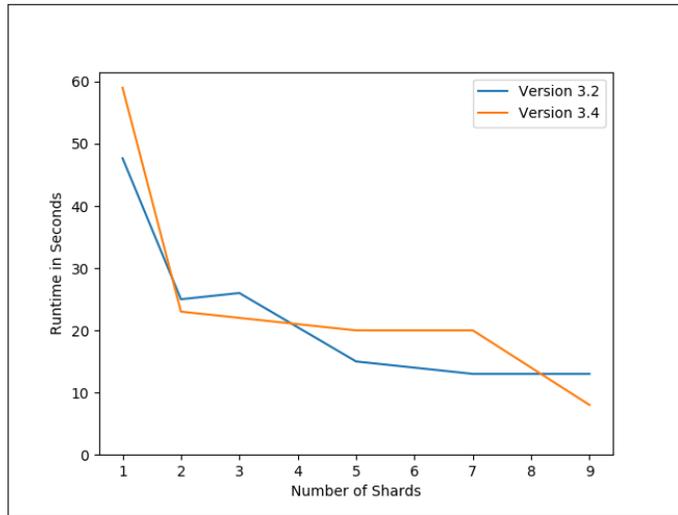


Fig. 10. MapReduce - Version 3.2 vs 3.4

FutureSystems. Using a combination of Python, Bash, and Cloudmesh Client, the a cluster is dynamically deployed with a selected number of Config Server Replicas, Mongos Routers, Shards, and Shard Replicas and either MongoDB version 3.4 or 3.2. Functions also exist for terminating the environment, reporting on data distribution, benchmarking, and reporting on performance testing.

An automated benchmarking process to show the impact of well distributed data across shards of a large data set has been run for various configurations. The impact of MongoDB version 3.4 versus 3.2, Sharding, and Replication on performance have been assessed. Testing showed performance and stability on Chameleon Cloud to be the best of our three cloud environments with Jetstream a close second after an environmental issue was resolved by the support team. FutureSystems performance consistently lagged behind the other two clouds. A key finding is that read performance, typically a high priority for noSQL data stores and Big Data operations, increases significantly as shards are added. Testing also showed that a predictable performance penalty is associated with replication. Our comparison of version 3.4 and 3.2 showed no significant differences between version 3.2 and 3.4 performance across various sharding levels.

## ACKNOWLEDGEMENTS

This work was conducted with the help of resources provided by FutureSystems and Chameleon Cloud.

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**Mark McCombe** received his B.S. (Business Administration/Finance) and M.S. (Computer Information Systems) from Boston University. He is currently studying Data Science at Indiana University Bloomington.

## A. CODE REFERENCES

References used in deployment, benchmarking, visualization programs are formally documented here as well as noted in a comment in the code [29] [30] [31] [32] [33] [34] [35] [36] [37] [38] [39] [40] [41] [42].

## B. EXECUTION INSTRUCTIONS

The project should be run on an Ubuntu 16.04 LTS (Xenial Xerus) machine. The required modules for the project can be installed in a virtualenv virtual environment using the file `project/S17-IO-3012/code/requirements.txt`.

The main script, `project/S17-IO-3012/code/bin/project.py`, can be run to execute all functionality. Project.py functions (deploy, kill, benchmark, report, distribution) are described in help, but sample instructions are provided below for each function.

`python project.py` has four functions.

### B.1. deploy

Runs a deployment. Takes 6 parameters:

1. Cloud - chameleon, jetstream, or kilo (futuresystems)
2. MongoDB Version - 34 for version 3.4, 32 for version 3.2
3. Config Server Replication Size - a number
4. Mongos Router Instances - a number
5. Shard Count - a number
6. Shard Replication Size - a number

Simple example:

```
deploy chameleon 34 1 1 1 1
```

More complex examples:

```
deploy chameleon 32 3 2 3 3
```

```
deploy kilo 34 2 2 1 1
```

### B.2. kill

- Deletes and undefines the current cluster. No parameters.

### B.3. benchmark

Runs a benchmark `mongoimport`, `find`, and `MapReduce` and logs timings. Takes one required parameter - *large* or *small* (for testing purposes).

### B.4. report

Regenerates PNG files in the `code/report/` directory based on current benchmarks

### B.5. distribution

Shows the data distribution of the current configuration. For meaningful results, must be run after benchmark.

## C. DIRECTORY STRUCTURE

The `project/S17-IO-3012/code` contains several directories.

### C.1. benchmark/

Contains all benchmark timing logs

### C.2. bin/

Contains all Bash and Python code

**C.3. configfiles/**

Contains all configuration file templates

**C.4. deploy/**

Contains all deployment timing logs

**C.5. json/**

Contains all json documents

**C.6. playbooks/**

Contains all Ansible YAML files

**C.7. report/**

Contains all reports in PNG format

**C.8. stdlist/**

Contains all bash script output logs

**C.9. work/**

Contains temporary work files

# Music Predictive Analysis Project based on Lyrics

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Project: S17-IO-3010, September 21, 2017

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Being certain that lyrics of your song will lead to the next greatest hit would boost confidence to a lot of amateur artists who are faced with fears of never making it thus never attempting to make good their creativity. With Machine Learning (ML) this can be a thing of the past, these artists would have the ability to let ML models determine the viability of their lyrics becoming the next hit based on history of other songs that have made it to top. Through training, the model can certainly determine the outcome of different songs which will be depicted in this project.

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**Keywords:** Cloud, I524

Report: <https://github.com/lmundia/sp17-i524/tree/master/project/S17-IO-3013/report/report.pdf>

Code: <https://github.com/lmundia/sp17-i524/tree/master/project/S17-IO-3013/code>

---

## 1. INTRODUCTION

When faced with the decision to forward their song to a recording company, amateur artists find it daunting due to uncertainty of whether their song would be recorded and if it is if it will make them wealthy. Having ability to run the lyrics through a predictive analysis process that would determine the viability of the song making it would be a huge win and confidence booster to many artists. That prediction is achievable by use of machine learning and creating a model that takes already greatest his and trains it to determine what makes the song successful. This would be done by analyzing the lyrics, the locality and time of release.

In this project, we will utilize machine learning to help determine the viability of a song becoming the next greatest hit based on the lyrics, time of production, locality and the artist. The project will utilize the greatest hits of all time [1] to train a model which will then be used to analyze larger dataset of random songs [2] and provide an in-depth analysis of the next possible hit. The project will utilize a Hadoop cluster deployed on Chameleon Cloud using CloudMesh to accomplish this analysis.

## 2. ENVIRONMENT

To achieve the analysis, Cloudmesh was used in order to allow the end users ability to choose a cloud of their liking. Chameleon Cloud and Jetstream were used for initial testing but changing the default cloud on CloudMesh would allow deployment to other clouds.

### 2.1. Cloudmesh

Cloudmesh is an open source component aimed at delivering software-defined system. It's a collection of virtualized bare-

metal infrastructure, networks, application, systems and platform software unifying different clouds as a Cloud Testbeds as a Service (CTaaS) [1]. Cloudmesh was developed by Professor Gregor von Laszewski in collaboration with his team at Indiana University [2]. In this environment, cloudmesh is used to automate installation of a four-node cluster.

### 2.2. Ansible

Ansible is also an open source platform used in automation of deployments and tasks executions [3]. It has the ability to execute scripts to a remote system thus making it easy to administer and manage hosts farm. Ansible is written in Python thus it requires python to be installed in the remote host for successful executions.

#### 2.2.1. Ansible Playbooks

Deemed as the real strength of Ansible, a playbook is a collection of instructions that defines what Ansible will do when it connects to each host [4]. Playbooks are written in YAML an easy to read data serialization language [5]. In this project, Ansible is used to deploy the required components to successfully accomplished the deployment, configuration and analysis of the defined files.

### 2.3. Apache Spark

Apache Spark is an open-source data processing and analytics engine designed to handle large scale dataset. Spark was originally developed by UC Berkeley but has been adopted in the Apache software stack since 2013 [6]. Spark has the ability to run as part of Hadoop, Mesos, Standalone or in a cloud environment [7]. In this project, Spark is deployed as a standalone environment and primarily used to analyze music data to in order to

identify patterns and make predictions.

## 2.4. MongoDB

MongoDB is a NoSQL, open source database program aimed at hosting documents in JSON-like format. MongoDB is favorable in storing unstructured data since it does not follow the traditional RDBMS structure. Its performance is also paramount when coupling related unstructured data [8]. For this project, MongoDB become the ideal database application because the source data structure is unknown and it can span in many directions where one dataset doesn't resemble the next. Putting such data in a structured database program would be cumbersome.

## 2.5. Python

Python is used as the programming of choice in this project due to its extensibility and also as a requirement for Ansible to execute successfully.

## 3. DEPLOYMENT

Environment deployment is automated as mentioned earlier using Cloudmesh and Ansible scripts. The environment is deployed on a 4-node cluster with the following resources.

### 3.1. Resources Table

Table 1 resources.

**Table 1. resources dedicated to the environment**

Node	Role	Flavor
Node1	Spark	m1.small
Node2	Mesos	m1.small
Node3	MongoDB	m1.medium
Node4	Analytics	m1.small

### 3.2. Cloudmesh

Code snippet below generates 4 node cluster that will be used in the inventory file for the Ansible roles. In order to use Cloudmesh Cluster, the following package levels or higher must be installed

- Cloudmesh client 4.7.2
- Pip 8.1.2
- Python 2.7.12

#### Algorithm 1. cloudmesh code

```

1  \$$ cm cluster define --count 4 --image CC-Ubuntu16.04
2  \$$ cm cluster use cluster-001
3  \$$ cm cluster allocate
4  \$$ cm cluster nodes > inventory.txt

```

#### 3.2.1. format inventory file

Define roles in the inventory file and also remove the resolved name. After formatting the inventory file, the server roles and their corresponding public IP address should look similar to the output below with the right IP address.

#### Algorithm 2. Inventory file

```

1  [spark\_server]
2  <ip address>
3
4  [mesos\_server]
5  <ip address>
6
7  [mongo\_server]
8  <ip address>
9
10 [data\_node]
11 <ip address>

```

### 3.3. Ansible

After configuring deployment of virtual machines and configuring the inventory.txt, Ansible playbooks are used to automate deployment of the required components to the nodes defined above. The following Ansible files are included: ansible.cfg – used to define default configurations for Ansible including role\_path and remote user.

#### Algorithm 3. ansible config file

```

1  [defaults]
2  roles\_path = roles
3  host\_key\_checking=false
4  callback\_whitelist = profile_tasks
5  remote\_user=cc

```

#### 3.3.1. Playbooks

The following playbooks are utilized for deployment

1. predict.yml – main file for the playbooks, used to call all the other playbooks and define their locations. Role-based playbooks are contained in scripts directory of the environment.
2. spark.yml – used to define the host, roles location and execution of Spark installation playbook. The playbooks redirect the folder structure to /roles/ansible-role-spark.
  - Tasks directory - contains main.yml playbook that's used to define all the tasks for Spark installation.
  - Defaults directory – contains main.yml that defines the default requirements for Spark installation including the spark version and download site for the distribution.
3. mesos.yml – used to define the host, roles location and execution of MongoDB installation playbook. The playbooks redirect the folder structure to /roles/ansible-role-mesos.
  - tasks directory – contains main.yml playbook that checks the operating system to determine the flavor of mesos that would be deployed. The environment contains playbooks for Debian and Redhat flavors.
  - defaults directory – contains main.yml which defines the version of mesos that will be downloaded and installed.

4. mongo.yml – used to define the host, roles location and execution of MongoDB installation playbook. The playbooks redirect the folder structure to /roles/ansible-role-mongo.
  - tasks directory - contains main.yml playbook that's used to define all the tasks for MongoDB installation. The file also includes task to create a database and initial user for the Mongo environment.
  - defaults directory – contains main.yml that defines the default requirements for MongoDB installation including the MongoDB version and download site for the distribution.
  - vars directory – contains main.yml that defines the variables for the environment like data path, admin account and password.
  - template directory – contains mongod\_config.j2 file which is used to define MongoDB configurations.
5. data.yml - used to define the host, roles location and execution of dataset playbook. The playbooks redirect the folder structure to /roles/ansible-role-dataset.
  - tasks directory - contains main.yml playbook that's downloads the MillionSongs dataset and copies into to MongoDB. The file also contains task to create collection and load data into MongoDB by executing a remote file myfiles.py

#### 4. CONCLUSION

Ability for amateur artists, artists and record labels to quickly determine the viability of a hit is paramount to their success and missed chances due to inexperience, fear of unknowns, bad song or acting when time is not ripe can be costly. Machine learning has the ability to change these outcomes, a well-trained model can help determine with high accuracy where the song will end up.

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# Deploying CouchDB Cluster

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+HID: S17-IO-3016

Project: S17-IO-3016, September 21, 2017

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**This project focuses on deployment of CouchDB Cluster using Ansible playbook on Ubuntu Chameleon Cloud VMs and benchmarking of the deployment.**

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**Keywords:** CouchDB

Report: <https://github.com/lmundia/sp17-i524/tree/master/project/S17-IO-3016/report/report.pdf>

Code: <https://github.com/lmundia/sp17-i524/tree/master/project/S17-IO-3016/code>

---

## 1. INTRODUCTION

CouchDB [1] is a no sql database management system under Apache. Data is stored as documents in CouchDB. In this project CouchDB cluster of one or more Chameleon cloud VMs is deployed using Ansible playbook and benchmarking is done to measure the time it took for deployment using a TBD benchmarking tool.

## 2. EXECUTION PLAN

This section depicts week by week execution plan for the project

### 2.1. Week 1

I was able to develop an initial Ansible script that will deploy CouchDB on Ubuntu 16.04 VM, upon successful installation the script will start CouchDB and then it will stop CouchDB on the remote VM. I booted Chameleon VM using Cloudmesh and then run Ansible playbook from my local machine. The tasks in my playbook run successfully.

### 2.2. Week 2

Run Ansible playbook to deploy CouchDB on Chameleon Cloud VM. Benchmark time it takes to deploy CouchDB on Chameleon Cloud VM

### 2.3. Week 3

Extend the Ansible script developed in Week 1 to deploy CouchDB into two Chameleon Cloud VMs.

### 2.4. Week 4

Run Ansible playbook to deploy CouchDB on two Chameleon Cloud VMs. Benchmark time it takes to deploy CouchDB on Chameleon Cloud VMs.

### 2.5. Week 5

Analysis of the benchmark results for deployment of CouchDB cluster. Document results in report and finalize report.

## 3. TECHNOLOGIES USED

- Ansible
- Cloudmesh
- Other technologies TBD

## 4. DEPLOYMENT

TBD

## 5. BENCHMARK RESULTS

TBD

## 6. CONCLUSION

TBD

## ACKNOWLEDGEMENTS

TBD

## REFERENCES

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# Analysis of USGS Earthquake Data

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Project: S17-IO-3017, September 21, 2017

US Geological Survey's (USGS) Earthquake Hazards Program monitor and report earthquakes, assess earthquake impacts and hazards, and research the causes and effects of earthquakes [1]. The geo-spatial data it collects is available for free. Big Data Analytics tools are used to analyze this data. Machine learning algorithms are used for advanced data analysis and earthquakes prediction.

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**Keywords:** I524, geospatial, MongoDB, Plotly, K-means clustering, DBSCAN, Python, pymongo, USGS, Ansible, CherryPy

Code: <https://github.com/cloudmesh/sp17-i524/tree/master/project/S17-IO-3017/code>

Report: <https://github.com/cloudmesh/sp17-i524/tree/master/project/S17-IO-3017/report/report.pdf>

## 1. INTRODUCTION

USGS collects volumes of geospatial data pertaining to earthquakes and makes it available for analysis. The project obtains a chunk of the data using GeoJSON web service provided by USGS. The data is saved locally in MongoDB database. Data is analysed using machine learning algorithms. The output is plotted (rendered) on web browser. A light weight web server is used to respond to the web requests. Project is capable of running in cloud environment. Deployment is automated using Ansible.

## 2. TECHNOLOGIES USED

Technologies used for development and deployment of this project are listed below.

1. **Cloudmesh** - Cloudmesh provides Cloud Testbeds as a Service (CTaaS). It is a platform where one can manage all cloud accounts and local files enabling one to copy them between services. Project uses cloudmesh to connect to various cloud environments.
2. **Ansible** - Ansible is an IT automation tool that automates cloud provisioning, configuration management, and application deployment. Once Ansible gets installed on a control node, which is an agentless architecture, it connects to a managed node through the default OpenSSH connection type. Project uses ansible for one-click deployment.
3. **Python** - Python is an object oriented, light weight programming language. Python is primary programming language used in this project.
4. **Mongo-DB** - MongoDB is an unstructured (NOSQL) database, which uses document-oriented data model. It

stores data in flexible JSON-like documents. The project uses Mongo-DB to store GeoJSON data of earthquakes locally.

5. **Plotly** - Plotly is data analytics and visualization tool. One can create interactive graphs using plotly. It provides graphing libraries for Python. The plotly is used in the project as a visualization tool.
6. **Scikit-learn** - Scikit-learn provides tools for data analysis and data mining. Scikit-learn provides a wide range of learning algorithms. Scikits are the names given to the modules for SciPy, a fundamental library for scientific computing. As these modules provide different learning algorithms, the library is named as scikit-learn. In this project data classification is done using scikit learn.
7. **CherryPy** - CherryPy is an object-oriented web application framework. It is designed for rapid development of web applications by wrapping the HTTP protocol. It is WSGI (Web Server Gateway Interface) thread-pooled web server. CherryPy is used as a web server in the application.

## 3. DESIGN

Figure 1 shows main components and data flow of the application. There are four major components in the application.

### 3.1. WebServer

Purpose of web server is to listen to the user's HTTP GET request, call appropriate python method at the backend, get the response from the python method, and send it to the web client as a response. The server listens at port 8081.

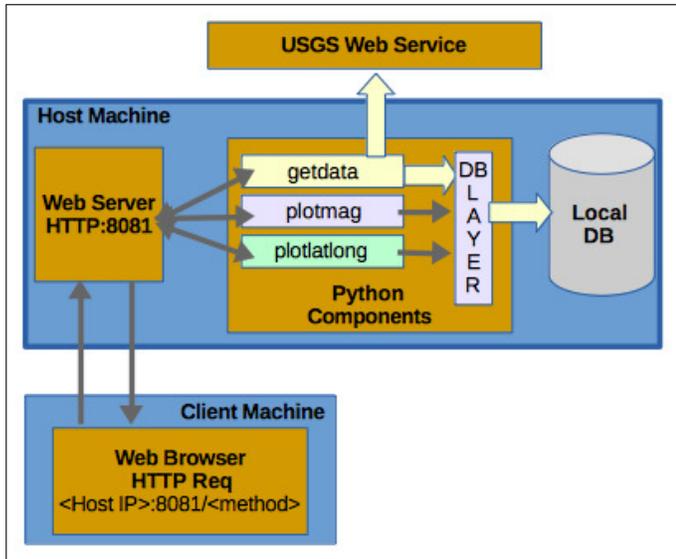


Fig. 1. Application Components

### 3.2. getusgsdata - getdata

getusgsdata component is responsible for fetching the data from USGS and storing it in local database. It uses dbleyer common component to communicate with the local database. Running this component at least once is necessary as it downloads the data on which other components are dependent.

### 3.3. kmeansplot - plotmag

kmeansplot component implements the K-Means clustering algorithm and plots it using plotly library. It reads the Magnitude and Depth data from local database using dbleyer common component. The algorithm classifies the data in 3 clusters based on the earthquakes magnitudes. Number 3 is selected by trial and error basis. Output of plotly.plot() function is set as *div* so that it returns the *div* with scatter plot and data, which has later been embedded into a simple HTML. This HTML is rendered on web browser as output.

### 3.4. dbscanplot - plotlatlong

dbscanplot implements DBSCAN algorithm for clustering the latitude-longitude data. It reads the data from local database using dbleyer common component. Clusters are plotted on a globe using plotly's Scattergeo() function. Following programming statements ensure showing North and South America region on globe.

```
geo = dict(scope = ('northamerica', 'southamerica'))
projection = dict(type = 'orthographic')
```

For clustering lat long data DBSCAN algorithm is used instead of K-Means because, (1) for clustering lat long data it needs an algorithm that can handle arbitrary distance function, (2) K-Means works well with linear data. Lat long data is not linear, (3) Unlike K-Means, number of clusters are not required to mention in DBSCAN. It is hard to predict clusters when locations are spread across world.

## 4. IMPLEMENTATION

### 4.1. USGS Web Service and Data Set

USGS earthquake data is fetched using the USGS web service and passing relevant parameters to it. Out of the voluminous world-wide data of decades this project uses data of earthquakes appeared in North and South America for duration of 2 years from 2015-1-1 till 2017-1-1, having magnitude over 4. To select North and South America region data, its Latitude and Longitude are taken from Search Earth Catalog tool provided by USGS. [2]. Web service returns data in JSON format.

### 4.2. Data Processing and Visualization

**Severity of earthquakes.** Severity of earthquakes is analysed by their magnitude and depth. Data is classified into clusters using K-Means clustering algorithm (Section 4.1). Clusters are plotted on a interactive scatter plot.

**Region affected the most by earthquakes.** Analysing Latitude-Longitude of epicenter of the earthquake shows the regions where earthquakes are frequent. Lat-long data is clustered using DBSCAN algorithm (Section 4.2). Clusters are plotted on a geo-scatter plot on a world map.

### 4.3. Deployment

Project is deployed using ansible. Ansible jobs are collected in a playbook and run on virtual clusters provided by Chameleon and Jetstream cloud. The tasks include cloning the git repository, installing software stack, installing dependencies and installing MongoDB.

### 4.4. Local Data Storage

To avoid frequent web service calls and unnecessary traffic, data once downloaded, is stored locally in MongoDB for further usage by other components. Data is fetched using pymongo library.

### 4.5. Steps to Execute

Steps to execute the project are explained in detail in README.md file [3].

## 5. CLUSTERING ALGORITHMS

### 5.1. K-Means Clustering

Given a target number,  $k$ , of clusters to find, K-means algorithm locates the centers of each of those  $k$  clusters and the boundaries between them. It does this using the following algorithm [4].

- Step 1: Start with a randomly selected set of  $k$  centroids
- Step 2: Determine which observation is in which cluster, based on which centroid it is closest to (using the squared Euclidean distance.

$$\sum_{j=1}^p (x_{ij} - X_{i_j})^2$$

where  $p$  is the number of dimensions)

- Re-calculate the centroids of each cluster by minimizing the squared Euclidean distance to each observation in the cluster
- Repeat 2. and 3. until the members of the clusters (and hence the positions of the centroids) no longer change.

### 5.2. DBSCAN

DBSCAN (Density-Based Spatial Clustering of Application with Noise) is a clustering algorithm. Given a set of points in some space, it groups together points that are closely packed together (points with many nearby neighbors), and marks points as outliers if they lie alone in low-density regions. Unlike K-Means Clustering, DBSCAN doesn't need to specify the number of clusters as it finds all the clusters that satisfy the requirement. Following points summarize the algorithm [5].

- Step 1: For each point in the data set, an n-dimensional sphere of radius *epsilon* is drawn around the point (if you have n-dimensional data).
- Step 2: If the number of points inside the sphere is larger than *min-samples*, the center of the sphere is set as a cluster, and all the points within the sphere belong to this cluster.
- Step 3: Loop through all the points within the sphere with the above 2 steps, and expand the cluster whenever it satisfy the 2 rules.
- Step 4: For the points, which do not belong to any cluster, are treated as outliers.

### 6. BENCHMARKING

The performance of application was tested on the speed and latency while data input/output and data processing. Two different sized datasets were used for testing. They are given in Table 'Datasets'. The Table 'VM Configuration' shows details of VMs used for performance testing. Results are shown in Table 'Benchmark Results'.

**Table 1. VM Configuration**

Cloud	Chameleon	Jetstream
Image	Ubuntu-Server-14.04-LTS	ubuntu-14.04-trusty-server-cloudimg
OS	Ubuntu 14.04	Ubuntu 14.04
RAM CPU (Cores)	2 GB	2 GB
HDD Size	20 GB	20 GB
Flavour	m1.small	m1.small
Group	pearth	pearth
Assign Floating IP	True	True

Figure 2 shows time taken in seconds for data read and data processing with small dataset. Figure 3 shows the result with large dataset.

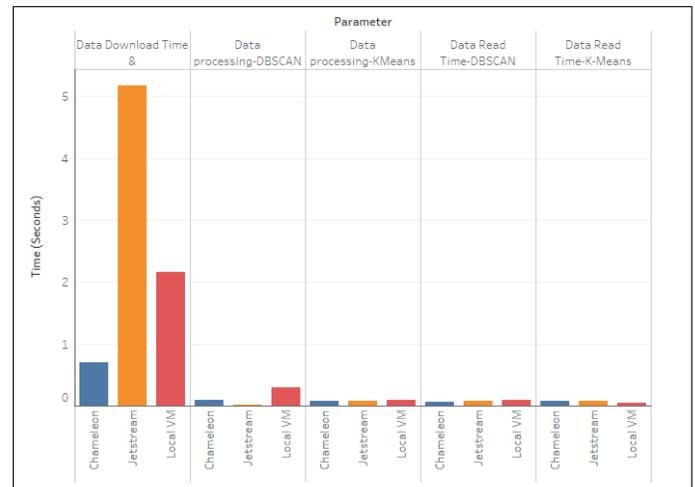
Performance tests are included in the python scripts themselves. As the scripts are executed, results are written in text files in 'benchmark' folder at project directory.

### 7. RESULT AND ANALYSIS

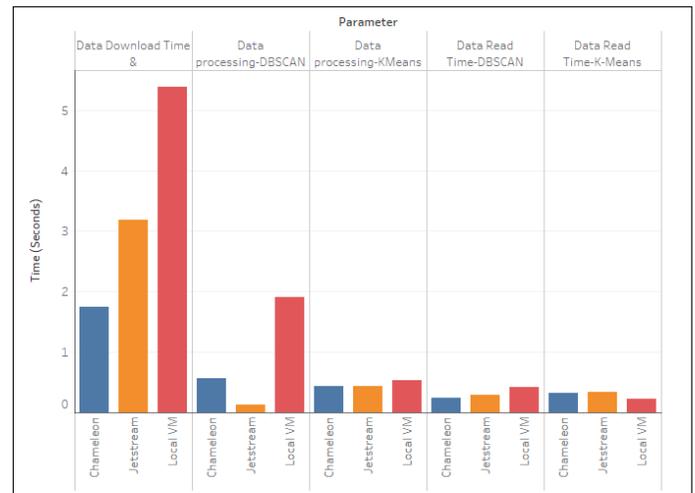
Table 3 shows the time taken to run ansible playbook successfully on various environments. It took maximum time to deploy the

**Table 2. Datasets**

Parameter	Dataset1	Dataset2
Region	North, South America	North, South America
Duration	2 years	2 years
Min Magnitude	4	3
Data Size	Small	Large



**Fig. 2. Time taken for small dataset**



**Fig. 3. Time taken for large dataset**

application on jetstream. Possible reason could be slow network connectivity.

**Table 3. Time taken for Deployment**

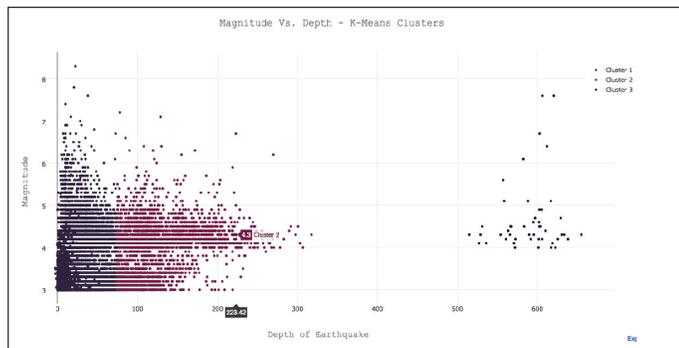
Environment	Time (hh:mm:ss)
Local VM	00:07:35
Chameleon	00:08:12
Jetstream	00:10:08

Figure 4 shows default page showing application usage. Output of K-Means clustering of magnitude and depth data is given in Figure 5. Figure 6 shows a closer look at scatter plot. Figure 7 is the output of DBSCAN clustering of earthquake locations. Both the graphs are interactive. On the 'Magnitude and Depth' graph one can choose one or more clusters. Mouse hover shows magnitude and its corresponding depth. The 'Earthquake locations' globe shows lat-long information on mouse hover. The user can rotate the globe with mouse key press.

**Application usage:**

1. Click [getdata](#) method to download data.
2. Click [plotmag](#) method to view earthquakes magnitude on scatter plot.
3. Click [plotlatlong](#) method to view lat long plot.

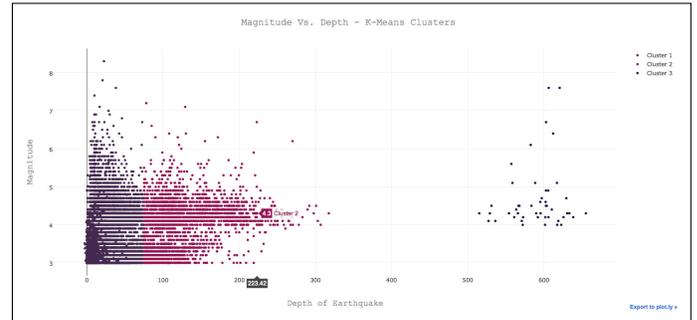
**Fig. 4.** Application usage



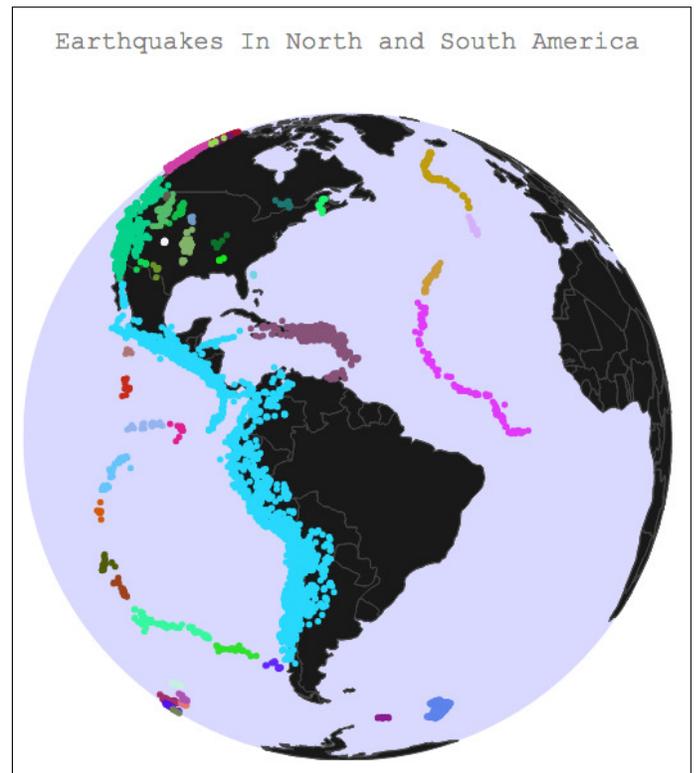
**Fig. 5.** Magnitude and Depth(Kms)

The focus of an earthquake is the actual point underground where rocks break. From the results it is clear that there were fewer earthquakes having the focus deep, greater than 300kms. Earthquakes having shallow focus (less than 70kms) are comparatively lesser than the ones having intermediate focus (70kms to 300km). Thus, maximum earthquakes occurred between 70kms to 300kms deep underground.

Analysis of earthquake locations shows that maximum earthquakes have happened in the Pacific coastal area of North and south America. We can confirm this result with USGS facts, which states "The majority of the earthquakes and volcanic eruptions occur along plate boundaries such as the boundary between the Pacific Plate and the North American plate. One of the most active plate boundaries where earthquakes and erup-



**Fig. 6.** Close look at the cluster



**Fig. 7.** Earthquake locations on globe

tions are frequent, for example, is around the massive Pacific Plate commonly referred to as the Pacific Ring of Fire [6]."

There is a subtle difference in output of K-Means and DBSCAN algorithms. K-Means worked with lesser number of clusters (3), while DBSCAN created greater number of clusters, more than 50 in this case. K-Means produced output linearly, cluster1 to cluster3. DBSCAN produced non-linear output. A cluster in Pacific ocean is Cluster28, whereas, the cluster adjacent to it is Cluster39.

## 8. CONCLUSION

This project was an opportunity to use Big Data open source software and projects. We can conclude that Ansible is a powerful tool for one click deployment and continuous integration. Cloudmesh client is a convenient tool to work with multiple cloud environments at the same time. Plotly is a powerful library that allows creating interactive visualization.

While researching for the algorithms we came to know that DBSCAN is better choice for classification if one doesn't want to specify number of clusters beforehand.

Analysis of earthquakes data showed interesting facts. In 2 years span from year 2015 till 2017 there were around 15,000 earthquakes of magnitude more than 3, and approx 7,100 earthquakes of magnitude more than 4.

## 9. ACKNOWLEDGEMENTS

This project is undertaken as part of the I524: Big Data and Open Source Software Projects course at Indiana University. The author would like to thank Prof. Gregor von Laszewski and his associates from the School of Informatics and Computing for providing all the technical support and assistance.

## 10. LICENSING

Project uses Apache license ver 2.0.

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## 11. APPENDICES

Appendix A: The work on this project was distributed as follows between the authors:

**Nandita Sathe.** She completed all the work related to development of this application including research, testing and writing the project report.

S17-IO-3018/report/report.pdf not submitted

# Twitter sentiment analysis of the Affordable Care Act in 2017

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Project: S17-IO-3019, September 21, 2017

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The mission of this project is to utilize technologies and cloud computing to perform a successful sentiment analysis through software deployment written in python. The software deployment will encompass data mining, analysis of big data, and comparison of this deployment across a variety of cloud computing services. The sentiment analysis will use the social media platform twitter and python libraries that effectively extract relevant data to the project goal.

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Keywords: Cloud, I524

Report: <https://github.com/cloudmesh/sp17-i524/tree/master/project/S17-IO-3019/report/report.pdf>

Code: <https://github.com/cloudmesh/sp17-i524/tree/master/project/S17-IO-3019/code>

---

## 1. INTRODUCTION

The current political climate of the United States is divided on many important issues. There is a disconnect between the motivations of the politicians of today and what is deemed important to the American people. The affordable care act(ACA) also known as Obamacare has been a target of the GOP, however it is uncertain if that sentiment is shared by most Americans. With a law that affects millions of Americans it is often difficult to gauge how the American people feel about the current healthcare law. Twitter is one of the biggest social medias on the internet with 67 million active users in the United States as of Q4 2016.[1] It is the goal of the project to gauge how Obamacare is viewed by twitter users who reside in the United States.

## 2. TECHNOLOGIES

Cloudmesh is an open source toolkit that allows the user to work across a variety clouds, virtual machines and clusters. This facilitates the ease of porting deployments to different clouds enabling the capability to benchmark cloud performance on a particular deployment. [2] The project was developed by Gregor von Laszowski and his colleagues at Indiana University. This will be the primary interface used to port the software to clouds such as chameleon cloud and futuresystems.

Ansible is open source software used for automation of provisioning of software deployments. This will be used when deploying on virtualization and cloud environments.

Chameleon cloud and futuresystems to be discussed here.

## 3. PYTHON

Early scripts have already been developed utilizing Twitters API and the python library tweepy to mine tweets that contain information relevant to Obamacare. Currently, the code authenticates with the twitter API, mines the tweets that contain a keyword of interest and finally a sentiment analysis which will rate a tweet by its polarity and subjectivity. For the sentiment analysis, the TextBlob library is used for its natural language processing(NLP) functionality. The final part of code outputs the tweet content and sentiment analysis into two columns into a csv file. This code will evolve to include data visualization through matplotlib and deeper analysis as the project moves closer to completion. Other python libraries will likely be added as well.

## 4. BENCHMARKS

Software will be deployed and benchmarked on various clouds.

## 5. LICENSING

TBD

## 6. WORK BREAKDOWN

Michael Smith is responsible for all aspects of this project.

## 7. CONCLUSION

The software once finalized will be deployed across various clouds with the help of cloudmesh and ansible. Benchmark performance of the various clouds as well as analysis of the

twitter sentiment data will encompass most the final project report.

## 8. AUTHOR BIOGRAPHIES

Michael Smith is a senior quality control peptide chemist at Creosalus Inc. in Louisville, Kentucky. Michael possesses a MS in pharmaceutical sciences and a BS in Biology from the University of Kentucky. He will obtain his MS in Data Sciences program from Indiana University in May 2018. His current interests are python programming, data analytics, and spending time with his children.

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- [2] Cloudmesh, "Cloudmesh," Webpage. [Online]. Available: <https://cloudmesh.github.io/>

# Detection of street signs in videos in a robot swarm

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Project: S17-IO-3022, September 21, 2017

**Extracting and identifying traffic signals from the videos captured by Robot swarms to help in recognizing the pattern and benchmarking the performance of the setup.** © 2017 <https://creativecommons.org/licenses/>. The authors verify that the text is not plagiarized.

**Keywords:** Cloud, I524

Report: <https://github.com/cloudmesh/sp17-i524/tree/master/project/S17-IO-3022/report/report.pdf>

Code: <https://github.com/cloudmesh/sp17-i524/tree/master/project/S17-IO-3022/code>

## 1. INTRODUCTION

For test purpose we created some mobile videos of traffic in a simulated traffic setup. All saved video files are uploaded on the Hadoop HDFS [1]. Batch processing is enabled on the input video files to search for key images, namely the red, green and yellow signals in the images using the OpenCV [2] library's Template matching functionality. Hadoop Map reduce [1] is used for processing and analysis of the images in the videos and getting a count of the how many red or green or yellow signals are encountered.

- a
- b

collectd [3] is used for benchmarking of the setup with Apache Hadoop using various sized data sets and number of nodes.

## 2. TECHNOLOGY USED

tables need a begin table end table

Technology Name	Purpose
Hadoop [1]	map reduce
OpenCV [2] Pattern matching in video	
ansible [4]	Automated deployment
collectd [3]	Collection of statistics of setup for benchmarking

## 3. PLAN

tables need a begin table end table

Week	Work Item	Status
week1	Ansible deployment script for Hadoop setup	planned
week2	Ansible deployment script for OpenCV setup	planned
week3	Creating sample videos	planned
week4	OpenCV template matching script	planned
week5	Deployment and test of basic setup	planned
week6	Ansible deployment of collectd	planned
week7	Performance measurement of setup and report creation	planned
week8	Exploring different setup	planned

## 4. DESIGN

TBD

## 5. DEPLOYMENT

TBD

## 6. BENCHMARKING

TBD

## 7. DISCUSSION

TBD

## 8. CONCLUSION

TBD

## 9. ACKNOWLEDGEMENT

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# Analysis of H-1B Temporary Employment-Based in Data Science Occupation

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Project: S17-IR-2002

This project aims to analyze The H-1B temporary employment-based visa for Data Science related occupations in the United States. We are trying to answer the number of questions related to Data Science related jobs in America's workforce based on H-1B visa.

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**Keywords:** Cloud, I524

<https://github.com/jardians/sp17-i524/blob/master/project/S17-IR-2002/report/report.pdf>

## 1. INTRODUCTION

The H-1B non-immigrant classification is a vehicle through which a qualified alien may seek admission to the United States on a temporary basis to work in his or her field of expertise. An H-1B petition can be filed for an alien to perform services in a specialty occupation. Prior to employing an H-1B temporary worker, the U.S. employer must first file a Labor Condition Application (LCA) [1] with Department of Labor Certification [2] and then file an H-1B petition with United States Citizenship and Immigration Services(USCIS). The LCA specifies the job, salary, length, and geographic location of employment. The employer must agree to pay the alien the greater of the actual or prevailing wage for the position [3].

To qualify as a specialty occupation, the position must meet one of the following requirements: (1) a bachelor's or higher degree or its equivalent is normally the minimum entry requirement for the position; (2) the degree requirement is common to the industry in parallel positions among similar organizations or, in the alternative, the position is so complex or unique that it can be performed only by an individual with a degree; (3) the employer normally requires a degree or its equivalent for the position; or (4) the nature of the specific duties is so specialized and complex that the knowledge required to perform the duties is usually associated with attainment of a bachelor's or higher degree

In the past 6 years, tech industry executive bemoan the lack of data scientists—the people who theoretically know how to look at the data your company generates, and delve into it to derive the all-important insights we keep hearing about. It's no secret that there's a shortage of data scientists in America's workforce. Many companies look to hire overseas to help ease the domestic talent shortfall (in fact, one in three data scientists

are born outside the U.S.) so understanding the ins and outs of visas is rapidly becoming a business necessity [4]. To accomplish the goals, I would like to answer question like the following:

- Is it the number of petitions with Data Engineer or Scientist jobs title increasing over time?
- Which part of the US has the most Data Engineer or Scientist jobs?
- what year petitions with Data Engineer or Scientist jobs granted the most between 2011 to 2016?
- Which employers file the most petitions with Data Engineer or Scientist jobs title each year?

## 2. PLAN

Following table gives a breakdown of tasks in order to complete the project. Assuming week1 starts after submission of the proposal. These work items are high level breakdown on the tasks and may changes if needed.

Time	Work Item	Status
Week-1	Ansible Playbook Deployment	Planned
Week-2	ETL and Analysis	Planned
Week-3	Performance Measurement	Planned
Week-4	Report Creation	Planned

Fig. 1. Planned Schedule

### 3. DESIGN

I break the high-level design of the technologies used into 3 main sections– storage, ingestion, processing and analyzing.

- Storage refers to decision around the storage system such as HDFS or HBase [5]
- Ingestion refers to getting data from source and loading it into Hadoop for processing.
- Analyzing refers to running various analytical queries on processed dataset to find answer and insight to the questions presented.

### 4. DATASET METADATA DESCRIPTION

The columns included in the dataset download from Kaggle [6] site are followed :

- CASE\_STATUS: Status associated with the last significant event or decision.
- EMPLOYER\_NAME: Name of employer submitting labor condition application.
- SOC\_NAME: the occupational code associated with the job being requested for temporary labor condition, as classified by the Standard Occupational Classification (SOC) System.
- JOB\_TITLE: Title of the job
- FULL\_TIME\_POSITION: Y = Full Time Position; N = Part Time Position
- PREVAILING\_WAGE: Prevailing Wage for the job being requested for temporary labor condition. The wage is listed at annual scale in USD. The prevailing wage for a job position is defined as the average wage paid to similarly employed workers in the requested occupation in the area of intended employment. The prevailing wage is based on the employer’s minimum requirements for the position. YEAR: Year in which the H-1B visa petition was filed
- WORKSITE: City and State information of the foreign worker’s intended area of employment
- LON: longitude of the Worksite
- LAT: latitude of the Worksite

### 5. DEPLOYMENT

Solution will be deployed using Ansible [7] ad-hoc commands and Linux commands. Driver script called `cc_main_driver.sh` should install all necessary software and project codes to the cluster nodes. The `cc_main_driver.sh` will copy both Python script called `cc_analyze_data.py` which analyzes and generates graphs/tables and shell script called `cc_etl_data.sh` into clusters. The `cc_main_driver.sh` will trigger `cc_etl_data.sh` to pull dataset from the web as well executes `cc_analyze_data.py` to analyze a dataset.

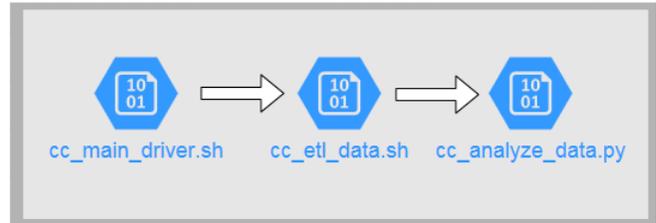


Fig. 2. Deployment Schema

### 6. BENCHMARKING

The original input dataset with approximately 3,000,000 rows (h1b\_3mRows) split into two smaller datasets: 1,000,000 rows (h1b\_1mRows) rows and 2,000,000 rows (h1b\_2mRows). Then, I executed Python script with Linux time function ( i.e: `time python ./cc_analyze_data.py`) against each of the input dataset mentioned above in order to measure both the storage size and elapsed time during the execution.

The benchmark testing on Chameleon Cloud environment revealed in the Figure-4 that elapsed processing time decreased when the number of rows in the dataset reduced. In the Figure-5, similar trend applied to disk space usage that it decreased linearly as the less number of rows need to be stored.

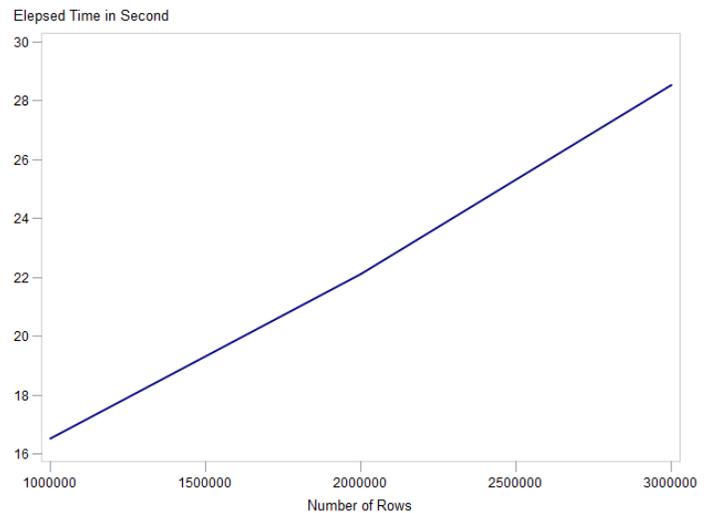


Fig. 3. Benchmark Testing - Number of Rows Vs. Elapsed Time

```

***** BENCHMARK *****
DATASET      REAL      USER      SYS      DISK
3000000 (h1b_3mRows) 0m28.528s 0m15.520s 0m0.384s 470 MB
2000000 (h1b_2mRows) 0m22.112s 0m09.671s 0m0.255s 312 MB
1000000 (h1b_1mRows) 0m16.528s 0m05.528s 0m0.201s 156 MB
  
```

Fig. 4. Benchmark Testing - Number of Rows Vs. Disk Storage

### 7. DATA REPORT

General petition distribution between Fiscal Year(FY) 2011 to FY 2016, United States Citizenship and Immigration Services (USCIS) approved 2,615,623 petitions submitted by the employer on behalf of alien workers as indicated in the Figure-5.

Of the petitions approved during FY 2011-2016, a total 10,132 petitions, or .38 % were Data Science related occupations (i.e: Data Scientist, Data Analytics, Data Science Engineer, Statistician and Data Modelling) as shows in the Figure-6.

```

***** CASE STATUS DISTRIBUTION *****
-----
CERTIFIED                                2615623
CERTIFIED-WITHDRAWN                     202659
DENIED                                   94346
WITHDRAWN                                89799
PENDING QUALITY AND COMPLIANCE REVIEW - UNASSIGNED 15
REJECTED                                  2
INVALIDATED                              1
-----
    
```

Fig. 5. General Distribution of Petition - All Jobs

```

***** CASE STATUS DISTRIBUTION *****
-----
CERTIFIED                                10132
CERTIFIED-WITHDRAWN                     1009
WITHDRAWN                                391
DENIED                                   245
-----
    
```

Fig. 6. General Distribution of Petition - Data Science Related Occupations

As Figure-7 indicated, petitions submitted regardless of the CASE\_STATUS and all JOB\_TITLE increased approximately 5 to 7 percent. For Data Science related petitions also increased especially in metropolitan areas such as San Francisco, New York and Menlo Park . The highest number of petition related to Data Science petitions to acquire H1-B visa was in the Fiscal Year 2016 as shown on the Figure-8.

```

***** PETITION PER STATE PER YEAR *****
-----
YEAR | 2011.0 | 2012.0 | 2013.0 | 2014.0 | 2015.0 | 2016.0 | TOTAL
STATE
ALABAMA      1487    1572    1487    1781    1873    2053    10253
ALASKA       205     273     260     246     213     199     1396
ARIZONA     4391    5488    6389    7306    8746    9734    42054
ARKANSAS    1680    1890    2442    2329    3015    3406    14762
CALIFORNIA  65690   76402   83852   98512   115743  119741  559940
COLORADO    3630    4378    4889    5811    6827    6502    32037
CONNECTICUT 5885    7827    7447    8917    10142   10035   50253
DELAWARE    2152    2348    3172    3184    3760    3522    18138
DISTRICT OF COLUMBIA 3491    3570    3687    3727    4099    4134    22708
FLORIDA    15227   16368   15283   17644   20401   20850   105773
GEORGIA    10829   12733   13994   17728   23026   24857   103167
HAWAII      655     725     615     602     598     557     3752
IDAHO       638     644     635     609     778     887     4191
ILLINOIS   18595   22350   24510   27407   32768   35184   160814
INDIANA    3837    4340    4281    5509    6150    6399    30516
IOWA       2308    2513    2607    3168    3207    2940    16743
KANSAS     1713    2046    2233    2424    2598    2768    13782
KENTUCKY   1600    2017    1889    2170    2403    2623    12702
LOUISIANA  1615    1661    1662    1838    2702    2191    11669
MAINE      541     586     672     714     718     687     3918
MARYLAND   8544    8350    8132    9601    10891   10738   56256
MASSACHUSETTS 14720   16556   16898   19913   23488   24891   116466
MICHIGAN   8305    9918    11535   13918   18318   20970   82964
MINNESOTA  5683    6900    7194    8996    9975    9937    48685
MISSISSIPPI 648     645     668     678     792     839     4270
MISSOURI   3756    4714    4988    6200    7182    7973    34813
MONTANA    163     137     156     134     205     191     986
NEBRASKA   1089    1242    1388    1708    1815    2014    9256
NEVADA     1129    1223    1119    1231    1350    1396    7448
NEW HAMPSHIRE 1185    1526    1558    1676    2078    1966    9929
NEW JERSEY 23611   27856   29794   36783   47662   48370   214076
NEW MEXICO 782     953     854     908     1005    1039    5541
NEW YORK   41769   44512   42565   48877   55017   58670   291410
NORTH CAROLINA 7783    10411   11668   13550   17413   18847   79672
NORTH DAKOTA 403     446     469     490     575     544     2927
OHIO       8582    10426   11642   13515   16066   16344   76575
OKLAHOMA   1457    1656    1577    1846    2046    2015    10597
OREGON     2859    3103    3712    4595    4803    4718    23790
PENNSYLVANIA 12896   15552   16779   19150   22202   23380   109959
PUERTO RICO 309     311     207     209     214     202     1452
RHODE ISLAND 1038    1323    1792    2225    2881    2458    11717
SOUTH CAROLINA 1628    1795    1672    2084    2801    2952    12932
SOUTH DAKOTA 328     286     261     281     398     348     1902
TENNESSEE  3463    4544    4268    4584    5161    5652    27672
-----
    
```

Fig. 7. H1-B Petition Per Year Per State - All Jobs

```

***** PETITION PER STATE PER YEAR *****
-----
YEAR | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | TOTAL
STATE
ALABAMA      8      8      9      6      4      2      37
ARIZONA     14      8      7      14     18     24     85
ARKANSAS     4      3      1      6      25     34     73
CALIFORNIA  183    219    301    508    733    1003   2947
COLORADO     5      4      6      17     18     17     67
CONNECTICUT 36     21     25     26     37     61     206
DELAWARE     9     13     14      9     20     17     82
DISTRICT OF COLUMBIA 12     12     16      8     25     25     98
FLORIDA     23     16     22     28     59     46     194
GEORGIA     19     19     27     40     84     105    294
HAWAII      NaN     3      3      3      5      4      18
IDAHO       NaN     NaN     NaN     1      2      1      4
ILLINOIS    66     60     66    100    123    173    588
INDIANA     14     21     26     18     28     28     135
IOWA        5      7      9      9      7     11     48
KANSAS      12     15     9     11     18     16     81
KENTUCKY    6      4      2      1      4      9     26
LOUISIANA   2      1     NaN     1      5      3     12
MARYLAND    53     60     41     63     50     56    323
MASSACHUSETTS 51     78     92    123    193    249    786
MICHIGAN    15     18     24     25     40     64     186
MINNESOTA   18     15     20     21     26     29    129
MISSISSIPPI NaN     4      1      2      2      2     11
MISSOURI    15     17     11     17     18     38    116
NA          1     NaN     NaN     NaN     NaN     NaN     1
NEBRASKA    8      5      2      6     18      9     48
NEVADA      3      9      4      5      4     11     36
NEW HAMPSHIRE 4      2      4      5      6      6     27
NEW JERSEY  96    124    142    150    168    223    903
NEW MEXICO  NaN     1     NaN     NaN     3     NaN     4
-----
    
```

Fig. 8. H1-B Petition Per Year Per State - Data Science Related Occupations

As revealed in Figure-9, New Jersey, California, Massachusetts and Illinois are top locations that hires Data Science talents. Almost all technology based companies are now aware that data-driven decision making is critical if they want to succeed. As showed in the Figure-10, some of the biggest and well-known technology companies are the biggest driving force in hiring talent pool with Data Science skills.

```

***** TOP 25 LOCATION HIRING DATA SCIENTIST *****
-----
SAN FRANCISCO, CALIFORNIA      332
NEW YORK, NEW YORK             224
MENLO PARK, CALIFORNIA        103
MOUNTAIN VIEW, CALIFORNIA     101
REDMOND, WASHINGTON            78
PALO ALTO, CALIFORNIA         71
SAN JOSE, CALIFORNIA          55
SUNNYVALE, CALIFORNIA         52
BOSTON, MASSACHUSETTS         45
BELLEVUE, WASHINGTON           44
CHICAGO, ILLINOIS              41
CAMBRIDGE, MASSACHUSETTS      36
SEATTLE, WASHINGTON            34
SAN MATEO, CALIFORNIA         27
AUSTIN, TEXAS                  25
ATLANTA, GEORGIA               25
REDWOOD CITY, CALIFORNIA     21
SANTA MONICA, CALIFORNIA      17
HOUSTON, TEXAS                 16
SANTA CLARA, CALIFORNIA       15
SAN DIEGO, CALIFORNIA         13
WASHINGTON, DISTRICT OF COLUMBIA 12
BURLINGTON, MASSACHUSETTS    12
LOS ANGELES, CALIFORNIA      12
CHARLOTTE, NORTH CAROLINA     11
-----
    
```

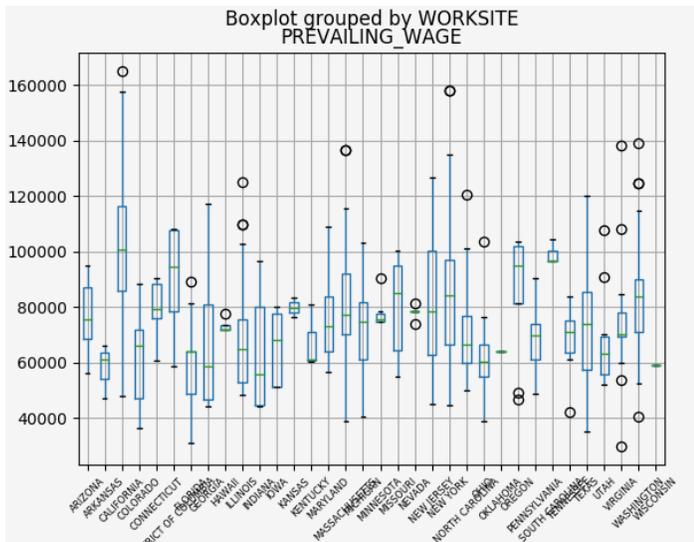
Fig. 9. Top 25 Location Hiring Data Scientist

```

***** TOP 25 COMPANY HIRING DATA SCIENTIST *****
MICROSOFT CORPORATION          139
FACEBOOK, INC.                 98
UBER TECHNOLOGIES, INC.       48
TWITTER, INC.                  31
AIRBNB, INC.                   25
GROUPON, INC.                  21
LINKEDIN CORPORATION          20
AGILONE, INC.                  19
IBM CORPORATION                 16
WAL-MART ASSOCIATES, INC.     15
INTUIT INC.                     14
RANG TECHNOLOGIES, INC.       13
PAYPAL, INC.                   12
SCHLUMBERGER TECHNOLOGY CORPORATION 11
APPLE INC.                     11
STITCH FIX, INC.              10
TRIPADVISOR LLC               10
INTEL CORPORATION              9
THE NIELSEN COMPANY (US), LLC  9
LYFT, INC.                     8
GOOGLE INC.                    7
AMERICAN EXPRESS COMPANY      7
CLOUDWICK TECHNOLOGIES INC.    7
ICUBE CONSULTANCY SERVICES, INC 7
ZILLOW, INC.                   7
    
```

**Fig. 10.** Top 25 Companies Hiring Data Scientist

As shown in Figure-11, for occupations in Data Science field, the median annual compensation reported by employers of H-1B workers between FY 2011 to FY 2016 was ranged from a low of \$40,000 to a high \$110,000 which depends on geological location.



**Fig. 11.** Data Scientist Wage Across States

**8. CONCLUSION**

Overall, there is compelling evidence that the H-1B visa program is helping to alleviate acute shortages in Data Science occupations since the number of petitions submitted increased linearly from FY 2011 to FY 2016. Armed with such information, as well as indicators presented above, Data Science occupation mostly concentrated in large metropolitan areas. Well-known technology companies has indicated hired professional with Data Science skill sets.

**9. ACKNOWLEDGEMENT**

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# On-line advertisement click prediction

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S17-IR-2013, May 04, 2017

This project aims at predicting the most suitable advertisements from an available pool with unique ad\_id to be displayed on a web-page. Each webpage has a window to display six advertisements and each window has a display\_id in which six ads can be displayed. Thus, six best advertisements need to be selected. This selection is based on highest relevance with the web page. Relevance factor is calculated by ranking ads based on the likelihood of click if displayed. Data is obtained as CSV files from Kaggle Data sets and is stored in Hadoop Data File system(HDFS). In this project, Ansible along with Cloudmesh client and Bash shell is used to automate the deployment of cloud architecture and necessary software on Chameleon cloud and for bench-marking. Apache Pig on Hadoop was chosen for data exploration and analysis. Pig engine executes the data flows in parallel by making use of Hadoop MapReduce framework.

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**Keywords:** Hadoop, On-line Advertisement, BigData, Cloudmesh Client, Ansible, Chameleon Cloud, Apache Pig, HDFS, MapReduce, I524

Report: <https://github.com/cloudmesh/sp17-i524/tree/master/project/S17-IR-2013/report/report.pdf>

Code: <https://github.com/cloudmesh/sp17-i524/tree/master/project/S17-IR-2013/code>

## 1. INTRODUCTION

It has been analyzed that an average American spends about 23 hours per week surfing on-line [1]. This on-line user activity is being captured by companies to perform analyzes for advertisement, recommendation and many other purposes. This has given rise to the field of "Web Analytics" and one such application is Ad Click prediction.

Many measures are available to assess the ad performance. One popular measure to assess the immediate ad response is click-through rate (CTR) of the advertisement [2] which is defined as the ratio of the number of clicks on an ad to the number of times the ad is shown, expressed as a percentage. In this project, I attempted to make use of CTR along with ranking each ad based on the level of relevance to the original web page. For calculating the CTR, historical data of user activity needed to be explored [3].

The user activity data from web that is available for prediction is enormous. Every page view and advertisement click is tracked by web browsers. This data for millions of users potentially generates enormous volumes. The current project uses big-data stack i.e Apache Pig along with Hadoop to analyze predict. Hadoop is a large scale data processing system which runs on parallel processing to handle huge volumes of data. Pig is a high level language which runs on top of Hadoop's HDFS infrastructure. Pig Latin scripts are simple to comprehend and SQL-like queries which can process large volumes of data.

Ansible along with Cloudmesh client is used to deploy the software on Chameleon Cloud. Ansible is a cloud automation

tool which allows easy deployment and configuration of multiple servers in one step. Cloudmesh allows us to deploy and install Hadoop instances on a cluster with any number of nodes.

## 2. BACKGROUND

### 2.1. About Data

The data set in this paper is taken from Kaggle data sets. It is released by Outbrain which has 2 Billion page views and 16,900,000 clicks of 700 Million unique users, across 560 sites [4].

The data set contains a sample of users' page views and clicks, as observed on multiple publisher sites in the United States between 14-June-2016 and 28-June-2016. Each viewed page or clicked recommendation is further accompanied by some semantic attributes of those documents [4]. It contains numerous sets of content recommendations served to a specific user in a specific context. Each context (i.e. a set of recommendations) is given a display\_id. In each such set, the user has clicked on at least one recommendation. Our task is to rank the recommendations in each group by the decreasing predicted likelihood of being clicked [4].

Each user in the dataset is represented by a unique id (uuid). A person can view a document (document\_id), which is simply a web page with content (e.g. a news article). On each document, a set of ads (ad\_id) are displayed. Each ad belongs to a campaign (campaign\_id) run by an advertiser (advertiser\_id). Figure 1 shows the fields in our dataset. Metadata about the document is also provided, such as which entities are mentioned, a taxonomy of categories, the topics mentioned, and the publisher [4].

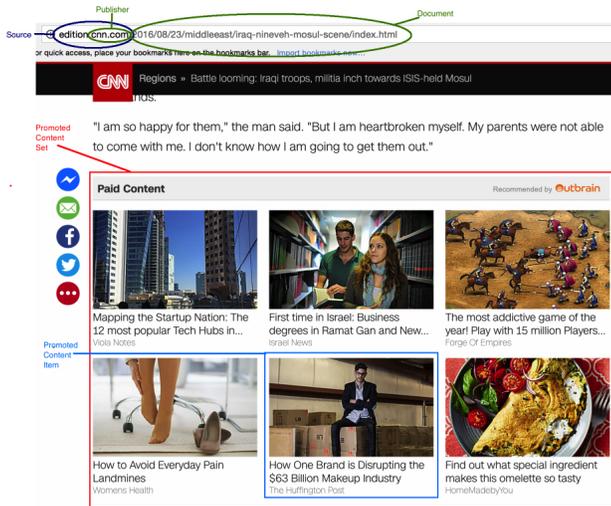


Fig. 1. Displaying Source, Publisher, Document, Promoted content set and items [4]

2.2. Ansible and Cloudmesh client toolkit

Ansible is an opensource cluster management tool which has the ability to maintain a fully immutable server architecture and design. It is a simple automation engine that automates cloud provisioning, configuration management, application deployment, intra-service orchestration [5]. It doesn't use agents or custom security infrastructure, so it's easy to deploy by using "YAML-language" (YAML, in the form of Ansible Playbooks).

Using Ansible, users can define any number of IP Addresses in hosts file, and create custom groups for specific tasks. These group names can be referred to in the YAML file to perform a specific set of tasks in each of the virtual machines. Ansible also has options to define specific roles for each task and make YAML files dynamic using global variables.

With Cloud mesh, the deployment becomes even simpler and easier. Cloud mesh client toolkit, a lightweight client interface to access heterogeneous clouds, clusters, and workstations, available as API, commandline client and commandline shell. Their quick start user manual has everything that is needed to start using the tool [6].

The current project uses Cloudmesh's "cm" command to perform multiple tasks including cluster deployment, installing and configuring Hadoop and Pig, enabling the cloud nodes to be able to ssh with each other and assigning floating IP addresses to each node. The configuration of the cluster can be defined in Cloudmesh's YAML file and accordingly the cluster will be created with the given OS and type.

2.3. Hadoop in Big-data

Hadoop is a distributed platform designed to help manage and analyze massive data-sets that are too big or costly to put in relational databases. Rather than storing and processing the whole data in one high-end computer, data can be spread across many smaller nodes. By spreading the data across multiple nodes, the storage as well computational speed can be scaled by parallel processing [7].

Hadoop framework is developed for distributed processing of large data sets across clusters of computers using simple programming models. It can scale up from single servers to thousands of machines, each offering local computation and

storage. The library is designed to deliver a highly available service on top of a cluster of computers, each of which may be prone to failures [8].

2.4. HDFS and MapReduce

Hadoop Distributed File System (HDFS) and the MapReduce parallel processing framework are two primary components at the core of Apache Hadoop. Figure 2 shows the high level architecture of Hadoop in regards to HDFS and MapReduce

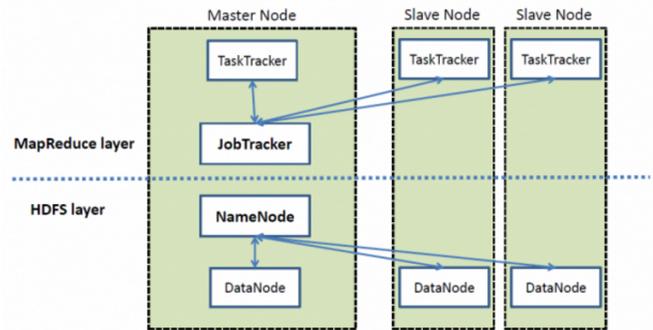


Fig. 2. High Level Architecture of Hadoop [9]

HDFS is a distributed, scalable, and portable file-system for Hadoop framework. Files are broken into blocks and spread across nodes in the cluster in HDFS. The blocks are also replicated on different nodes so that even if one of the nodes fails another one of the live nodes still has a copy of the data. There is a NameNode and DataNodes. The NameNode maintains the references on the file split up in blocks across nodes in the cluster. While reading, client process contacts the NameNode for this metadata and ask the corresponding DataNodes for those blocks for reading [7]. MapReduce is for processing files stored in a distributed environment like HDFS. A typical MapReduce application has two functions, a Mapper and a Reducer. Mappers and Reducers run as tasks on nodes in the cluster. Two processes JobTracker and TaskTracker manages MapReduce framework. The JobTracker is the master process that coordinates the Map and Reduce tasks sent across the cluster.

2.5. Apache Pig

Pig platform is designed to work with large data sets for analysis. The Pig dialect is called Pig Latin, and the Pig Latin commands get compiled into MapReduce jobs that can be run on a suitable platform, like Hadoop. Figure 3 illustrates how it makes use of MapReduce framework.

Pig is a high level language which is similar to SQL in syntax. The structure of Pig is designed such that the Pig scripts are made amenable for parallel processing. Pig scripts are automatically optimized so that the programmers can focus on semantics rather than efficiency [10]. Pig also has options to create user defined functions to perform complex tasks using Pig.

2.6. Chameleon cloud

Chameleon Cloud is a cloud platform offered for research purposes free of charge. It is maintained by the Chameleon community and is funded exclusively for use by students and faculty by the National Science Foundation. Chameleon Cloud is deployed

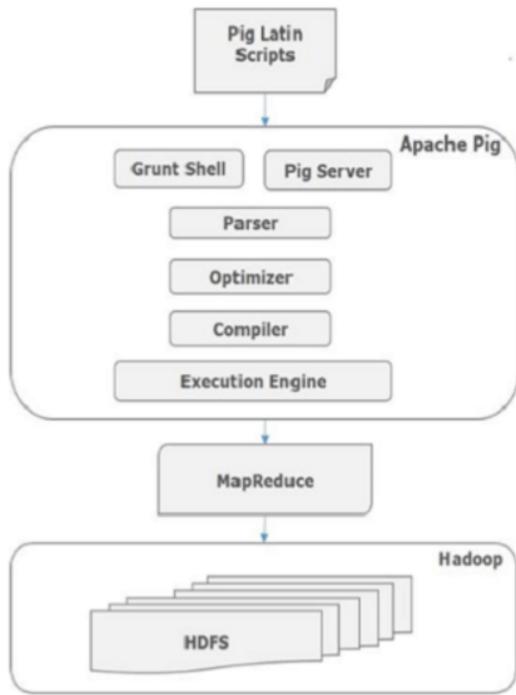


Fig. 3. Architecture of Apache Pig [9]

at University of Chicago and Texas Advanced Computing Center, and consists 650 multi-core cloud nodes, 5PB of total disk space, and leverage 100 Gbps connection between the sites.

The current project uses a cluster created on Chameleon cloud instance with three virtual machines on which Hadoop operates. Ubuntu 14.04 was installed on these machines with 20 GB disk space and 2 GB ram each.

**2.7. Data Analysis**

Though page\_views data is available, it has been excluded from analysis since the data was in orders of 100s of gigabytes for just 2 weeks. With the resources available we could only process two days of data for analysis. The prediction will be low in confidence if only two days are considered. Since the objective was to produce a reliable prediction of Ad ids with given resources, it was chosen to predict the more likely ads by relevance factor. Data was analyzed using Apache Pig in the MapReduce mode. Clicks\_train and events files were joined to get a list of documents to make the predictions. The above list was joined to documents\_events, documents\_categories and documents\_topics to generate a master dataset of all the required documents, their topics, categories and entities. The data in promoted\_content was joined with the data in documents\_events, documents\_categories and documents\_topics to generate a dataset which has all advertisement ids and their related document entity, topic and category. A master join between the two lists on the event, topic and category ID was performed to get matching document IDs. On this data, relevancy score for each match was calculated by multiplying the confidence levels. The final list was grouped by document ID and top six matching ad\_ids were generated based on the highest relevance score. These ads are the recommendations for each page. This recommendation engine is purely based on matching the association probabilities provided for web pages and advertisements

Flavor	m1.medium	m1.large	m1.xlarge
Server	Ubuntu14.04	Ubuntu14.04	Ubuntu14.04
VCPU	2	4	8
Ram	4 GB	8 GB	16 GB
Disk	40 GB	80 GB	160 GB

Table 1. Virtual Machine Configuration

with different topics, events and categories.

**3. SETUP AND CONFIGURATION**

This project was setup using Ansible and Cloudmesh Client. Cloudmesh client was used to install and deploy Hadoop clusters on Chameleon Cloud. Ansible was then configured to perform a set of tasks on the namenode of the server. File movement was handled using Ansible playbooks. The final Pig script was run on the namenode Hadoop server using automated Ansible scripts.

Multiple configurations were used for bench-marking the clusters, from m1.medium to m1.xlarge clusters with 1 to 10 nodes on Chameleon Cloud. One of the nodes in each cluster was configured to act as namenode and the rest as datanodes. The details of each flavor are given in Table 1, 2 and 3. With medium and large clusters it took extremely long time to do the analyses. So, we set our default configuration to deploy clusters with extra large clusters.

**3.1. Deployment**

**4. WORK FLOW**

The deployment of clusters was done using Cloudmesh client's "cm deploy" command. A three node Hadoop cluster is created and enabled cross SSH between the nodes so that they will be able to communicate with each other. Next step was to use Ansible to transfer the data files and Pig script to cloud. Once this data transfer was done, Ansible scripts were used to move the files from the cloud to HDFS. The pig script was run using Ansible from the local system and timed for bench-marking. The final step was to transfer the output files back from hdfs to local system using Ansible.

**5. EXPERIMENTS AND RESULTS**

Multiple experiments were conducted using different sizes of input data on different clusters. Deployment and performance results were used to benchmark Cloudmesh client and Chameleon cloud. Then performance bench-marking was done for an incremental number of web pages. The results were produced based on the time taken to predict the most likely to be clicked Ad for different number of web pages. Each document ID corresponds to a page that needs predictions and a list of 6 Ad\_id are predicted for each document\_id based on relevance score calculated. The score was calculated using the confidence levels given for different relevance factors. The relevance factors included the topic, entity and category to which each web page and ad was probable to belong. The time taken to deploy the clusters and to move the data were also recorded for analysis.

### 5.1. Deployment bench-marking

Cluster was deployed on Chameleon cloud with Hadoop and Pig for conducting analyses. Deployment bench-marking was done on clusters with different flavors of chameleon cloud nodes including m1.large and m1.xlarge. Time taken for deploying Clusters with 1 to 10 nodes was noted to check the trend of increase. This trend is presented in Fig. 4. The time taken to deploy a Hadoop cluster can be skewed by multiple things including network connectivity and cluster latency. In general, we observed an increasing trend in the deployment time of the clusters as the number of nodes increased.



Fig. 4. Benchmarking Results: Time taken for Deploying Hadoop and Pig

### 5.2. Moving files

Two separate time readings were taken, to move data along with other binary files to namenode of the Hadoop cluster and then to move data to HDFS from namenode. This is performed on the cluster with m1.xlarge flavor. Data movement entirely depends upon network connectivity on both ends, and there were no notable trends observed in the time taken for moving to HDFS across different configurations with an average of 61 seconds. The time taken to move data to the cloud was irrespective of the cluster size as files needed to be put only on namenode. The average time taken for moving files to the namenode on chameleon cloud was 881 seconds.

Figure Fig.5 compares the time taken for deployment, moving files to cloud and then moving the data files to HDFS.

### 5.3. Performance bench-marking

Pig scripts were written to analyze the data that was moved to HDFS. The script takes input from HDFS location, performs a series of joins and filters out some data, and dumps the output to a HDFS location. Time taken for this entire process is recorded using time command of Linux shell. In order to automate this, the Pig script was looped in a bash script by giving the number of records to process as an input variable.

Figure Fig.6 compares time taken for predicting top six advertisements for different cluster sizes with m1.xlarge cluster flavor. From the figure, the performance results show that it scaled almost linearly with some inconsistencies up to 20000 web pages. The inconsistency may be mainly due to the environment. The performance also depends on various things such as network connectivity, and there was a notable decrease in time taken as the cluster size increases. The graphs are plotted for time versus the number of web pages to which predictions are made.

We can also observe that in figure Fig.6 time taken for predicting using Pig with data files in and outside HDFS. In local, the

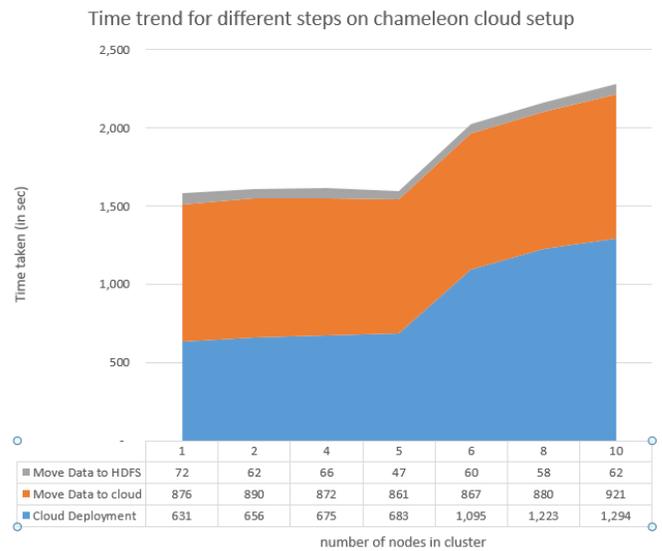


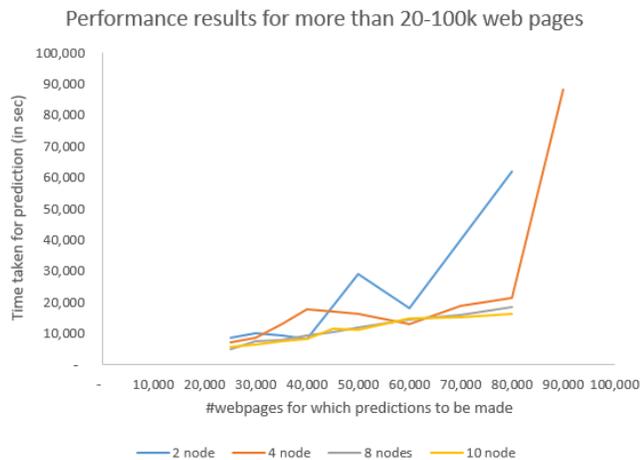
Fig. 5. Benchmarking Results: Time comparison for deploying clusters, moving file to cloud, moving data to HDFS

data files are kept outside HDFS and output is written to a file outside HDFS. Whereas in 1 node, input files are put in HDFS and output is also stored to HDFS. This can be used to illustrate how the performance of Pig improves with HDFS.



Fig. 6. Benchmarking Results: Time taken for predicting best six Ads for each webpage

Figure Fig.7 captures the time taken for different cluster sizes from 20,000 web pages onwards. We can observe for higher number of webpages the time taken to predict the best six relevant ads is extremely high after a certain limit. We also observe that the limit is higher for larger clusters.



**Fig. 7.** Benchmarking Results: Time taken for predicting best six Ads for each webpage

## 6. CONCLUSION

Big data technologies such as Hadoop and Pig can be used to process large volumes of data in parallel to make quick analyses. Pig latin is a high level language for writing sql like queries to process data from files. Apache Pig is efficient in query optimization and enables parallelism for its processing. It was even more efficient when data files were available in HDFS and output is written to HDFS as the time taken for either loading and/or storing significantly improved. The current project used Apache Hadoop and Apache Pig on Chameleon cloud to process large data related to online advertisement prediction. Online advertisement is one space where large amounts of data is collected and it demands the use of Hadoop like parallel processing and distributed systems to get meaningful insights from the data economically.

The processing time increased as the input query size increased. These nodes can be horizontally and vertically expanded to utilize the full extent of Hadoop's parallel processing capabilities in order to scale up.

## 7. FUTURE WORK

Planning to conduct predictions based on Ensemble methods. One way to predict is through click-through rate and one way is to predict by relevance factor. Using relevance factor as one of the attributes along with platform, user id and geo-location, logistic regression can be run to predict if the top ad ids generated by relevance factor to be included in the list or not. Since all that information is given in page\_views file which is in order of 100s of gigabytes for just 2 weeks data, we need larger clusters.

## ACKNOWLEDGEMENTS

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## AUTHOR BIOGRAPHIES

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## A. EXECUTION INSTRUCTIONS

This project requires Ubuntu 16.04 LTS (Xenial Xerus) machine. The file requirements.txt provided in Code repository can be used to install required modules in a virtual environment virtualenv. README file is provided in Code repository should be referred to deploy, analyse and benchmark.

### A.1. List available definitions

To list already defined clusters, stacks and sec groups  
 cm cluster avail - for cluster definitions  
 cm hadoop avail - for hadoop stack definitions  
 cm secgroup list - for secure groups

### A.2. Cluster delete

To delete a cluster in use:  
 cm cluster delete

### A.3. Change Cluster

To use a cluster other than the one in use.  
 cm cluster use <cluster-xyz>

### A.4. List cluster nodes

To list current cluster nodes  
 cm cluster nodes - generally first node is namenode and rest are datanodes

### A.5. List node details

To list the details of a node  
 cm vm list | grep <nodename>

### A.6. ssh node

To ssh to any node  
 cm vm ssh <nodename>

### A.7. Change to hadoop user

To change to hadoop user from cc user on chameleon cloud  
 sudo su - hadoop

### A.8. Kill benchmark script

To kill benchmarkscript  
 ps -ef | grep pig.sh  
 kill -9 <process-id>

### A.9. Time taken for each iteration

time taken to predict for 1000 webpages is 1000 iteration  
 cat homehadoopnohup.out

### A.10. Output files

To see the output files  
 hdfs dfs -cat /outbrain/<iteration-number> (in cluster node)

## B. DIRECTORY STRUCTURE

The Code directory /project/S17-IR-2013/code contains several sub directories.

### B.1. ./

Contains all README.rst, requirements.txt and copy\_repository\_files.sh  
 copy\_repository\_files.sh copies all the files to outbrain directory in HOME directory. If outbrain directory already exists, then it takes the backup of the existing directory.

### B.2. ./scripts/

Contains all shell and bash scripts. All the scripts are put in sub directories.

### B.3. ./scripts/deploy/

Contains scripts for deploying cluster  
 install\_hadoop\_pig.sh is hard coded to deploy m1.xlarge cluster on Chameleon clod and installs required software. Number of nodes should be provided as an argument and it is configured to time the deployment.  
 re\_deploy\_cluster.sh deploys one more cluster along without disturbing the existing cluster. It also requires number of nodes as the argument and is configured to deploy m1.xlarge cluster on Chameleon cloud along with required software

### B.4. ./scripts/benchmark/

Contains script for performance bench-marking  
 benchmark\_pig.sh is a bash script for performance Benchmarking. It is hard coded to run in a loop for 1000 to 10000 web pages with a step size of 1000.

### B.5. ./scripts/utils/

Miscellaneous scripts used for automation  
 replace\_namenode.sh is for replace namenode details in pigscript and hosts file after deploying the cluster.

### B.6. ./conf/

Contains all configuration file templates  
 hosts file is for configuring the ip address to which files needs to be moved

### B.7. ./playbooks/

Contains all Ansible YAML files  
 move\_data.yml is for moving files from local machine to namenode of the cluster in use. It takes input from hosts file  
 move\_data\_hdfs.yml is for moving data to HDFS from namenode. It also takes input from hosts file.

### B.8. ./pig/

Contains pig script  
 outbrain\_pig is pig script for selecting best six advertisements for each webpage. This script is called in benchmark\_pig.sh

# Flight Data Analysis Using Big Data Tools

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project-S17-IR-2016, September 21, 2017

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**Analysis of flight data provides insights on the United States of America's Airline data by using Hadoop in the cloud environment. The On-time performance of flights operated by large air carriers are tracked and made as a report, Air Travel Consumer Report, which is a big data set. Hive component of Hadoop ecosystem, is utilized to process the big data in distributed environment. Efficient accessing and processing of the user queries is achieved by this analysis on flight data.**

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**Keywords:** Apache, Hive, Ansible, Pig, I524

Report: <https://github.com/cloudmesh/sp17-i524/tree/master/project/S17-IR-2016/report/report.pdf>

Code: <https://github.com/cloudmesh/sp17-i524/tree/master/project/S17-IR-2016/code>

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## 1. INTRODUCTION

Real world data is large and growing exponentially from several years. This data can be in structured or unstructured format which is popularly known as Big Data[1]. Aviation industry manages enormous amount of data, which consists of the information regarding the delayed, cancelled, diverted or on-time flights by large air-carriers[2]. This is essentially a big-data set, where statistics are publicly available as the Air Travel Consumer Report.

Access to multiple clouds is provided by a cloud manager known as Cloudmesh Client[3]. With the help of this cloud manager, Hadoop cluster is built with necessary add-ons such as Apache Spark[4], Hive[5], Pig[6]. Cloudmesh Client is also used in the deployment of the cluster on various clouds such as Chameleon cloud[7] or Jetstream[8] cloud. Deployment part is automated with the help of ansible[9] scripts where data is extracted, stored and analysed automatically to produce the results.

Big Data analysis of this data will provide a consistent understanding and importance of the given data. With 35 million flight departures per year, data is critically important for any planning decision made by airlines and airports. The results of analysis has benefits which can help airline operations to predict and reduce redundancy[10].

## 2. INFRASTRUCTURE

Cloudmesh client and Chameleon cloud forms the infrastructure of this analysis project.

Cloudmesh client is a toolkit which provides a client interface for accessing different clouds and clusters. It includes a commandline interface to provide abstraction from backend databases. Simplicity is one of the key and powerful features

of the cloudmesh client. It makes switching between various clouds easy by providing a convenient programmable interface.

Chameleon cloud is a large scale platform which is an open research community for development of programmable cloud services. It provides wide range of services such as Infrastructure-as-a-service, platform-as-a-service and delivery of high functioning cloud environment.

## 3. DEPLOYMENT TOOLS

### 3.1. Ansible

Ansible is an open source software that provides automation for configuration management and application deployment. It facilitates a simple automation platform that makes the application easier to deploy. It also handles ad-hoc task execution and multinode orchestration. Ansible is a software which has an agent-less architecture. This is because there are no daemon processes running in the background. Components of Ansible comprises of modules, playbooks, inventory and ansible towers. Modules can control system resources like services, packages, or files. Inventory is configuration file that reflects the nodes that are available for access. Nodes are represented by hostnames or IP addresses. Playbooks are Ansible's configuration, deployment and orchestration language. These are in the YAML format. Playbooks are generally used to manage configurations and deployment on remote machines. Ansible tower makes Ansible a center for automating tasks by providing a web based console[11].

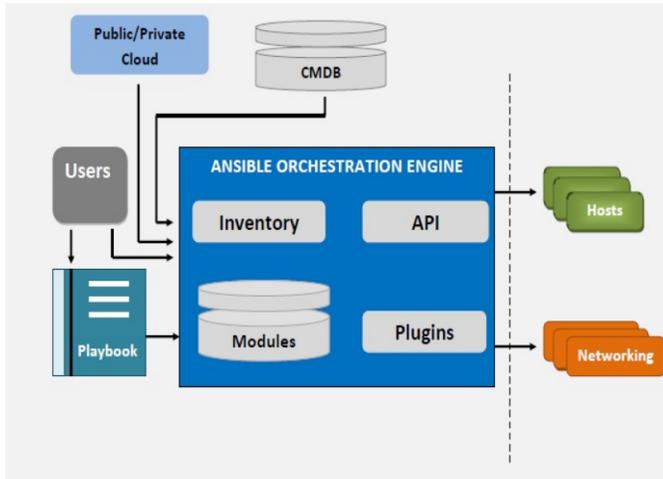


Fig. 1. Architecture of Ansible [12]

#### 4. ANALYSIS TOOLS

##### 4.1. Apache Hive

Hive is one of the ecosystems in Hadoop[13] framework which is built to analyze the data on hadoop cluster. Syntax of Hive is based on SQL[14], which is also known as HiveQL. MySQL or PostgreSQL[15] can be used for implementation of the queries. Hive provides tools which enable easy data extraction, transformation and data loading. Files can be stored in Hadoop Distributed File System(HDFS)[16] and accessed by Hive efficiently.

Schema of the Hive tables is stored in Hive Metastore. Metastore holds the information about tables and partitions which are present in the data warehouse. In Hive the default Metastore is Derby Database, which is a relational database management system provided by Apache Software. There are two components of Hive, HCatalog and WebHcat. HCatalog is a storage management layer for Hadoop which provides data processing tools such as Pig and MapReduce. WebHcat provides a service that is used to run Hadoop MapReduce, Pig, Hive jobs using REST interface[17].

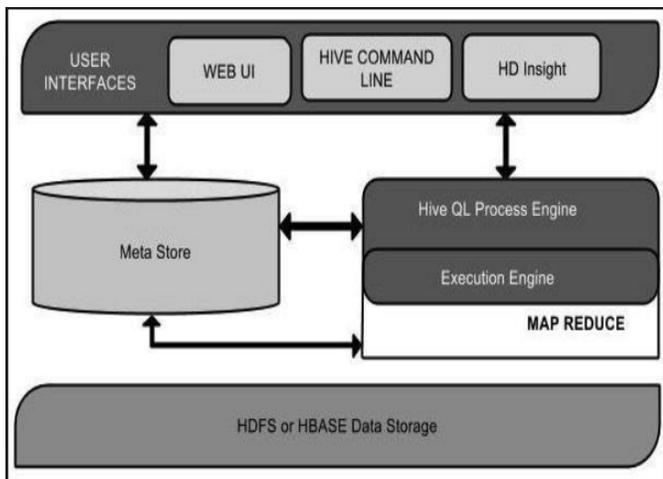


Fig. 2. Apache Hive Architecture [18]

Hive’s SQL provides the basic SQL operations, such as,

- Filtering the rows from the table using WHERE clause.
- Selecting columns from table using SELECT clause.
- Joining two tables
- Aggregations of the data using ‘group by’ clause.
- Storing the results in a hdfs directory.

##### 4.2. Hadoop Distributed File System

Hadoop Distributed File System provides a distributed file data storage system which spans large clusters of servers. It distributes -the storage and computation across many servers which maintains economy of the storage[16].

The file system is designed to be fault-tolerant. When HDFS takes data, the information is broken into pieces and distributed them to different nodes in a cluster. This provides parallel processing on clusters. MapReduce programming model is implemented when the applications are executed.

HDFS uses master/slave architecture, where each cluster consists of a Namenode, which manages file system operations and supports Datanodes, which manage data storage on individual compute nodes. Namenodes monitor the Datanodes in creating, deleting and replicating data by mapping them into data nodes.

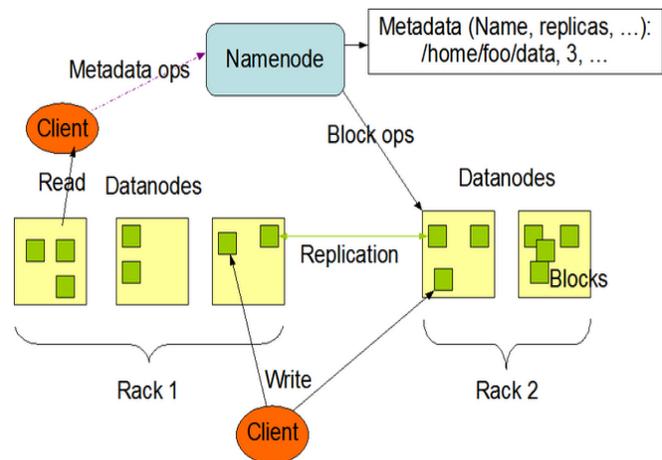


Fig. 3. Architecture of Hadoop Distributed File System [19]

#### 5. IMPLEMENTATION

Implementation of Hive to perform data analysis consists of the following steps.

- Virtual machines are created on Chameleon Cloud with the help of Cloudmesh Client.
- Hadoop cluster is deployed on Chameleon cloud.
- Flight Data is loaded into HDFS.
- Data is then transferred to Hive tables.
- Finally, analysis is done on Hive tables using HiveQL, this can either be done using Hive interface or by installing PostgreSQL interface.

### 5.1. Analysis in Hive Query Language

The following are the queries in Hive QL, which are similar to SQL statements.

What are the total number of flights which are cancelled?

```
SELECT year, month, count(cancelled) as Cancelled-flight
FROM Airline
WHERE cancelled = 1
GROUP BY YEAR, MONTH
ORDER BY YEAR, MONTH
LIMIT 20
```

What are the total number of flights which are diverted?

```
SELECT year, count(diverted) as Diverted-flights
FROM Airline
WHERE diverted = 1
GROUP BY month
ORDER BY month
LIMIT 10
```

Similarly, analysis of the data is done where the queries are as follows.

What is effect of flight distance on cancellations?

What is the effect of flight distance on average departure delay?

What is the monthly average departure delay?

What is the yearly average departure delay?

### 6. TECHNOLOGIES

- Distributed Computation and Storage:- HDFS and Hive
- Development:- PostgreSQL and Java
- Deployment:- Ansible

### 7. BENCHMARKING

After the deployment stage, benchmarking is implemented. This process is important as it evaluates the performance of the application and the system. This project is implemented on the chameleon cloud and the results are observed. Different cloud environments are used for creting these benchmarks

Characteristics of Chameleon cloud on which the analysis is implemented are,

Chameleon	VCPU	RAM(GB)	Storage(GB)
m1.small	1	2	20
m1.medium	2	4	40
m1.large	4	8	80

Fig. 4. Different types of chameleon clouds

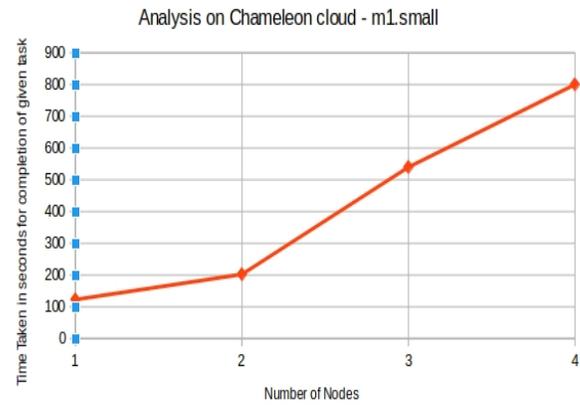


Fig. 5. Analysis time taken for a HiveQL-m1.small

The following are the observations from the analysis on chameleon cloud of different flavors.

These are the observed results when m1.small cloud is used for analysis As the number of nodes in a cluster increase, the amount of time the task takes to complete is increasing. This trend is also observed when m1.medium and m1.large flavors of Chameleon cloud are used.

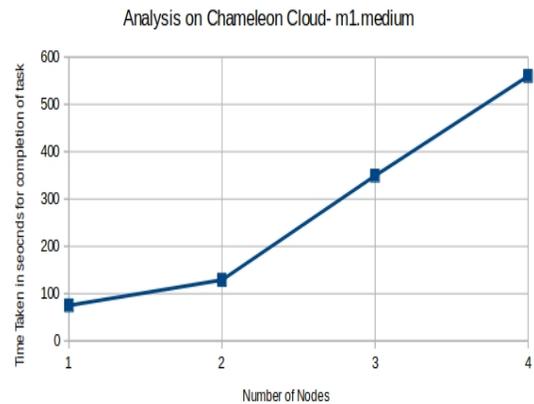
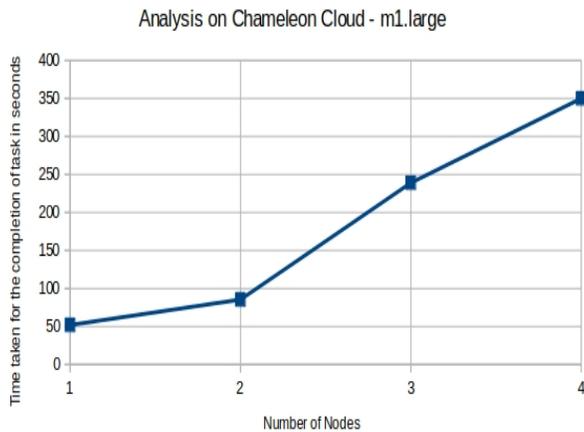


Fig. 6. Analysis time taken for a HiveQL-m1.medium

### 8. CONCLUSION

Deployment and the analysis of the flight data is implemented by using Apache Hive, Cloudmesh and Ansible automation. The results obtained from the qeries in Hive environment gives insights on the available flight data. Hive uses map and reduce functions internally which is taken care of Hadoop system. Observations such as number of flights cancelled, number of flights departed from an airport are made from Hive Query Language. From these results trends and patterns are observed which provide detailed analysis of the data.



**Fig. 7.** Analysis time taken for a HiveQL-m1.large

## 9. ACKNOWLEDGEMENTS

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# Real-time Analysis and Visualization of Twitter data

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A real-time system has been developed which extracts live data from twitter, processes the data, calculates a sentiment score based on ensemble of Naive Bayes and Textblob and finally visualizes the sentiment across time and geographical locations. The system has been deployed in chameleon and jetstream cloud platforms. Live data from twitter is injected into the system using tweepy package in Python. Naive Bayes classifier was built in a two-node Apache Spark cluster by training on 3.5 Million tweets. An ensemble of the Naive Bayes classifier and the built-in classifier of Textblob module (Python) were used to determine the sentiment score. The results of the Natural Language processing algorithms were visualized in batches using d3.js and Highcharts. © 2017 <https://creativecommons.org/licenses/>. The authors verify that the text is not plagiarized.

**Keywords:** Real-time streaming, data visualization, Twitter, Natural Language Processing

Report:<https://github.com/cloudmesh/sp17-i524/tree/master/project/S17-IR-P001/report/report.pdf>

code:<https://github.com/cloudmesh/sp17-i524/tree/master/project/S17-IR-P001/code/ansible>

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3.4 Tweet Pre-Processing	4	In 1969, Drs. Jerry Boucher and Charles E. Osgood, psychologists at the University of Illinois, proposed the 'Pollyanna Hypothesis' which asserts that "there is a universal human tendency to use evaluatively positive words more frequently and diversely than evaluatively negative words in communicating" [1]. Such theories were hard to validate due to the absence of significant data and the lack of generality. With Social media turning into the primary platform where people express on a day-to-day basis these claims can be analysed by sampling a portion of the data and applying Natural Language Processing algorithms to determine positivity/negativity of this data. The first step in this process involves extraction of data from Social media using	
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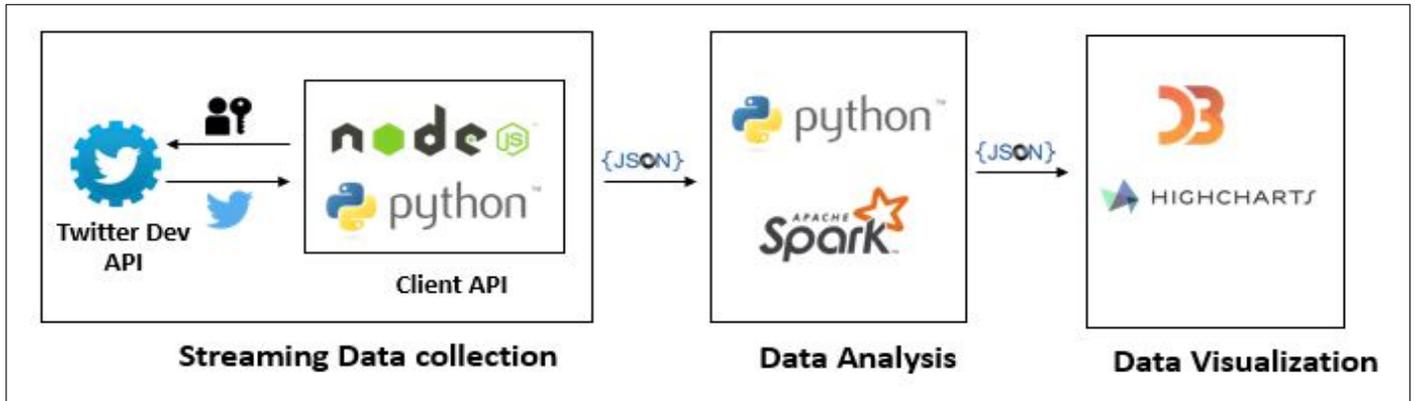


Fig. 1. System Architecture

the corresponding APIs. Once the data has been extracted, it is cleaned and restructured to make it suitable for analysis. The results of the Analysis are then visualized in a dashboard to better understand the outcomes.

Microblogging website like Twitter is used for analysing behaviour of people because it has emerged to be one of the predominant platforms where people express their opinions about current issues, complain about products, discuss details of ongoing events etc. Twitter data also aids in understanding behavioral patterns across diverse demographics - location, gender etc. Twitter generates nearly 200,000 tweets in less than a minute [2]. This large sample of data can then be used to test the hypothesis. Big data technologies prove to be particularly useful in storing, processing and analysing such large data sets. It also makes it possible to setup real-time systems that can output results with a latency of very few seconds.

The data for the system was extracted from Twitter using its API through Python. This data is processed and manipulated in Python and PySpark which is finally visualized using D3.js and Highcharts. The remainder of the paper is organised as the System Architecture, Work flow, Deployment, Benchmarking and Conclusion.

## 2. SYSTEM ARCHITECTURE

The streaming pipeline for analysing the data consists of different components to aid in different stages of the analysis. The architecture of these components have been elaborated in this section. The system architecture is shown in the Figure 1.

### 2.1. Python

Python was primarily used for tweet extraction, pre-processing and analysis. Various packages were used to aid in the process. 'Tweepy' package [3] was used for extracting tweets directly from Twitter API. The user has to create an application by logging into the tweepy portal and using the unique access tokens and consumer keys he/she can access the data from Twitter. OAuth-Handler module assists in accessing the data securely. StreamListener module is used to directly extract the tweets from Twitter. 'JSON' library [4] was used to handle the JSON data output from tweepy and to provide as input to highcharts and D3.js. 'Pandas' citewww-pandas, which is Python's data analysis library was used for manipulating the data while pre-processing. 'Numpy' [5] package was used for data handling. 'zipcode' [6] package was used to extract geographical data for visualizing on maps. 'NLTK' [7] package was used for building classification model

through 'Textblob' module [8]. 'wordcloud' [9] and 'matplotlib' [10] were useful in creating wordclouds of the positive and negative tweets.

### 2.2. Apache Spark

Spark provides a distributed cluster computing framework for processing large amounts of data. The architecture of spark is shown in Figure 2 The Spark system encompasses a Master/Driver and Workers. The Master contains the Spark context which serves as the execution environment for Spark. Each worker node contains one or more executors which run processes. The driver manages all the workers via an external processes like YARN or Mesos [11]. Spark supports multiple languages which include Scala, Java, Python and R. In addition to the spark core framework, it has an Application Programming Interface for Streaming (Spark Streaming), SQL(Spark SQL), Machine Learning(Spark MLLib) and graph computation (Spark GraphX).

Spark is built on Hadoop and it uses the Hadoop Distributed

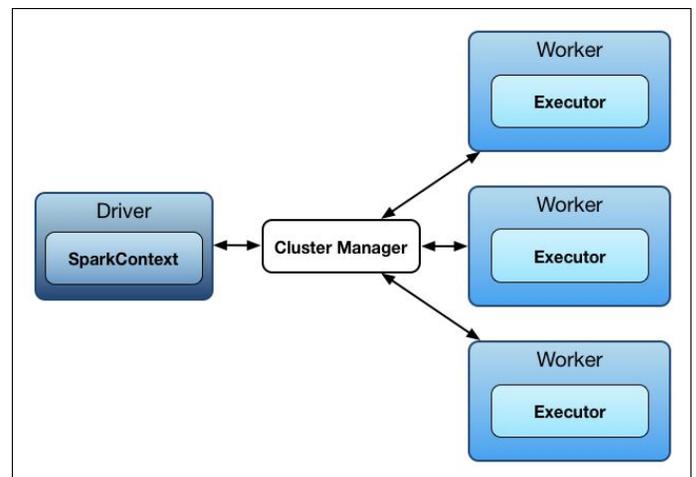


Fig. 2. Architecture of Apache spark

File System(HDFS) for Data Storage. It can also access diverse data sources including Cassandra, HBase, and S3. Spark stores the data in the form of Resilient Distributed Data(RDD). RDD is the basic data storage unit in spark. They are read-only, logically partitioned collection of records and they are stored in a fault-tolerant manner. Each partition in an RDD may be stored and

computed at a different node. RDDs are created in two ways: one is by paralleling an existing collection and the second is by referencing an existing data set [12].

The spark can be operated in either Standalone mode or in cluster mode. While operating in cluster mode, spark makes use of YARN framework for resource management and distributed computing. The YARN is responsible for allocating tasks, delivering data to the worker nodes and collecting the results of the process.

### 2.3. Node.js

Node.js is an open source, asynchronous, Javascript run-time environment which enables JavaScript to be used for server side scripting [13]. It has an event driven architecture that focuses primarily on throughput and scalability of web applications. It works based on callbacks rather than threading to signal completion of tasks. Though it does not support threading it allows multi-core usage through child processes. The cluster modules aids in balancing load across the cores. Node.js combine JavaScript with Unix network programming in order to provide concurrency without compromising on performance of the server side program. It is comparable to systems like Ruby's Event Machine or Python's Twisted. In Node.js there is no mechanism to explicitly call the event loop start. The event loop is entered after the input script is executed and exited when there are no more callbacks. It is commonly used for running server side web applications to produce dynamic web page content before the page is sent to the user's web browser.

### 2.4. D3.js

D3.js is a JavaScript library for manipulating website elements based on user data. D3 uses using HTML, SVG, and CSS for rendering the web page [14]. It combines powerful visualization components thereby providing a data-driven approach to web-page DOM (Document Objects Model) manipulation. D3.js offers flexibility by exposing the full capabilities of web standards such as HTML, SVG, and CSS. With minimal overhead, D3 is extremely fast, supporting large data-sets and dynamic behaviors for interaction and animation. It works by selecting elements of a HTML webpage and adding an svg element on top of it. The SVG element can vary through a series of objects like a rectangle, circle, text etc. Each of these objects has their own attributes defining their shape, label, position etc. in the web page. These shapes can also be styled by using a style class in a CSS file. Hence, D3.js in a nutshell accesses HTML, CSS and SVG components of a web page which makes rendering visualization of data in an efficient, simple and fast manner.

### 2.5. Highcharts

Highcharts is an online Data Visualization product created by the Highsoft team based out of Norway [15]. It is a charting library written entirely in JavaScript. It allows creation of interactive visualizations that can be hosted on web pages or web applications. The data to be visualized is input as JSON file. as input data Highcharts currently supports line, spline, area, area-spline, column, bar, pie, scatter, angular gauges, area-range, area-spline-range, column-range, bubble, box plot, error bars, funnel, waterfall and polar chart types [16].

## 3. WORK FLOW

### 3.1. Cloudmesh Client

Cloudmesh is a cloud management client that provides seamless integration to multiple clouds from command line. Some of the features of cloudmesh include heterogenous cloud integration, deployment of hadoop cluster with add-ons such as spark and pig [17]. It also enables automated builds

### 3.2. Ansible

Ansible is a powerful IT automation engine that helps in the deployment of applications. It doesn't use any customized security infrastructure that and it is very easy to deploy. The YAML, a simple language, is used to write ansible scripts. The main component of the ansible is a playbook which is YAML file that contains all the processes and applications that have to be deploys in the remote system [18].

Ansible pushes small chunks of code called modules that are executed on the nodes. These modules are executed over ssh by default and removed once they are completed. Also, these modules can reside anywhere and do not require the use of database systems, servers or daemons [18].

Ansible supports the use of ssh keys as well as passwords. However, ssh keys are relatively simple to use. Another noteworthy feature of ansible is that root logins are not required and later one can sudo to any user. The Ansible authorized key module is an efficient way to control other hosts. Additional options such as kerberos or identity management systems are also available for use [18].

The Playbook is the heart of an ansible work flow. The playbook enable the user to control the infrastructure details of the project such as the number of machines to be considered for the task and the processes to be deployed in each of those machines [18]. A basic ansible playbook is shown in Figure 3 The list of hosts

```

---
- hosts: webservers
  serial: 5 # update 5 machines at a time
  roles:
  - common
  - webapp

- hosts: content_servers
  roles:
  - common
  - content

```

**Fig. 3.** Structure of an Ansible Playbook [18]

is usually provided in a file and each group of hosts is usually given a name that is later reference in the playbook. While running an ansible playbook, the inventory/host file is also passed in the command. Logging into machines do not require an SSL signing in. A sample ansible inventory is shown in Figure 4.

```

[webservers]
www1.example.com
www2.example.com

[dbservers]
db0.example.com
db1.example.com

```

Fig. 4. Structure of an Ansible Inventory [18]

### 3.3. Tweet Extraction

Python is used as the platform for collecting real-time data from Twitter. Using the 'tweepy' package, a tweet extracting module was built which authenticates the collection of data from Twitter's API. This is done by using the 'Consumer key' and an 'Access token' generated by Twitter's developer API. This Consumer key and access token are unique to the application created by the user. Of the total number of tweets authored in Twitter at a given time, only 1% -2% of the tweets can be extracted. Of these tweets that were extracted, only 1% -2% of the tweets are geo-tagged. While extracting the tweets, filter was applied on Language to extract only those that were authored in 'English' language. Tweets were collected at the rate of generation as a JSON object in Python. The data was not stored in a RDBMS/NoSQL database since data files in the Gigabytes range slowed down the system when implemented in Chameleon cloud platform. Instead, batch processing technique was used, where the tweets were extracted and processed in batches. The results of analysis of this batch of tweets were then visualized. The results of each of the subsequent batches were aggregated with the previous batch in Python. The visualizations were also subsequently updated.

### 3.4. Tweet Pre-Processing

Since the extracted tweets were in JSON format, they had to be pre-processed in order to be used for analysing and calculating sentiment scores. The various steps in pre-processing have been elaborated in this section.

#### 3.4.1. Parsing

The data had to be parsed to get convert the data in JSON format to a pandas data frame with columns populated with : textual content, location, country code, country name, state code, time of generation etc. The missing values were replaced with 'NA's.

#### 3.4.2. Tokenization

A custom tokenizer was built that does not separate the hashtags # from the word. Similarly, @ and the textual part of the mentions were retained as a single entity. Other special cases included retaining all the characters in emoticons together as a token, extracting URLs together etc. After testing the performance of the tokenizer manually, the datasets were given as input to the tokenizer. Files with a single token on each line and an empty line following each tweet were created.

#### 3.4.3. Word Vector Creation

For each of the tweets, word vector files were created which includes the tokens from the tweets as individual features and values were given based on their presence in each tweet. The value for that respective column was set to be 1 if the word/token was present in the tweet and 0 otherwise.

#### 3.4.4. Feature Engineering

Two lexicons were provided: Arguing Lexicon and MPQA subjectivity lexicon. Features were created from each of these lexicons for the train and test data-set of each target.

- **Arguing Lexicon:** Arguing lexicon [19] is a hand built lexicon built by Somasundaran, et al., contains 17 ".tff" files describing patterns that represent arguing. Each file contains patterns that are specific to one type of argument. For instance, "authority.tff" contains patterns that might occur in the text that involves a person or an entity exhibiting authority in some manner. There are certain areas in the pattern files that contain words that start with "@". The corresponding definition for these words were given in 5 macro files. Modals, Spoken, Wordclasses, pronoun and intensifiers are included in the 5 macro files. For example, in "emphasis.tff" there is a pattern "@GONNA", the value of which is present in the "modals.tff" macro file.

```
@GONNA: ["am going to"," are going to"," is going to","
am gonna"," are gonna"," is gonna"]
```

Here, "@GONNA" was replaced by the corresponding list of values shown above. It can be any one the listed values. All the 17 files were read in python as a list of patterns. Macro files were used to replace the macros present in these 17 files wherever necessary. Regex package in python was used to read and compile each pattern in each of the 17 files as regular expressions. 17 new features were created and 0/1 values were assigned if a text contains at least one regular expression from the list for each lexicon file. The created feature would have the value 1 if any one of the regular expression has a match with the input tweet, otherwise 0. This process was repeated for all the targets' train and test data-sets.

- **MPQA subjectivity lexicon** was also used in the process of creating new features. This lexicon contains a clue file which was developed by Riloff and Wiebe, 2003 as a part of their work in subjectivity expressions [20]. The clues in the file were provided in the following format:

```
type=strongsubj len=1 word1=abuse pos1=verb
stemmed1=y priorpolarity=negative
```

A clue that is subjective in most context is considered strongly subjective (strongsubj), and those that may only have certain subjective usages are considered weakly subjective (weaksubj). "Word1" denotes the token or stem of the clue, whereas "pos1" denotes the part-of-speech of the corresponding word. Apart from subjectivity, the polarity of the word whether its positive, negative, neutral or both is given by "priorpolarity".

### 3.5. Classification Model

#### 3.5.1. NLTK - Textblob

Textblob is a python wrapper(for python 2 and python 3) class of the NLTK package. It provides various modules for utilizing

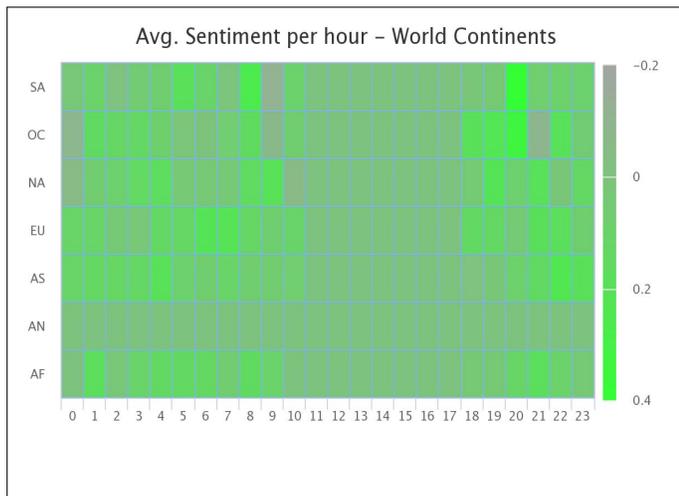
the functions of NLTK. Hence, the usage requires NLTK and all NLTK corpora to be installed initially. The sentiment analyser tool in textblob gives the polarity when a sentence is given as input. It can recognize several different languages.

**3.5.2. PySpark with NLTK**

Spark framework comes with a powerful Machine Learning API called MLLib. The MLLib contains predefined functions for popular machine Learning Algorithms. The NaiveBayes classifier was used along with the python’s NLTK toolkit to get the sentiments associated with each tweet. The resulting model was stored in a the local file system. Each subsection describes the functions and modules used to build the Naive Bayes Classifier.

The output of tweet extraction is read by the Spark Context using a JSON reader. The data is then pre-processed and cleaned by removing the stopwords from the tweets. The tweets then tokenized using the NLTK tokenizer. The tokenized tweets are used to create feature vector with features using the hashing trick. Hashing maps the data of an arbitrary size to a fixed size which is 50000 in this case. A Labelled Point vector which is a type of RDD with the label and feature vector as a key value pair. The Labelled Point vectors are useful in training supervised algorithms in MLLib. Sixty percent of the Labelled point data was used for training the Naive Bayes Classifier. The model obtained as a result of training is stored in the local file system. The model is tested on the remaining data. The predictions along with the correct labels are also stored locally in file. To process and manipulate the data the classic Hadoop functions such as Map, FlatMap and Filter were used. The functions are described in the upcoming sections.

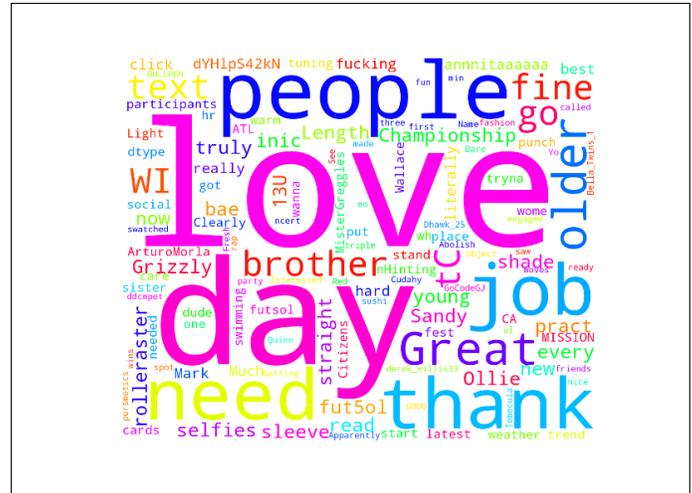
- **Map:** Map applies a function to all the elements of a RDD. This is achieved in PySpark by using Lambda functions.
- **FlatMap:** Flat Map is similar in function to map however , it transforms an RDD to a collection and then back t an RDD. The results in a flattened output. The input and output RDDs can be of different sizes.
- **Filter** The filter applies a condition to every row of an RDD and retains rows that satisfies that condition.



**Fig. 5.** Tweets Count - Time

**3.6. Data Visualization**

Data Visualization is an integral part of the sentiment analysis of Twitter data. Visualization tools such as D3.js and Highcharts [16] have been used to visualize the data. Visualizations created using Highcharts are updated as batches of tweets are extracted and processed in real-time. These charts change dynamically as each batch of tweet data gets processed over time. Visualization created using D3.js is directly connected to the Twitter API and thus it gets updated without any latency. A series of visualizations have been created in D3.js and Highcharts to analyze the data and project results of NLP analysis onto geographical and temporal spaces. The section below elaborates on the visualizations implemented.



**Fig. 6.** Word Cloud for Positive tweets

**3.6.1. Temporal Analysis**

To analyze the data with respect to time, the tweets were aggregated with respect to the time stamp. The tweets generated all over the world were collected by filtering on ‘English’ language. The number of tweets generated from each country was plotted along the time axis to identify the period of time during the day when people tweeted the most. A matrix was created to understand the average positivity/ negativity/ neutrality of people around the world during different times of the day.

- **Count of Tweets generated vs Time:**  
The plot of the number of tweets generated in a given period of time is shown in figure 7. Line chart has been used because it clearly depicts the trend in number of tweets in a given second. The time (in UTC) is plotted along the horizontal axis and the number of tweets is plotted along the vertical axis. In the figure 7, the number of tweets have been plotted for the time period 19 : 54 : 30 to 19 : 58 : 00 on April 09, 2017. It is possible to select the time range for which we want to see the trend in more detail by clicking and dragging the mouse in the horizontal axis [21]. The tool-tip gives information about the exact time-stamp and the corresponding number of tweets generated at that time. The plot can be used to observe the peaks in activity in Twitter over a period of time.
- **Average Sentiment across Continents vs Time:**  
The chart giving the sentiment score as a function of continent and time is shown in the figure 5. Each block in this



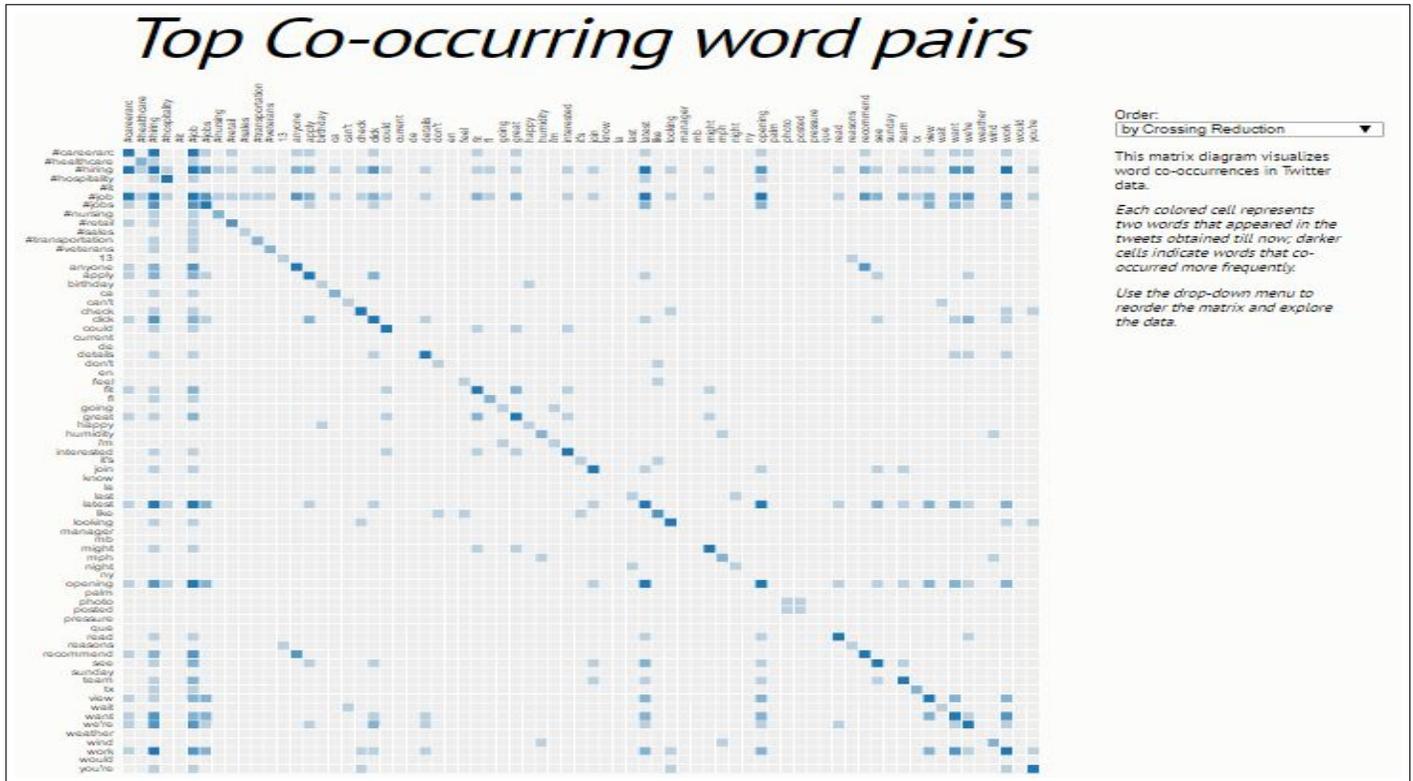


Fig. 9

frequently used. The negative wordcloud shown in Figure 8 clearly projects abusive words commonly used in tweets which in most cases are indicative of the sentiment.

**3.6.3. Analysis for US-States**

US is one of the major locations from where a significant number of tweets are generated. In the data that was collected from Twitter for the purpose of analysing sentiment, it was observed that majority of the tweets were from USA. Thus, Visualizations were created for analysing the amount of tweets generated and the average sentiment conveyed by these tweets across the states of the USA. Highmaps [25] were used for visualizing this data, where the values were projected onto the geographical map of US based on the latitude and longitude information. Heat maps have been used to represent this data, where the intensity of color is used to differentiate the value across multiple regions.

• **Number of tweets in US States:**

From the Figure 10, one can see the number of tweets generated across the different states in the US. For the geo-tagged tweets available in the data, the country of tweet generation was extracted. Those tweets with Country code as 'US' were filtered and the state code was extracted for these tweets. The state code was then used to map the latitude-longitude information for each of the states. The number of tweets generated was aggregated at the State level. This was then used as JSON input to generate the graph in Highmaps [26]. The color scale shown at the bottom of the graph gives the intensity of Blue used for different frequency ranges. The number of tweets generated from each state has been projected on to the corresponding geographical location. This has been developed as an interactive graph, where particular regions can be zoomed to get a clearer view of the

distribution. From the graph we can see that there is more activity along the coastal regions of the US as compared to Northern states of America. it can be seen that most tweets are generated from California on the West coast and majority of tweets are generated from the East coast of USA.

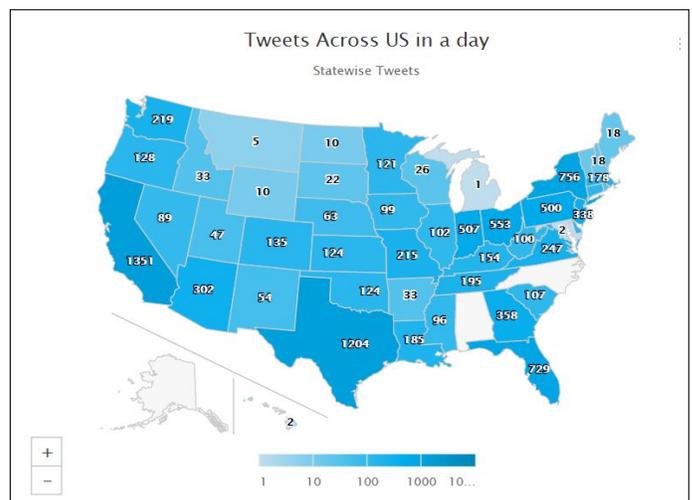


Fig. 10. Number of tweets in US States

• **Average Sentiment across US States:**

The average sentiment across the various states of US was visualized as shown in the Figure 11. Data was extracted using a procedure similar to that explained in Section 4.3.1.

The average sentiment score was calculated by taking average of the sentiment scores of all the tweets from a given state. This graph was also developed as an interactive graph, where one can zoom into regions of interest for better understanding. The color corresponding to each class (Positive/Negative/Neutral) is shown at the bottom of the plot. In addition to creating a heat map for understanding the majority sentiment, pie charts were imposed onto the states to provide the percentage distribution of negative, positive and neutral tweets [27]. The heat map assigns the color of majority class to the state. In this way, the majority region of the pie chart will be indistinguishable from the background and one can see the distribution of other two classes in the same state. From the graph, it can be seen that majority of the states have neutral sentiment. The pie charts show that, though most states have a neutral sentiment, some states are less negative than the others.

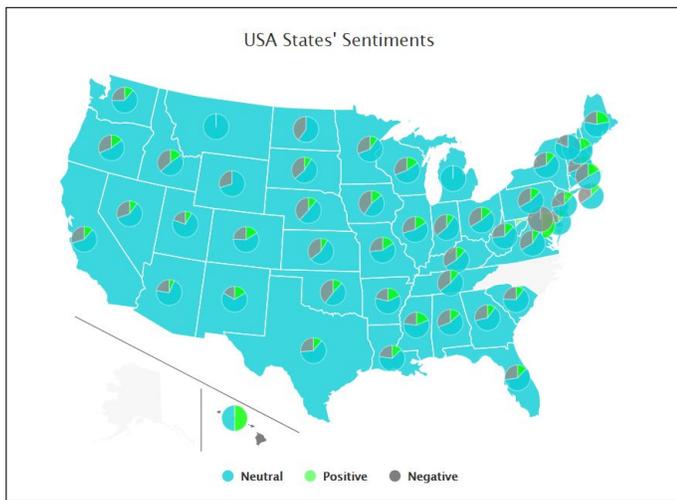


Fig. 11. Average Sentiment across US States

3.6.4. Analysis for World Countries

All tweets with geo-location information were analysed to understand the amount of tweets generated and their average sentiment with respect to countries. These values were then projected onto the world-map to identify regions of high activity and regions of positive, negative or neutral sentiment. The first graph displays real-time generation of tweets by highlighting the country from where it is generated. The latter is a heat map displaying the average sentiment across world countries in the map.

• Number of tweets in World Countries:

Figure 12 shows the number of tweets generated in each country. This visualization was developed as a combination of bar chart and the geographical map. It was created using D3.js by obtaining the JSON data from node.js [28]. The visualization directly connects with the Twitter API in real-time with a delay of 2-3 seconds. Each geocoded tweet is visualized as a point of longitude and latitude on the map. When a tweet is generated, it is indicated by animated concentric circles around that point. After the animation ends it is marked by a dot with color corresponding to the color of the country in the bar chart. In parallel, a counter tracking number of tweets generated from the corresponding

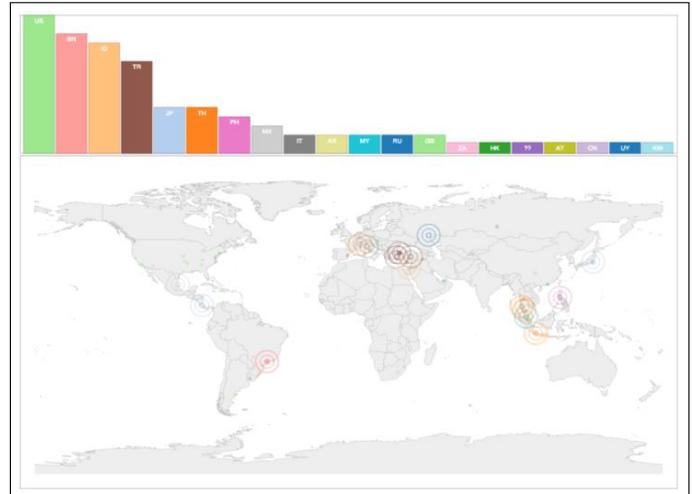


Fig. 12. Number of tweets in World Countries

region is incremented and plotted on the bar chart. Only top 20 countries in terms of tweet generation are visualized in the bar chart. The country code is specified at the top of the corresponding bar. From the plot, it can be seen that maximum number of tweets are generated from US, which is in line with what was observed in the data collected.

4. DEPLOYMENT

4.1. Hadoop and Spark

Cloudmesh was used to deploy Hadoop and spark in the Virtual machines. A cluster with three nodes were created. One of the machines served as the master while the other two machines were the worker nodes. Two playbooks were created: the first playbook was used to install cloudmesh client and the second playbook was used to deploy a hadoop cluster with spark as an add-on. An overview of the tasks performed by the ansible playbook that deployed a hadoop cluster with spark in 3 virtual machines is detailed below.

1. Virtualenv and Virtualenv wrapper were installed
2. the python dependencies for cloudmesh were installed.
3. Dependencies for cloudmesh client were installed
4. Install cloudmesh client in the local system
5. Generate ssh key if it doesn't exists
6. A default cloud was selected
7. The ssh key was added to cloudmesh
8. The security group was uploaded into cloudmesh
9. A cluster with three nodes was defined
10. Hadoop was deployed using spark as an add-on
11. The cross ssh connection between the three nodes was verified to enable communication between the nodes.

#### 4.2. Implementation of Naive Bayes Classifier using spark ML-Lib

The code for the Naive Bayes classifier was uploaded in a common repository in github. An ansible script was written that fetched the code and executed it inside the master node. The model and the classified results were saved inside the master node's Hadoop distributed File system. This file was later pushed to a git repository which further utilized the results to create visualizations using D3.js

#### 4.3. Analysis of Tweets using Python

Python was used to extract tweets from the twitter and the following packages of python was used for performing the multiple text analysis mentioned

1. Tweepy
2. Pandas
3. TextBlob
4. Numpy
5. Zipcode
6. matplotlib
7. nltk

The version of Python used was 2.7x. **Ansible-node** role was used to install python and its dependencies, followed by the installation of pip which was used to install the python packages mentioned above.

#### 4.4. Visualization components

Two components of visualization was deployed. One using nodejs and d3.js for visualizing the tweets in their geo location in a world map. Another is the set of charts and maps using Highcharts visualizing the results of the analysis performed in the previous step. Later part of the **Ansible-node** role was used to install nodejs and its dependencies, and start the python http server for viewing the visualizations.

**Table 1.** Chameleon cloud Specification

Value	Chameleon
<b>group</b>	default
<b>secgroup</b>	default
<b>image</b>	Ubuntu-Server-14.04-LTS
<b>flavor</b>	m1.medium

### 5. BENCHMARKING

Benchmarking was done to evaluate and compare the performance of the system by varying the Cloud environment, cluster set-up, algorithms and data sizes. Benchmarking was also done on system performance in local machines. Local machine used was dual core machine with 8 GB RAM and 64bit OS. The configuration of the machines on which the analyses were run is as given below: The system was deployed in Chameleon cloud platform. The virtual machines used for the analysis had the following configuration:

#### 5.1. Naive Bayes vs NLTK-Textblob

Two different algorithms were used to classify the tweets based on positive, negative or neutral sentiment. Naive Bayes classifier was developed in PySpark and the saved model was used for the classification task. The model was built on annotated training data and tested on data extracted from Twitter. Textblob module of the NLTK package in Python was also used for classifying the tweets. The performance of both the machine learning models were verified on a common validation set. Table 2 gives the accuracies of the two models on 10,000 tweets extracted from Twitter and annotated manually. Since Textblob had better accuracy than Naive Bayes classifier, all the analyses were done based on the sentiment scores determined using Textblob.

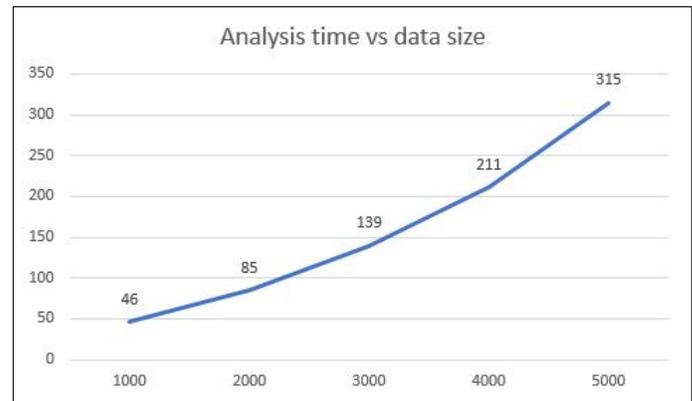
**Table 2.** Accuracy of ML models

Model	Accuracy
<b>NLTK-Textblob</b>	62.81%
<b>PySpark-Naive Bayes</b>	51.36%

#### 5.2. Chameleon

Chameleon cloud was one of the three platforms used for deploying the real-time system. The time taken for installation of dependencies and the time taken for execution of the algorithms were recorded. Textblob tweet analyses was done using Python in a single cloud virtual machine. To run this analyses all package dependencies like Pandas, TextBlob, Numpy, Zipcode, matplotlib, nltk and node.js had to be installed in the cluster. Time taken to determine the sentiment score of tweets using textblob is shown in Figure 13.

The Naive Bayes classifier built in PySpark was implemented



**Fig. 13.** Run time of Textblob

in multiple nodes within a cloud Virtual machine. To implement this model, Hadoop, Spark and HDFS had to be installed in each of the nodes in the cluster. As clearly seen from the Table 3 PySpark takes longer time to to get executed as compared to Textblob due to the parallel processing of data. Also, the installation of dependencies take significant amount of time as compared to the system execution. Table 4 gives the run time of implementing the classifier in a cluster with 1,2 and 3 worker nodes respectively. It can be seen that the run-time for 3 nodes is almost similar to 1 node and higher than the 2 nodes due to

the time that takes for communication between the nodes in a cluster.

**Table 3.** Run time for installation and execution

Task	Nodes	Runtime
Installation- Python packages	1	31s
Node.js	1	21s
Tweet Pre-processing	1	46s
Textblob-1000 tweets	1	0.21s
PySpark dependencies	3	148s
Naive Bayes	3	30s

**Table 4.** Running time of Naive Bayes model on 1-3 nodes

Run time of Naïve Bayes	
No. of nodes	Run Time (in s)
1	32
2	24
3	30

## 6. CONCLUSION

A framework is built for visualizing the analysis performed on the real time tweets. By obtaining the tweets from the twitter streaming API, different text analysis was performed on the tweets and the results were aggregated at multiple levels (geographically, time, etc.) and was projected using charts built using High charts and D3.js. A Naive Bayes Classifier is built on a spark cluster which was used for classifying the sentiments. Finally, multiple benchmarks were performed pertaining to deployment of required software, analysis time vs data size, and time taken for building a classifier in spark based on the number of worker nodes and cluster size.

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## 7. WORK BREAKDOWN

The work in this project was equally distributed between the following authors.

**Sowmya Ravi:** Building Spark pipeline and using Pyspark for building Naive bayes Classifier algorithm, benchmarking & troubleshooting and writing report.

**Sriram Sitharaman:** Creating visualization using D3.JS & NodeJs, building ansible scripts, Writing Python Scripts for Data analysis and writing report.

**Shahidhya Ramachandran:** Writing report, Writing Python scripts for Data Analysis, Creating visualization using High-Charts.

# Aviation Data Analysis Using Apache Pig

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Project-002, September 21, 2017

Data science is a challenging field which gives actionable insights into data, enabling businesses to take calculated decisions. Big data techniques help and accelerate the analysis of data in real time. Big Data can be used to monitor things as diverse as flight data, traffic data, and financial transactions. With huge increase in the volume of air travel and drastic weather changes, flights delays and cancellation are on the rise. This project aims at tracking the aviation data and providing a list of the busiest airports by total flight traffic across the US. The system has been deployed in chameleon cloud platform. Apache Pig deployed on a Hadoop cluster is used to join multiple features across massive datasets to query and analyse the data across a Distributed File System.

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**Keywords:** big data, Apache Pig, Apache Hadoop, Chameleon Cloud, Aviation Analysis

Report:<https://github.com/cloudmesh/sp17-i524/blob/master/project/S17-IR-P002/report/report.pdf>

Code:<https://github.com/cloudmesh/sp17-i524/blob/master/project/S17-IR-P002/code>

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## 1. INTRODUCTION

Air travel is getting increasingly popular with the airlines providing cheaper fares and better services [1]. However, owing to the increased congestion in traffic during festive season and ever fluctuating weather conditions, there are cancellations and delays to the flights. Cancellations tend to be costly for both passengers and the airline companies and pose difficulties for the customers who might have appointments or connecting flights. According to new Department of Transportation filings [2], the resulting change fees and cancellation penalties passengers end up paying up to a whopping \$2 billion a year.

With the increasing availability of data and improvement technology, there is growth in the area of big data and computing [3]. There has been development of new tools and frameworks to efficiently process large amounts of data. These tools rapidly process data and execute complex parallel algorithms while automatically splitting the the work across a set of available nodes. Earlier data processing applications could not handle the high volume, velocity, and variety of big data. This is the data which is difficult to handle in conventional data analytics. Big Data is now being used to monitor things as diverse as flight data [4], traffic data, and financial transactions. The challenge of Big Data is how to use it to create something that is value to the user. How to gather it, store it, process it and analyze it to turn the raw data information to support decision making. This paper aims to leverage big data by deploying a Hadoop cluster and running an analysis across large datasets containing airline

cancellations and delays details using Pig Scripts and provide insights almost in real-time.

Hadoop allows to store and process Big Data in a distributed environment across group of computers. It is intended to scale up starting with a single machines and will be scaled to many machines. In our analysis we benchmark the performance of the clusters for various data sizes and cluster configurations. We utilize Chameleon cloud to run the Hadoop cluster and perform our benchmark.

## 2. ARCHITECTURE

### 2.1. Cloudmesh Client

Cloudmesh client is a lightweight cloud client to manage virtual clusters. It enables users to access multiple cloud environments from command shell and commandline. Cloudmesh client allows to easily manage virtual machines, containers, HPC tasks, through a convenient client and API. It is a client based toolkit that is installed and run on the users computers. The installation has been done on Ubuntu 16.04 for this project. It has a layered architecture that allows easy development of new features. A resource abstraction layer allows the integration of a multitude of resources spanning HPC, Containers, and Cloud resources.

Using Cloudmesh Client's "cm define" and "cm deploy" command with the right configurations, it is possible to define and create a multi node cluster and install Hadoop with addons. The architecture of Cloudmesh Client makes the deployment of clusters simple from Ubuntu shell with basic commands.

### 2.2. Ansible

Ansible is an open-source automation tool that automates software provisioning, configuration management, and application deployment. Once Ansible gets installed on a control node, which is an agentless architecture [5], it connects to a managed node through the default OpenSSH connection type. The architecture of Ansible is shown in 3. As with most configuration management softwares, Ansible distinguishes two types of servers: controlling machines and nodes. First, there is a single controlling machine which is where orchestration begins. Nodes are managed by a controlling machine over SSH. The controlling machine describes the location of nodes through its inventory.

Ansible manages machines in an agent-less manner, it doesn't require any software to be installed on the remote machines to make them manageable. By default is manages remote machines over SSH or WinRM [6], which are natively present on those platforms. These modules are temporarily stored in the nodes and communicate with the controlling machine through a JSON protocol over the standard. Ansible is decentralized, if needed, Ansible can easily connect with Kerberos, LDAP, and other centralized authentication management systems.

The design goals of Ansible includes consistency, high reliability, low learning curve, security and to be minimalistic in nature. Ansible doesn't require dedicated users or credentials - it respects the credentials that the user supplies when running Ansible. Similarly, Ansible does not require administrator access, it leverages sudo, su, and other privilege escalation methods on request when necessary [7].

The functioning of Ansible allows users to define the ip address of namenode in the hosts file, and give the required instructions in .yml file. The configuration yml file is called Ansible Playbook, and can be run to perform all the tasks listed in it on all the servers mentioned in the hosts file. This way Ansible makes handling multiple virtual machines simple by iteratively

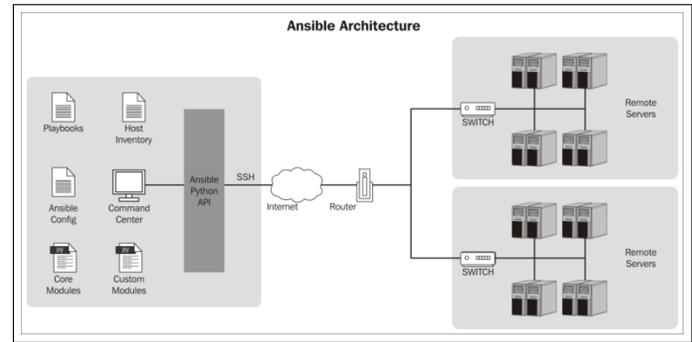


Fig. 1. Architecture of Ansible [8]

performing a set of tasks on all the hosts. In the hosts file, individual host name can be grouped together to form host groups, which can be called for advanced installations. Ansible also has options to assign roles to perform a specified set of tasks, its own version of modularization. There are options to use variables in the playbook. The current project uses Ansible to handle the movement of files between servers, and to run Shell commands on Hadoop namenode.

### 2.3. Chameleon Cloud

Chameleon Cloud is an open source large scale cloud platform available for the research community. The current commercial cloud platforms are mostly inaccessible for the student and research community. Chameleon project was created with funding from National Science Foundation and has 650 multi-core cloud nodes, 5PB of total disk space, and ability to leverage 100 Gbps connection between the sites. Chameleon cloud enables users to experiment on transformative concepts in deeply programmable cloud services, design, and core technologies on problems ranging from the creation of Software as a Service to kernel support for virtualization. However, Chameleon cloud of supported research includes many other areas such as developing Platforms as a Service, creating new and optimizing existing Infrastructure as a Service components, investigating software-defined networking, and optimizing virtualization technologies. [9]

The current project uses Chameleon Cloud instance created for the Big Data class at Indiana University. The current instance allows cloud created in three flavors - small, medium and large. Chameleon Cloud allows users to create any number of virtual machines with the required flavor, and allows to assign floating public IPs to be accessible from the outside. Each of the virtual machines can be created using any Operating System, and the current project uses Ubuntu14.04 version installed on Chameleon Cloud.

### 2.4. Hadoop

Apache Hadoop is an open-source software framework for storage and large-scale processing of data-sets on clusters of commodity hardware. Hadoop is written in Java, and it allows parallel processing of large datasets. Hadoop has four main components [10]:

1. **Hadoop Common:** These are the basic Java libraries and configuration files required for Hadoop to run
2. **Hadoop YARN:** Yarn is Hadoop's resource navigator. It is used for resource management and job scheduling

3. **HDFS:** The Distributed File System is Hadoop’s data storage. It distributes the data across Hadoop cluster
4. **Hadoop MapReduce:**It is a Yarn based system used to redistribute Hadoop jobs across cluster

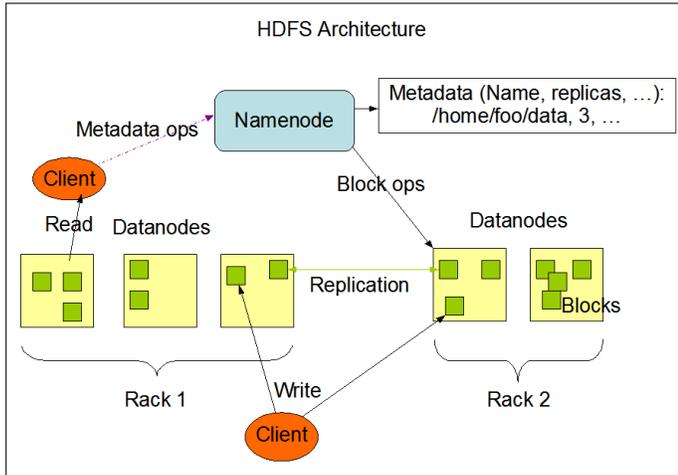


Fig. 2. Architecture of Hadoop [11]

**2.4.1. HDFS**

HDFS is a fault-tolerant system designed to be deployed on low-cost hardware. HDFS works well with large data sets and provides high throughput access to application data. A typical file in HDFS is in gigabytes to terabytes in size. HDFS has a master-slave architecture. A typical HDFS cluster consists of a single NameNode, a master server that manages the files system, a number of DataNodes which manages the storage attached to the node they run on. Internally, a file is split into multiple blocks and these blocks are stored in a set of DataNodes. The NameNode executes file system namespace operations like opening, closing, and renaming files and directories. It also determines the mapping of blocks to DataNodes. The DataNodes also perform block creation, deletion, and replication upon instruction from the NameNode.

The NameNode and DataNode are pieces of software designed to run on any machine. HDFS is built using the Java language. Any machine that supports Java can deploy HDFS. A deployment takes place in such a manner that one machine runs the NameNode software and each of the other machines runs one instance of the DataNode software. The presence of a NameNode is a must and the presence of a single NameNode in a cluster greatly simplifies the architecture of the system. The system is designed in such a way that user data never flows through the NameNode.

**2.4.2. MapReduce**

Hadoop enable distributed processing of massive structured/unstructured data across multiple commodity computers where each node contains it own data storage. This programming model of parallel processing and assimilation is the MapReduce program. MapReduce hsa two main functions - a Mapper class and a Reduce class. MapReduce serves two essential functions: It parcels out work to various nodes within the cluster or map, and it organizes and reduces the results from each node into a cohesive answer to a query.

MapReduce is composed of several components, including:

- **JobTracker:** the master node that manages all jobs and resources in a cluster
- **TaskTrackers:** agents deployed to each machine in the cluster to run the map and reduce tasks
- **JobHistoryServer:** a component that tracks completed jobs, and is typically deployed as a separate function or with JobTracker

**2.5. PIG**

PIG uses Pig Latin to analyse data in Hadoop. To perform data analysis, programmers need to write a Pig script using the Pig Latin language. Pig converts these scripts into multiple MapReduce jobs. There are various components in the Apache Pig framework:

- **Parser:** It checks the syntax of the script and displays the output (logical statements) in the form of DAG,
- **Optimizer:** performs logical optimizations such as such as projection and pushdown,
- **Compiler:** complies the logical output into series of MapReduce jobs,
- **Execution engine:** executes the MapReduce jobs are submitted to Hadoop in a sorted order.

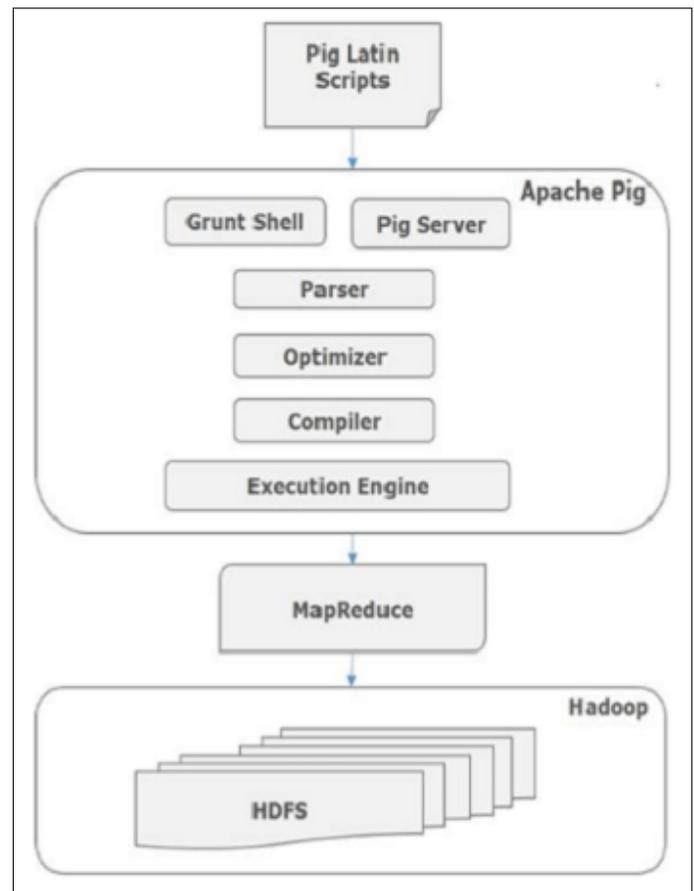


Fig. 3. Architecture of PIG [12]

### 3. WORK FLOW

#### 3.1. Hadoop Deployment

The deployment was done from an Ubuntu14.04 instance running on Oracle Virtual Box. Hadoop instance with three nodes was deployed on Chameleon cloud using Cloudmesh Client was used to automatically create the cluster and deploy Hadoop software with Pig and Spark add-ons. Three virtual machines with Ubuntu14.04 version were installed on Chameleon Cloud, and Hadoop along with Pig and Spark add-ons was deployed to the clouds with one name node and two data nodes.

#### 3.2. Cluster Configurations

Hadoop was deployed on a cluster with three nodes. Three virtual machines were created on Chameleon Cloud for this purpose, with one instance as namenode (master) and rest of the instances as datanodes (slaves). All the three virtual machines were created with Ubuntu14.04 OS. Each of the vms had 20 GB space, with 2GB ram and one CPU. This configuration is called the "small" flavour in Chameleon Cloud. Each vm was assigned a separate floating public IP which could be used to SSH and connect.

#### 3.3. Ansible Playbook

Ansible was installed in the oracle virtual box and configured to automatically perform file transfers and to run Pig code on the cluster. All our interactions are with the namenode of Hadoop, so the public IP of the namenode of our installation was given in the hosts file of Ansible for all purposes.

Five Ansible Playbooks were setup, each with the following purposes:

1. Transfer data and Pig Script files to namenode from local location
2. Transfer data files to hdfs location on namenode using *hdfs dfs* command
3. Run pig code using *pig <any\_pig\_script>* shell command on the name node
4. Transfer the output files from hdfs back to namenode
5. Transfer output files to local location

Each of these would run on the locations mentioned in hosts file on usernames CC and hadoop, which were the default users created by cloudmesh client.

### 4. AIRLINE ANALYSIS

#### 4.1. Datasets

The current project focuses on analysing flight cancellations and delays data to find trends. The dataset is taken from the US Department of Transportation's Bureau of Statistics [13]. Their website releases monthly air travel statistics and summary report of all the flights information of previous month. Along with this report, they release the raw data which is openly available to be downloaded and analysed. The two datasets we use are taken from the raw data provided in the website. A brief description about the datasets is given below.

1. **Delayed Flights** contains information about all the cancelled or delayed flights ranging across the years 1987 to 2008. It has 29 columns which are described in the Table 1.

Column Name	Description
Year	1987-2008
Month	1-12
DayofMonth	1-31
DayOfWeek	1 (Monday) - 7 (Sunday)
DepTime	actual departure time
CRSDepTime	scheduled departure time
ArrTime	actual arrival time
CRSArrTime	scheduled arrival time
UniqueCarrier	unique carrier code
FlightNum	flight number
TailNum	plane tail number
ActualElapsedTime	in minutes
CRSElapsedTime	in minutes
AirTime	in minutes
ArrDelay	arrival delay in minutes
DepDelay	departure delay in minutes
Origin	origin IATA airport code
Dest	destination IATA airport code
Distance	in miles
TaxiIn	taxi in time, in minutes
TaxiOut	taxi out time in minutes
Cancelled	was the flight cancelled?
CancellationCode	reason for cancellation
Diverted	1 = yes, 0 = no
CarrierDelay	in minutes
WeatherDelay	in minutes
NASDelay	in minutes
SecurityDelay	in minutes
LateAircraftDelay	in minutes

**Table 1.** Delayed Flights Column Information

Column Name	Description
iata	Airport Code
airport	Airport Name
city	Airport City
state	State Code
country	Country Code
lat	Lattitude
long	Longitude

**Table 2.** Airports Column Information

- Airports** is a reference dataset, which gives the airport names and locatons. The column description is shown in the Table 2.

The Delayed Flights dataset is around 250 mb in size and the airports dataset is around 250 kb since it is reference data.

#### 4.2. Pig Script

Pig installation runs on the Hadoop hdfs system. The script needed for this analysis was based out of the idea from the blog post written by Sumit Anand [14]. It takes the two datasets, performs basic joins, orders the rows and returns top five airports which cause most delays in all the years. This script was run on the namenode on Pig hadoop mode, with the input files given from hdfs dfs locations. This script analyses the data and outputs into hdfs location. The codes are written in Pig Latin language and can be run in Pig grunt shell.

### 5. BENCHMARKING

Benchmarking is a process in software development which allows developers to determine the performance of their systems. This can be done for multiple reasons including looking for improvements and future planning. The basic requirements of a benchmark are that the environmental conditions of test should be same each time it is run, and the test should be repeatable.

The current paper presents multiple levels of benchmarking, starting from the time taken to deploy Hadoop cluster with three nodes, the time taken to move files from local to namenode and hdfs, time taken to run the pig code and time taken to move files from hdfs to namenode and local. Deployment of Hadoop cluster is done using Cloudmesh Client, and the rest of the tasks are done using Ansible. For all Ansibls steps, there are individual playbook files which can be called from separate Ansible commands. Each of these steps has been timed using Ubuntu Shell's "time" command.

Excluding the time taken to download, install and configure Cloudmesh Client, the time taken to create three vms with the "small" configuration, deploy Hadoop with three nodes, Spark and Pig addons is 8 minutes 46 seconds. This deployment was done from Oracle Virtual Box with a ram capacity of 8 GB.

The experiment was performed on the entire dataset, and the tests were repeated with 50% and 25% of the data. The results of the benchmarking tests are given in the tables 3, 4 and 5.

### 6. SUMMARY

Airline industry is rapidly growing as the customers who take flights are increasing. Considering this trend, the cancellations

Task	Time Taken
Copy Data to cloud	1 min 33 sec
Copy Data to HDFS	23 sec
run pig script	3min 1 sec
Copy output to cloud	25 sec
Copy output to local	17 sec

**Table 3.** Benchmark Results for the entire data

Task	Time Taken
Copy Data to cloud	54 sec
Copy Data to HDFS	20 sec
run pig script	1 min 55 sec
Copy output to cloud	24 sec
Copy output to local	16 sec

**Table 4.** Benchmark Results for the 50% of the data

Task	Time Taken
Copy Data to cloud	27 sec
Copy Data to HDFS	19 sec
run pig script	1 min 6 sec
Copy output to cloud	22 sec
Copy output to local	17 sec

**Table 5.** Benchmark Results for the 25% of the data

and delays come into focus. It is imperative that Big Data technologies are deployed in this sector for quick results. This project aims at using Hadoop and Pig to run a basic analysis on Flight Delays data and benchmark the clouds' performance.

As we can see from the benchmark results, there is a drastic decrease in the first three steps (copy data to cloud, copy data to hdfs and run pig script) when the input file size is decreased. This is expected since there is less data for Hadoop to crunch. However in each of these cases, the output is top 3 airports, which is a textfile with three records. Thus we do not see much of a change in the time to copy the output (last two steps).

Overall, the time taken to run this entire process starting from copying data to namenode to getting output to local is taking less than 6 minutes for the entire dataset. Keeping in mind that our benchmark was for the "small" flavor of Chameleon Cloud (2GB ram) this is a good score, and if the cluster is vertically or horizontally scaled up, this analysis will yield results quicker. In order to take full advantage of Hadoop's parallel processing capabilities, it would be ideal if the number of nodes in the cluster were increased (horizontal scaling).

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support.

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## WORK BREAKDOWN

The work in this project was distributed between the following authors.

**Karthik Anbazhagan:** Research on project topic selection, writing project report and considering options for expanding the project to second cloud.

**Harshit Krishnakumar:** Designing work flow, cloud deployment, Pig scripts, automation using Ansible, benchmarking and writing project report.

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# Detecting Stop Signs in Images and Videos in a Robot Swarm

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S17-IR-P003, September 21, 2017

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**This project is designed to deploy a scalable stop sign detection algorithm to process real-time image and video streams. The deployment is automated allowing for minimal user-interaction. Spark on Yarn provides the distributed computing power required to scale the stop sign detection algorithm to process big data. This system is useful in automated driving vehicles and advanced driver assisted systems (ADAS) to detect and classify the street signs and control the vehicle accordingly. A comparative benchmark is developed based on the performance of the application on multiple cloud systems.**

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**Keywords:** Street Signs, Ansible, Video Streams, OpenCV, Spark, Cloud

Report: <https://github.com/cloudmesh/sp17-i524/tree/master/project/S17-IR-P003/report/report.pdf>

Code: <https://github.com/cloudmesh/cloudmesh.street>

---

## 1. INTRODUCTION

There are many applications developed based on simple idea of object detection, like auto-tagging pictures (e.g. Facebook, Phototime), counting the number of people in a street (e.g. Placemeter), tracking an object in video streams, detecting vehicles to name a few. Based on this concept of object detection, we deploy a scalable software for stop sign detection using Spark on multiple clouds. The software deployment is automated using Ansible. Cloudmesh provides simple command line interface for defining the number of clusters as well as deploying them. Benchmarks are developed based on the performance of this software on different cloud systems. The database of street signs will be restricted to US street signs. The only publicly available dataset for US traffic signs is the LISA dataset [1] which is very huge. Hence, the video streams used for this project are captured by us using a mobile camera.

OpenCV is a computer vision library used to process video streams in Python. A lot of computing power goes into processing videos in real-time, this is where the cloud systems come in. We leverage the distributed computing power of Spark on Yarn for faster processing of images and videos. This solution is deployed on two different clouds to benchmark their performance. In this era of autonomous driving and advanced driver assisted systems (ADAS), detection and classification of traffic signs is a handy feature. Benchmarks have been created for the traffic sign detection on the German and Belgium Traffic Sign Datasets [2].

## 2. REQUIREMENT ANALYSIS

The following technologies are used throughout the project:

- Cloudmesh provides command line interface to connect and deploy clusters to different cloud systems.
- Ansible is an agentless, automated software deployment tool.
- Python - Programming language.
- Spark - Distributed computing engine.
- YARN - is the resource manager for Spark.
- OpenCV - Image and video analysis for street sign detection using open source computer vision libraries. The OpenCV library provides several transformations that can be applied to images (apply filters, transformation), detect and recognize objects in images.

## 3. SCOPE

The initial project idea was to automate the deployment of street sign detection algorithm over multiple cloud systems. As we proceeded through the project, we realized that training of Haar Cascade classifier is challenging. For a training dataset of 1000 samples the training can go on for 3-4 days. It turned out to be an exhaustive process. The resultant classifiers were unable to detect the specific signs. The details of the OpenCV training process we followed are given in the appendix. Due to difficulty training classifiers for street signs, we had to reduce the scope of this project to detect only stop signs using a pre-trained classifier available on Github []. The stop sign detection is implemented for both images and videos using Spark.

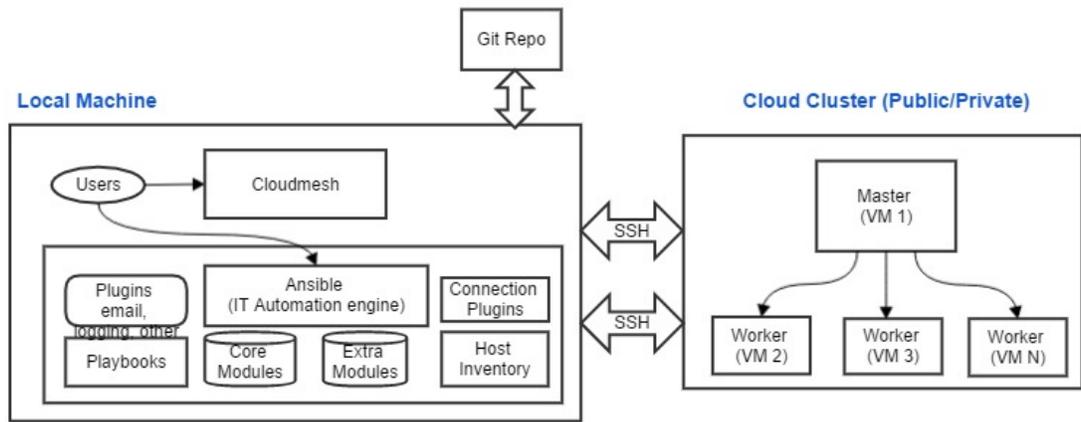


Fig. 1. System Architecture

#### 4. SYSTEM ARCHITECTURE

Figure 1 shows an overview of our system architecture. Ansible and Cloudmesh client are installed on the host or local machine. Roles are defined in the Ansible playbook for each of the different steps in the deployment process. We execute the Ansible playbooks to instantiate the cloud machines, deploy Hadoop and Spark on them and then carryout the stop sign detection on Spark using Yarn resource manager. Once the job is submitted to Spark, the driver program initializes the SparkContext object which is responsible for the execution of the job. Input data is parallelized and sent to the worker nodes for processing. Yarn acts as the resource manager and provides executors to the worker nodes. The output is saved to the local file system on the master node and transferred to the host machine through a script. More details on the mechanics can be understood in the following sections.

#### 5. CLOUD INFRASTRUCTURE

For the purpose of this project, we have been provided with two clouds – Chameleon [3] and Jetstream [4]. Chameleon cloud is a National Science Foundation funded experimental testbed that provides large scale cloud services to "members of the US computer Science research community and its international collaborators [3]." One can create virtual machines and manage them through the OpenStack Horizon interface. Jetstream allows researchers to leverage the computational power of cloud while retaining the look and feel of our home machines. Jetstream adds cloud based computational power to the national cyberinfrastructure [4]. Both Chameleon and Jetstream provide a cloud computing environment to researchers based on OpenStack [4]. The comparison of hardware specifications for the two cloud systems is given in table 1.

#### 6. CLOUDMESH

Cloudmesh provides an easy interface to multiple clouds such as Chameleon and Jetstream through the command line. Cloudmesh client can be installed via pip. It is a lightweight utility that enables users to connect to different clouds from their laptops or computers. Users can customize Cloudmesh client to

	Chameleon	Jetstream
CPU	Xeon X5550	Haswell E-2680
cores	1008	7680
speed	2.3GHz	2.5GHz
RAM	5376GB	40TBr
storage	1.5PB	2 TB

Table 1. Comparison of Cloud Specification [4] [3]

suite their needs of cyberinfrastructure. It provides simple command line scripts to deploy Hadoop with Spark add on to either of the clouds mentioned in section 5. A set of cluster machine instances can be defined using command:

```
cm cluster define --count 3
```

Cloudmesh commands to create and deploy Hadoop clusters with Spark are included as tasks in the ansible playbooks to automate the deployment.

#### 7. ANSIBLE AUTOMATION

Ansible is an easy to use, opensource automation tool that is used to automate the deployment of our project on the cloud infrastructure. Ansible is an agentless tool, that is, it does not require ansible to be deployed on the remote machines. It runs only on the host machine to deploy the required processes to the remote machines through SSH authentication. Using Ansible, we can create modules for each step of the deployment process and define the roles individually. An inventory file is used to define the machines in groups as required. A sample inventory file looks like:

```
[master]
192.128.0.1
[workernode]
192.168.0.2
192.168.0.3
```

Roles are defined in Ansible for the deployment of Hadoop-Spark cluster, environment setup on the virtual machines, stop sign detection as well as to fetch the results back to the local.

### 8. PYTHON-OPENCV

Python is preferred due to ease of use and familiarity over other programming languages. OpenCV also provides python library to enable object detection in python using this computer vision library. The initial scope included training a Haar Cascade Classifier to detect traffic signs and then testing the classifier on test data. But as explained in appendix section - Training a Haar Cascade Classifier - a decent classifier could not be trained. The stop sign detection algorithm utilizes a pre-trained stop sign classifier available on Github to perform the detection in images and videos. The results of the algorithm are saved as images in the `/github/cloudmesh.street/ansible/output/output/` folder on your local machine, assuming that the git repository is cloned to `/github/cloudmesh.street/`. The output files will have a bounding box around the detected object. The `signdetectionusingspark.py` file is used to process both images and videos. Based on whether the input is either image or video, the path to these files has to be modified in the `spark-submit` task of ansible playbook.

### 9. SHELL SCRIPT

Shell script is used to time each of the deployment step for benchmarking. Shell script is also useful in cases where a deployment terminates in an error and needs to be continued from some intermediate steps. Individual shell scripts are created for each tasks in case of such issues to allow execution from the point of interruption.

### 10. BENCHMARK

Benchmarks are created based on the performance of the software in different cloud environments. The benchmarks for Jetstream are limited due to issues with their cloud. As the test data is images and videos, spark ran into memory issues on the `m1.small` flavor. Hence, we have done benchmarking using the medium and large flavours only. Tables 2 and 3 reflect that the configurations for the same flavors on the two clouds are different. We cannot directly compare the performance if the two machines have different specifications. Benchmarking is done for the deployment and the analysis on Chameleon and Jetstream.

JetStream	VCPU	RAM(GB)	Storage(GB)
m1.small	2	4	20
m1.medium	6	16	60
m1.large	10	30	60

**Table 2. Jetstream Flavour Specifications**

#### 10.1. Chameleon Cloud Benchmarks

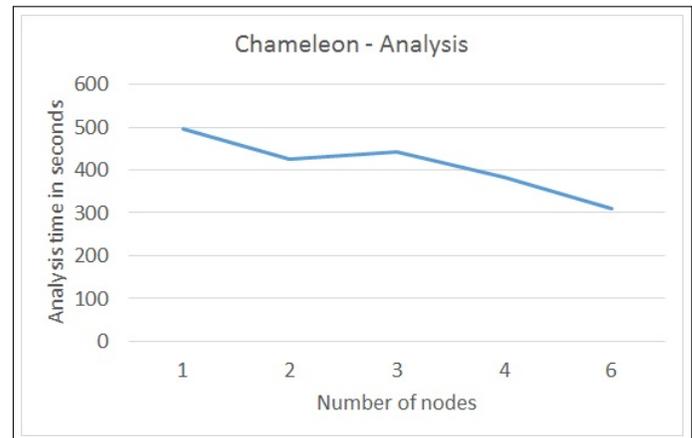
##### 10.1.1. For flavor m1. medium and 50 Test Images

Figure 2 shows the time taken for analyzing the 50 images on Chameleon cloud for 1, 2, 3, 4, and 6 node clusters. We can see that as the number of nodes increases the time taken to analyze

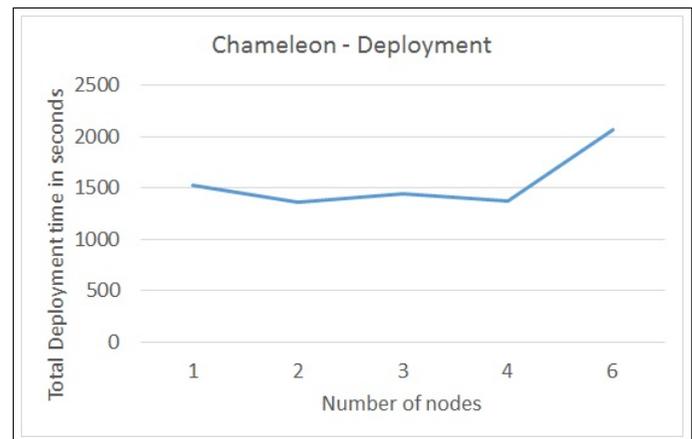
Chameleon	VCPU	RAM(GB)	Storage(GB)
m1.small	1	2	20
m1.medium	2	4	40
m1.large	4	8	80

**Table 3. Chameleon Flavour Specifications**

the images reduces. Figure 3 reflects the total time required to complete the deployment. We can see that the total deployment time doesn't vary much upto 4 nodes but there is a steep increase in the deployment time for 6 node cluster.



**Fig. 2. Time taken by sign detection task - 50 test images**



**Fig. 3. Time taken for complete deployment - 50 test images**

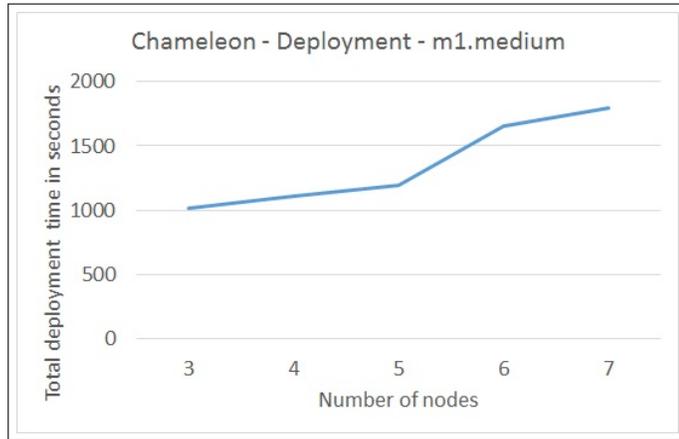
##### 10.1.2. For flavor m1.medium and a Video Input

The video input file tested on the medium flavor is just 2 sec long but since it gets converted to frames, it comes out to 53 images that are sent to spark for processing. Figure 5 shows the time taken for analyzing a single video that is 2 seconds long on Chameleon cloud for 3, 4, 6, and 7 node clusters. We can see that as the number of nodes increases the time taken to analyze the images reduces a lot. Figure 4 reflects the total time required to complete the deployment. We can see that the total deployment

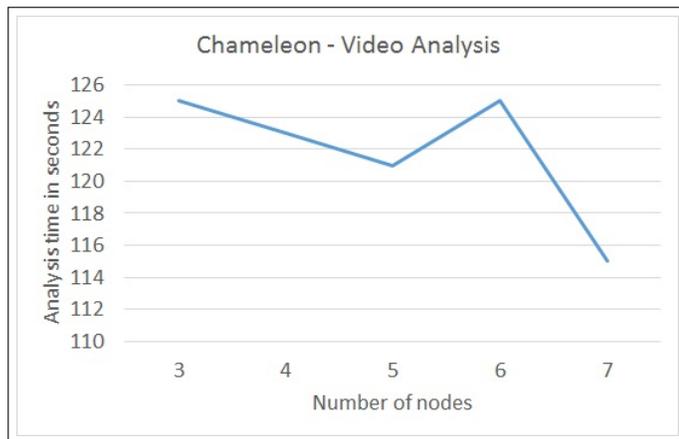
time doesn't vary much upto 4 nodes but there is a steep increase in the deployment time for 6 node cluster.

**10.1.3. For flavor m1.large and a Video Input**

The video input file tested on large flavor is 5 sec long and after extracting the frames, it comes out to 120 images that are sent to spark for processing. Figure 7 shows the time taken for analyzing a single video that is 5 seconds long on Chameleon cloud for 1, 2, 3, and 4 node clusters. We can see that as the number of nodes increases the time taken to analyze the reduces which is expected. Figure 6 reflects the total time required to complete the deployment. We can see that the total deployment time increases steeply at first and then starts to normalize.



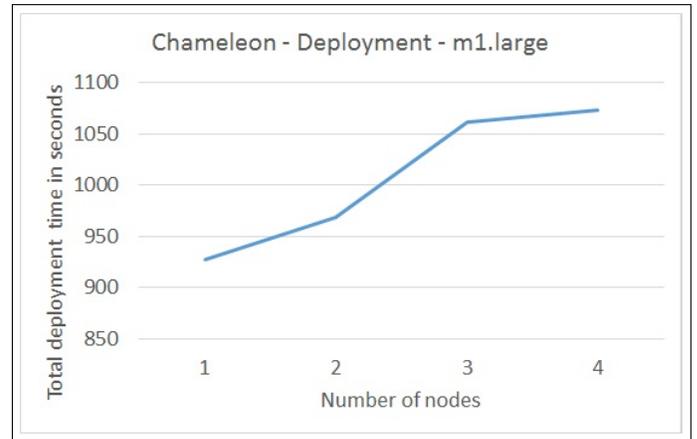
**Fig. 4.** Time taken for complete deployment - 1 Video (2 sec)



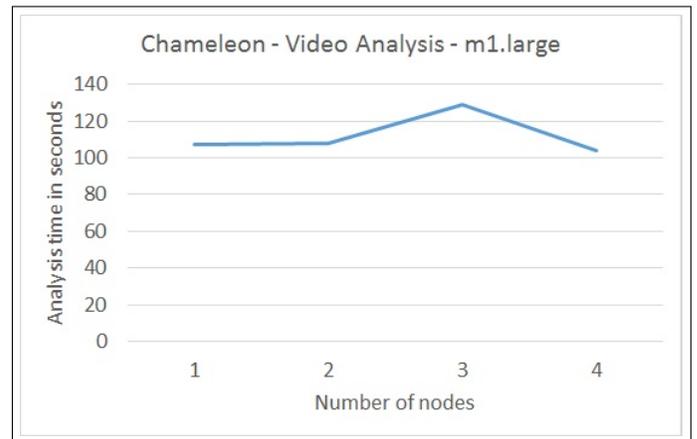
**Fig. 5.** Time taken for sign detection task - 1 Video (2 sec)

**10.2. Jetstream Cloud Benchmarks**

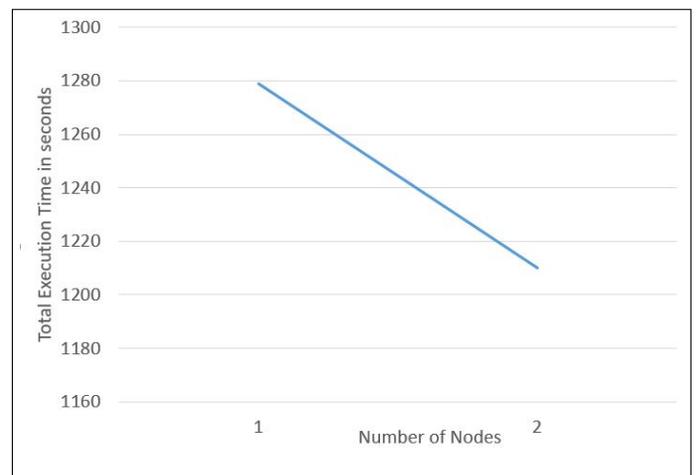
8 shows the time taken to the complete deployment on Jetstream when the number of images parsed are 4. It can be seen from the graph that as the number of nodes is increased the processing time is reduced. 9 and 10 reflect the performance of Jetstream cloud for 4 and 50 input images respectively. Sufficient data could not be gathered for Jetstream due to some issues with Jetstream. Hence we cannot conclude much about the performance of Jetstream.



**Fig. 6.** Time taken for complete deployment - 1 Video (5 sec)



**Fig. 7.** Time taken for sign detection task - 1 Video (5 sec)



**Fig. 8.** Total time required to deploy for 4 test images

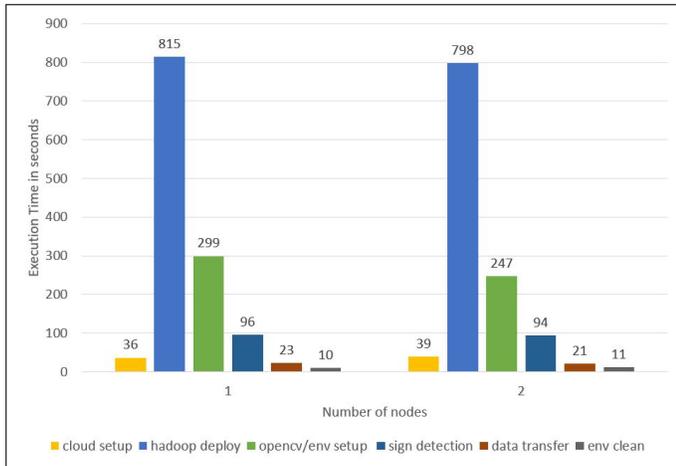


Fig. 9. Time taken by each task for 4 test images

## 11. USE CASES

1. Street Sign Detection for autonomous vehicles.
2. Analysis of traffic signs in Google Street View to estimate all signs ahead hence, useful in ambulance, fire brigade services, simplest path finder etc.

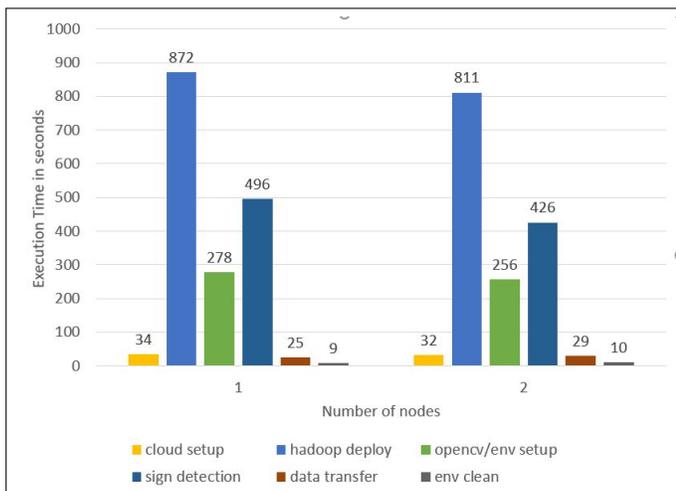


Fig. 10. Time taken by each task for 50 test images

## 12. FUTURE WORK

This work can be expanded to detect and classify all the U.S. traffic signs which can be adapted for advanced driver assisted systems (ADAS). Moreover, efficiency of sign detection over cloud can be increased by effective distribution of data, for e.g. using Hadoop distributed file system. An extension of the stop sign detection in video streams would be to output the data as videos rather than images in realtime. As the current system is scalable, benchmarks can be developed for larger dataset with multiple classifier, similar to the German and Belgium Traffic Sign Detection and Classification benchmarks [2].

## 13. CONCLUSION

We have been able to successfully deploy the software to Jetstream and Chameleon clouds and test their performance. On large flavors of chameleon cloud the deployment time starts to flatten out over the curve. As the number of nodes increases the time taken to deploy Hadoop and spark to those clusters increases and on the up side the analysis on Spark is faster.

## ACKNOWLEDGEMENTS

This project is undertaken as part of the I524: Big Data and Open Source Software Projects coursework at Indiana University. We would like to thank Prof. Gregor von Laszewski, Prof. Gregory Fox and the Associate Instructors for their help and support. Results presented in this paper were obtained using the Chameleon testbed supported by the National Science Foundation.

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## A. OPENCV IMAGE PROCESSING

OpenCV provides a range of computer vision algorithms to detect objects in images. One of the simplest method for object detection is based on color. The results of Color based detection method are largely affected by the lighting conditions and one require the user to calibrate multiple times before they might get a better result in the real world [5]. Hence this technique is not very popular when detecting objects in the real world Haar features is a sophisticated technique that uses the features specific to the object in question. It been seen that working with RGB pixel values in every single pixel in the image results in computationally expensive and slow feature calculation. "A Haar-like feature considers neighboring rectangular regions at a specific location in a detection window, sums up the pixel intensities in each region and calculates the difference between these sums. This difference is then used to categorize subsections of an image [5]." OpenCV provides a Haar feature based cascade classifier that can be used for object detection, as proposed by in [6].

### A.1. Data Collection

The publicly available data set for U.S street signs is the LISA traffic dataset [1]. This dataset contains images for 47 different traffic signs. But since the data set itself is approximately 7GB, we extracted 50 images from the dataset for the purpose of testing. For our training set, we captured images of street signs and put together a few positive images for the street signs. The positive images were cropped to only contain the street sign and resized to 50x50.

### A.2. Train a Haar feature-based Cascade Classifier

Based on tutorials provided in [7], [8], we carried out multiple experiments to train a classifier to detect street signs. Since each sign needed to be trained separately, we picked stop, yield, and signal ahead signs to start with. To train a classifier, we firstly required gathering at least a few positive and many negative images. The positive images are images of the object alone cropped to a size of 24x24 or 50x50 whereas the negative images should not contain the object in consideration here. In case we have a single positive image or a few positive images, OpenCV provides a utility called `opencv_createsamples` to generate the training and test datasets in \*.vec format that is supported by the `opencv_traincascade` utility. The samples generated from the `opencv_createsamples` can be passed to the `opencv_traincascade` utility to get a trained classifier. Multiple experiments were carried out by differing the sample sizes (the width by height of the positive images) and varying the number of positive and negative images. As the dataset and width by height increases the computational time increases. Below are the trainings that were carried out for stop sign:

```
opencv_traincascade -data classifier -vec samples.vec
```

```
-bg negatives.txt -numStages 20 -minHitRate 0.999
-maxFalseAlarmRate 0.5 -numPos 120 -numNeg 200 -w 50
-h 50 -mode ALL -precalcValBufSize 1024
-precalcIdxBufSize 1024
```

```
opencv_traincascade -data classifier -vec samples.vec
-bg negatives.txt -numStages 20 -minHitRate 0.999
-maxFalseAlarmRate 0.5 -numPos 200 -numNeg 350 -w 50
-h 50 -mode ALL -precalcValBufSize 1024
-precalcIdxBufSize 1024
```

```
opencv_traincascade -data classifier -vec samples.vec
-bg negatives.txt -numStages 20 -minHitRate 0.999
-maxFalseAlarmRate 0.5 -numPos 600 -numNeg 100 -w 50
-h 50 -mode ALL -precalcValBufSize 1024
-precalcIdxBufSize 1024
```

When we increased the number of positive samples to 600 for the 50x50 image size, the training ran for 3.5 days. The resulting classifier was unable to detect the stop signs in the test data. After a couple more experiments and another week invested in training the classifier to no good results, we found success with a pre-trained classifier for stop signs available at [9]. The results of this classifier are shown in 11.



**Fig. 11.** Stop Sign Detection

After successful testing of stop sign classifier, we proceeded to train the classifiers for Yield sign and Signal Ahead sign. We trained 3 classifiers each for both these signs while increasing the number of positive images from 600, 900, 1200. Even after increasing the number of positive images up to 1200 the resulting classifiers were not efficient enough to detect the signs in images. As each training had resulted in a loss of approximately 3.5 days, we realized that this could not be covered as part of this project and restricted ourselves to the stop sign detection.

### A.2.1. Outcomes

- From the many experiments we carried out, we learned that there is no fixed number of samples that will yield a decent result.
- Future work can be done on training the U.S traffic signs, since there are no classifiers available for them. With the growing market for autonomous vehicles and assisted driving technology, having trained classifiers for the traffic signs might prove to be helpful.

## B. EXECUTION SUMMARY

This section specifies the week by week timeline for project completion.

1. Mar 6 - Mar 12, 2017: During this week we created virtual machines on Chameleon cloud using Cloudmesh and submit the project proposal.

2. Mar 13-Mar 19, 2017: Deployed Hadoop cluster to Chameleon cloud using Cloudmesh and develop Ansible playbook to install the required software packages to the clusters (OpenCV, Python and dependencies)
3. Mar 20-Mar 26, 2017: Collated data for training and test data sets and trained stop sign classifier. Developed Ansible playbook to deploy Hadoop and Spark to the cloud machines.
4. Mar 27-Apr 02, 2017: Trained data for stop and yield sign classifiers using OpenCV. Developed Ansible playbook to setup the OpenCV python environment on Spark clusters.
5. Apr 03-Apr 09, 2017: Trained data for signal ahead sign using OpenCV. Test stop sign classifier on local machine and chameleon cloud.
6. Apr 10 - Apr 16, 2017: Tested classifier on Spark and created deployable software package using shell script.
7. Apr 17-Apr 23, 2017: Completed project report and developed benchmarks for the project.

# Using Hadoop and Spark for Big Data Analytics: Predicting Readmission of Diabetic patients

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project-004, September 21, 2017

This project proposes and demonstrates the use of Hadoop and Spark on cloud to run predictive analytics using machine learning on large amount of data. Our case study is to predict the readmission likelihood for diabetes patients using their available medical history.

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**Keywords:** Hadoop, Spark, MLLib, Ansible, Cloudmesh Client, Predictive Analysis

Report: <https://github.com/cloudmesh/sp17-i524/tree/master/project/S17-IR-P004/report>

Code: <https://github.com/cloudmesh/diabetic>

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## 1. INTRODUCTION

The idea behind this project is to introduce Hadoop-Spark distributed cluster for building predictive analytics applications. Spark allows us to build applications that are scalable and faster when compared to standalone applications performing similar analytics tasks.

We chose the case study of predicting the likelihood of a diabetes patient getting readmitted within 30 days from the date of discharge using his/her available medical data. Predictive analytics based on medical data to provide healthcare is an active area of research. Predicting readmission likelihood is aimed to providing better care to patients. Readmissions happen due to deterioration of patients' health. Readmission predictions help doctors and patients to take preventive steps to avert medical emergencies that need hospitalization.

We approached this problem as a classification problem to classify the patients into 'Yes' or 'No' classes, indicating whether the patient is likely to be readmitted or not in the next 30 days. We used different machine learning algorithms on the available data, after some pre-processing, to predict the same. The accuracy percentages obtained for all the utilized classification algorithms are included in the report.

Our other important goal is to propose an end-to-end solution that is scalable and faster than a standalone predictive analytics application. While our dataset has about 100,000 records, anticipating real-world scenarios with huge amounts of data we are proposing a Hadoop based solution. We are utilizing Spark for

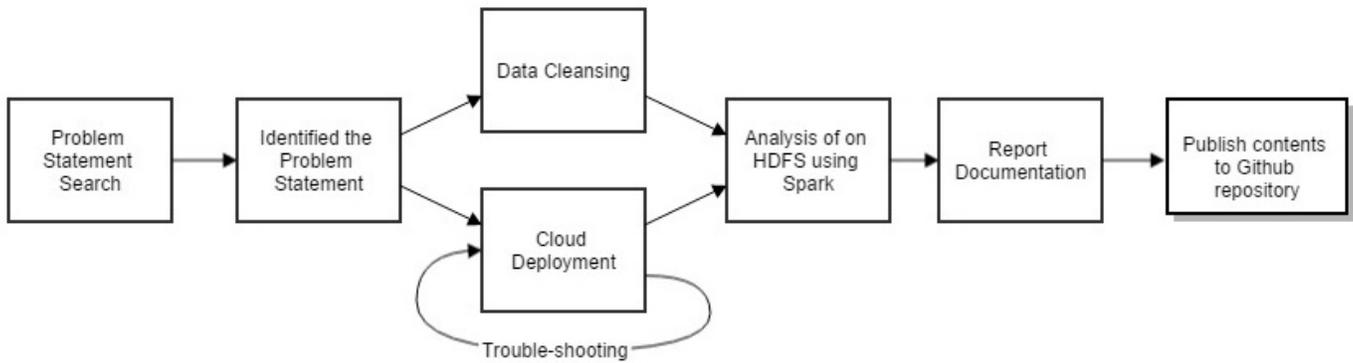


Fig. 1. Workflow of the project

its faster processing [1] and advanced analytics through packages like MLlib [2], which provides several commonly used machine learning algorithms. Finally we are implementing this solution over cloud infrastructure to meet our infrastructure requirements. This helped us demonstrate an end-to-end solution closer to real-world scenarios, where enterprises utilize cloud infrastructure in a pay per-use model. This helped us save time and resources in setting up the infrastructure.

We deployed our solution on two different clouds and obtained metrics to assess the infrastructure performance with our solution. We also deployed our solutions on a distributed Hadoop/Spark environment built on on-premise machines. We also automated the deployment of Spark cluster on cloud virtual machines using Ansible. We compared the performance metrics of all the three infrastructure choices, with respect to our application and included them in this report. Our project workflow can be seen in the Figure 1.

2. ARCHITECTURE

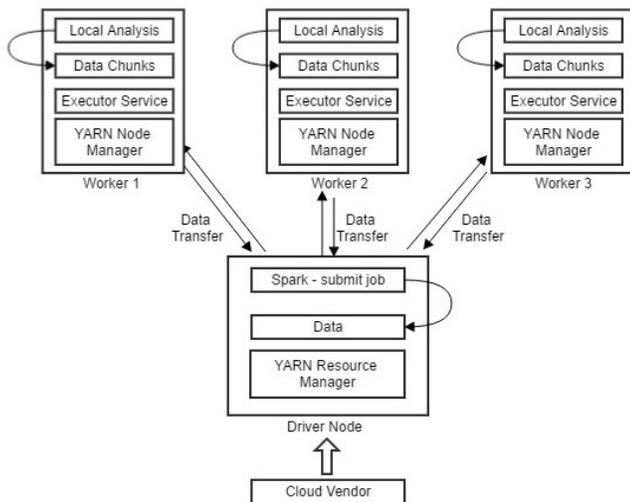


Fig. 2. Architecture Diagram

Figure 2 gives an overview of our solution’s architecture. We deployed a spark driver node and three worker nodes. A driver node is a node that runs the driver program. It declares the transformations and actions on RDDs (Resilient Distributed

Datasets) of data and submits such requests to the master [3]. In practical terms, the driver is the program that creates the Spark Context [4], connecting to a given Spark Master. It is a node where the yarn resource manager resides. A worker node is a node, which executes the program that involves individual data analysis task. Running the spark-submit script from the master node starts the spark job. It divides the data into data chunks and transfers them to individual worker nodes. Then a processing task is performed on the data chunks on the individual worker nodes. The processed data and analytics results are then written back to the HDFS file system as needed.

We then deployed Hadoop and Spark on these machines to setup a HDFS Spark cluster on our cloud and on-premise machines. We stored our dataset on the Hadoop’s HDFS file system. Finally, we ran our predictive analytics application, which utilizes MLlib, on Spark cluster by launching it using spark-submit.

3. TECHNOLOGIES

Table 1. List of technologies used

Technology	Usage
Hadoop[5]/Spark [6]	Big Data Technologies
Python[7]	Development
MLlib[2]/scikit-learn[8]	Machine Learning Library
GitHub[9]	Project Repository
Ansible[10]	Application Deployment & Configuration Management
Chameleon[11], JetStream[12], VirtualBox[13]	Benchmarking
LaTeX [14]	Document Preparation

We used specific technologies for specific tasks in this project as listed in Table 1:

- **Hadoop:** Apache Hadoop is a framework for processing and storing huge amounts of data, commonly known as ‘Big

Data', in a distributed applications. It allows users to build scalable and highly available data applications. Hadoop has four modules: HDFS, YARN, MapReduce and Hadoop Common. Hadoop Distributed File System (HDFS) allows users to store large amounts of data. YARN is the framework for job scheduling and resource management. MapReduce supports parallel processing of large data sets stored in the distributed environment through HDFS. Hadoop Common provides utilities that support other Hadoop modules.

- **Spark:** Spark runs on Hadoop and provides faster data processing capabilities for data on HDFS. It primarily uses a new data structure called Resilient Distributed Dataset (RDD) for processing. RDD is a read only multiset of data items distributed over cluster of virtual machines. Spark also has a new feature of fault tolerance and in the event of a primary master node failure, the secondary master takes over. Spark, unlike Hadoop applications, allows the iterative reading and writing in-memory. After processing it writes the data to HDFS.
- **Python:** We chose python as per our programming language. Python is one of the programming languages supported by Spark API through pyspark. We used it because of its simple syntax and data manipulation capabilities.
- **scikit-learn:** It is an open source Python library that provides Machine Learning algorithms and other utilities to preprocess and visualize data [8].
- **MLlib:** Spark MLlib is the Spark's machine learning library provides machine learning algorithms that can be applied on Resilient Distributed Datasets [15]. It also provides other data manipulation utilities. MLlib has API available in Java, Python, Scala and R [2].
- **GitHub:** GitHub is 'a web-based Git or version control repository and Internet hosting service' [16]. We used Github repositories to store all the files related to documentation, Ansible scripts and python code.
- **Ansible:** We are using Ansible for automating deployment of our software on cloud. We used Ansible scripts to automate deployment of cloudmesh client along with its prerequisites like pip, virtualenv etc. We also used Ansible for automating deployment of Hadoop and Spark.

#### 4. CLOUD INFRASTRUCTURE

We have setup the required infrastructure by provisioning virtual machines on two cloud vendors, Chameleon, Jetstream and our on-premise machines.

##### 4.1. Chameleon Cloud

Chameleon is a collaborative cloud service primarily meant for research community. It allows users to explore problems ranging from the creation of Software as a Service to kernel support for virtualization. It is a good example of IAAS loaded with software defined networking and optimized virtualization technologies. We created three virtual machines on this cloud. One for Master node and two for worker nodes of Spark.

##### 4.2. Jetstream Cloud

Jetstream is a cloud service which aims to provide researchers Jetstream's development was led by Indiana University's Pervasive Technology Institute (PTI) in collaboration with other universities [12] across the United States. This cloud service was used to provision the necessary virtual machines. We created three virtual machines on Jetstream for Spark cluster nodes.

##### 4.3. Virtual Box

It is a fully virtualized hypervisor which gives the ability to spawn virtual machines in local commodity hardware. In fully virtualized environment, the guest OS is not aware of the underlying resources on which it is running as the hypervisor creates a complete simulation of the underlying hardware.

A brief comparison of multiple attributes of the clouds used are displayed in Table 2.

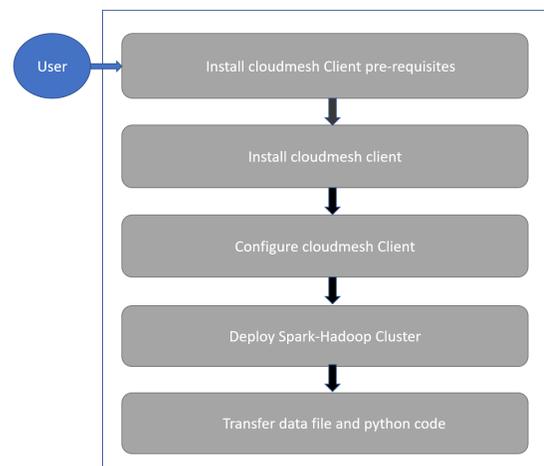
**Table 2.** Comparison of cloud vendors

Clouds	Chameleon	Jetstream	VirtualBox
CPU	Intel Xeon X5550	Dual Intel E-2680v3	Intel Core i5-6200U
RAM	2 GB	2 GB	2 GB
Number of CPU's	1	1	1
CPU Cores	1	1	2
CPU Speed	2.3 GHz	2.3 GHz	2.3 GHz

#### 5. AUTOMATED DEPLOYMENT: ANSIBLE

The Ansible playbooks allow us to install and enable several packages in different VMs simultaneously. This removes the overhead of the logging into individual machine to install different packages and services.

For this project, we used Ansible to automate the deployment of spark and its prerequisites. The Ansible script is written such that we can leverage the cloudmesh client technology to deploy the spark cluster. The steps involved in the script can be seen in Figure 3.



**Fig. 3.** Automated Cloud Deployment using Ansible

We used the below listed Ansible playbooks for our project:

1. *inventory*: This file is used by the playbook to install packages and services on target servers. This Inventory file consists of target servers and these servers can be categorized into groups like webservers, dbbservers etc. Under each group, we can list the server which serves common purpose.
2. *playbook-cloudmesh-first-time-install.yml*: This file was used for deployment of cloudmesh client. It installs all the prerequisite of cloudmesh client first, checks if the ssh keys are already present, and then deploys the cloudmesh client.
3. *cloudmesh-first-time-configure.yml* : It is used to configure the cloudmesh after installation. The main tasks for this playbook include configuring cloud provider name and cloud user name, adding the ssh-key to the cloudmesh database, and upload the ssh key to the cloud.
4. *deployment-playbook.yml*: It is used to deploy the hadoop-spark cluster in chameleon and jetstream clouds. The main tasks include defining a cluster, defining a hadoop-spark stack on the cluster, syncing the clustering with github and deploying the hadoop cluster.
5. *transfer-files-remotely.yml*: It is used to transfer pyspark codes and input files from local machine to report machines. The main tasks include reset of cloudmesh database, upgrade the python-pip, uninstall and install of cloudmesh client.
6. *upgrade-cloudmesh.yml*: It is used only when there is a need to upgrade.

We developed Ansible playbook for installation and configuration of cloudmesh client. We also developed playbook to deploy hadoop/spark cluster on different clouds. After successful deployment of Hadoop-Spark/hadoop cluster we require the python modules that perform data analysis and the data files in spark master node. For this, we developed an Ansible playbook to automate the manual process of uploading the file, authentication and downloading the file. We invoked the Ansible scripts through shell script, running on local Virtual Machines.

## 6. DATA CLEANING AND PRE-PROCESSING

We approached the problem from a pure data perspective to address the challenge of lacking medical domain knowledge. For some basic information, we relied on the dataset description on UCI website [17], ICD-9 [18] and earlier studies [19]. The initial data set is publicly available on the UCI Machine Learning Repository [17]. The initial data set has information extracted from the database satisfying the following criteria [19]:

- Each row corresponds to an inpatient encounter (a hospital admission).
- All of the encounters are "diabetic" encounters, that is, one during which any kind of diabetes was entered to the system as a diagnosis.
- Each encounter also corresponds to a patient stay between 1 and 14 days.
- Laboratory tests were performed during the encounter.
- Medications were administered during the encounter.

101,766 encounters were present in the data set that satisfy the above five inclusion criteria. Each encounter consists of 55 features describing the diabetic encounters, including demographics, diagnoses, diabetic medications, number of visits in the year preceding the encounter, and payer information. We defined the readmission field with 2 values: "YES," for cases where the patient was readmitted within 30 days of discharge and "NO," for both readmission after 30 days scenario and no readmission at all.

Diagnosis 1, 2 and 3 had many categorical values in the form of ICD-9 codes and had missing values. These ICD-9 codes were sorted and grouped into 9 categories, namely Circulatory, Respiratory, Digestive, Diabetes, Injury, Musculoskeletal, Genitourinary, Neoplasms and Other based on the ICD-9 codes [19]. The missing values were assigned the group 'Other'.

This data set had several features with empty fields. So we removed the features missing high percentages of data as they affect our analysis. The removed features were weight, medical specialty and payer code. The race attribute had 2% missing values which were filled by the mode value 'Caucasian'.

Observations only with unique patient ids were considered, excluding those with discharge disposition corresponding to the patient's death.

We filtered our data set according to the above-mentioned constraints and retained 62,937 encounters each corresponding to an unique patient and 55 features describing such encounter. We prepared three data-sets to test the multiple machine learning algorithms (Stochastic Gradient Descent, Gaussian Naïve Bayes, K-means and Decision Tree). Finally we also removed the patient id and encounter id as they were not relevant to learning algorithms.

We used one hot encoding to convert the categorical data features to numerical data. This creates new dummy features to represent the categorical data in numerical format.

The first data set was prepared using one hot encoding on the original data (with 62,937 observations), that resulted in 136 features representing the original 55 features.

For our second data set we implemented feature selection using a Variance Threshold algorithm that removes all low-variance features [20]. We set a variance threshold of '0.8'.

The data set B was formed using this algorithm, which helped extract 26 features.

The original data contains the age attribute grouped in 10-year intervals from 0 to 100 years. For the third data set we grouped the 10 intervals to 3 intervals by combining the age groups younger than 30, 30-60 and older than 60 years. One-hot encoding was then applied to form the third data set. This data set contained 129 features.

## 7. PRELIMINARY DATA ANALYSIS

The unit of our analysis is an encounter; to keep the observations independent, we only analyzed one encounter per patient. We performed early data analysis in python in a local machine. We implemented four classification algorithms using scikit-learn library on each of the 3 data sets created. The data sets were first divided in training and testing set. The training set had about 80% observations (5000 observations approx.) whereas the testing set had the remaining 20% observations (12937 observations).

Each of the algorithms provided by scikit-learn were used following in the manner:

**Table 3.** Results from scikit-learn

Classification Technique	Number of Features	Accuracy (%)
SGDClassifier[21]	136	90.68
	26	86.31
	129	86.96
GaussianNB[22]	136	10.43
	26	88.30
	129	9.96
KMeans[23]	136	55.26
	26	55.24
	129	55.26
DecisionTreeClassifier[24]	136	83.35
	26	82.50
	129	83.28

1. Create and fit a model using the observations and readmission of the training set.
2. Predict labels of the testing set.
3. Calculate the accuracy using the predicted labels and true labels of the testing set. The parameters needed in implementing the above-mentioned algorithms were set so as to be valid to our data, give optimum results and make the results to be reproducible.

KMeans clustering gave us approximately 55% accuracy with all the three data sets. Though it is an unsupervised learning algorithm, we used it to examine if the clustering divided the data into readmission classes, Yes and No, to an acceptable level. We concluded that clustering based on the Euclidean distance may not be the right approach for this classifying this data set. The accuracy percentages obtained for other classification algorithms can be found in the Table 3.

## 8. DATA ANALYSIS ON SPARK CLUSTER

We performed data analysis on Spark cluster using pyspark MLlib on data stored on HDFS.

### 8.1. Start the Spark service

Start the service of spark using the following command:

```
$SPARK_HOME/sbin/start-all.sh
```

Stop the service of spark using the following command:

```
$SPARK_HOME/sbin/stop-all.sh
```

Using the command 'jps' we get a list of the following services:

```
nodemanager
resourcemanager
master
namenode
applicationmaster
```

### 8.2. Data Storage

Uploading input data and code to Driver Node After the Spark setup is ready for the deployment, the data is pushed from the localhost to the remote spark master node. For this we used an Ansible script.

#### 1. Ansible script

- (a) In the host files we set the target master(driver node) IP address as follows:

```
[remotehosts]
129.114.33.106 ansible_ssh_user=cc
```

- (b) Now , add the following entry in the yaml file to transfer the file to destination

```
- hosts: remotehosts
  tasks:
    - name: Transfer file from local to
      satyam-001
      synchronize:
        src: /home/<username>/ansible
        script/ansible-spark/trainindat.csv
        dest: /home/cc/
        mode: push
      delegate_to: 127.0.0.1
```

2. Using Github we uploaded the input data csv file and python execution code to a git repository. We installed git package in the spark driver node. We used 'wget' command with the repository path to download the data set to the virtual machine.

After the data is downloaded to the virtual cloud machine, we uploaded the file to HDFS through the following command.

```
Hdfs dfs -put <source file path> <hdfs-folderpath>
```

This HDFS file serves as an input for our analytics application.

### 8.3. Launching Data Analysis Application

We used python programming language to develop an application that performs predictive analytics tasks. We leveraged pyspark.mllib library for machine learning algorithms.

We launched our application code using the following command

```
$ ./bin/spark-submit --class path.to.your.Class
--master yarn --deploy-mode cluster [options]
<app jar> [app options]
```

There are 4 main steps to each implementation of.

- Input formatting: MLLib classes expect RDD's of Labeled-Points. For this we parsed the data and converted each entry into a LabeledPoint , with label specifying the true output class.
- Next, the processed data frame is divided into train and test datasets.
- Train the model with the algorithm and training data
- After training, We used the model to predict the classes for test data and calculate the accuracy

**Table 4.** Results from Spark MLlib

<i>Classification Technique</i>	<i>Number of Features</i>	<i>Accuracy (%)</i>
Logistic Regression SGD[25]	136	90.88
	26	90.99
	129	90.88
Naive Bayes[26]	136	84.97
	26	85.02
	129	84.987
K-means[27]	136	55
	26	55
	129	55
Decision Tree[28]	136	91.01
	26	90.75
	129	90

**9. RESULTS**

Kmeans did not successfully separate the data class wise as observed in scikit-learn library, as shown in Table 4. We used supervised classification algorithms namely decision tree, logistic stochastic gradient descent and naïve bayes. We obtained good accuracies of 80-90% with classification algorithms.

Similar analysis in a real world scenario can be utilized to predict the readmission likelihood using medical records of diabetes patients. This enables doctors to pay special attention to those patients, identify the causal factors and give preventive care.

**10. BENCHMARKING**

We performed benchmarking to assess the performance with respect to four different aspects. (1) Spark deployment time in multiple clouds with variation in number of virtual machines. (2) Run-time of different algorithms on multiple clouds with variation in number of virtual machines. (3) File transfer time of two files of different size in multiple clouds. (4) Accuracy of multiple algorithms in Spark MLlib and scikit-learn.

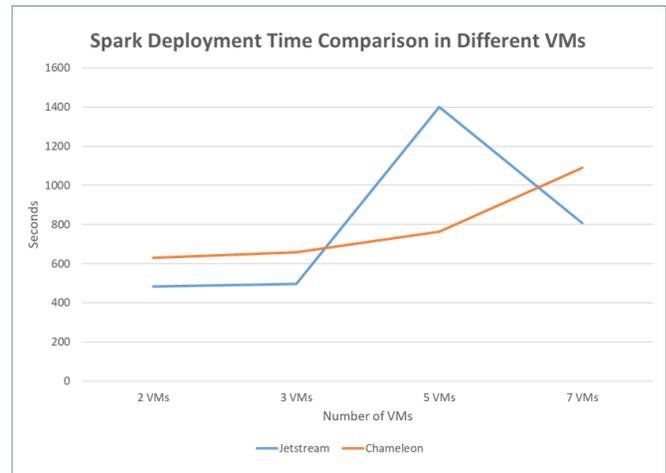
**10.1. Comparison of Spark Deployment Time**

We compared the Hadoop-Spark deployment time with different number of machines on each of the clouds, Jetstream and Chameleon. In Table 5, we can see the Hadoop-Spark deployment times for clusters of different sizes on Chameleon and Jetstream clouds.

The variation of Hadoop-Spark deployment times on Chameleon and Jetstream clouds is shown in Figure 4. We observed that Spark deployment times on Jetstream are lesser than those observed on Chameleon, with the exception of cluster with 5 VMs. This aberration was caused due to a network issue, which was confirmed from the deployment logs. The log files recorded several unsuccessful ping requests to the cluster nodes before successful completion of deployment.

**Table 5.** Hadoop-Spark deployment time

<i>Number of VMs</i>	<i>Chameleon (seconds)</i>	<i>Jetstream (seconds)</i>
2	631.11	484.62
3	657.86	496.15
5	763.14	1399.54
7	1089	806.36



**Fig. 4.** Comparison of Spark deployment results

**10.2. Computation time of algorithms in clouds**

We can see in Table 6 the computation time required for running different Spark MLlib algorithms in multiple VMs in Chameleon and JetStream clouds.

**Table 6.** Computation time of algorithms in clouds in multiple VMs

<i>Algorithms</i>	<i>Number of VMs</i>	<i>Chameleon (seconds)</i>	<i>Jetstream (seconds)</i>
Logistic Regression SGD	1	91.67	115.55
	3	82.57	102.71
	5	31.38	57.23
Naive Bayes	1	66.09	58.48
	3	58.44	45.89
	5	23.2	36.47
Decision Tree	1	72.36	86.69
	3	60.62	71.54
	5	30.25	50.37

Figure 5 shows the performance of multiple machine learning algorithms provided by Spark MLlib on clusters in Chameleon, Jetstream and Virtual Box.

Figures 6 and 7 shows the run-time comparison for machine learning algorithms using Spark MLlib in Jetstream and Chameleon, for predicting readmission likelihood, for 3 and 5

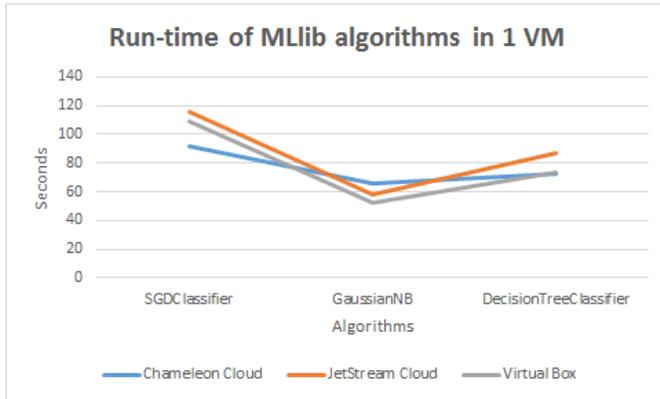


Fig. 5. Run-time in different clouds.

VMs. We can see that the run-time decreased with increase in the number of cluster nodes for all algorithms.

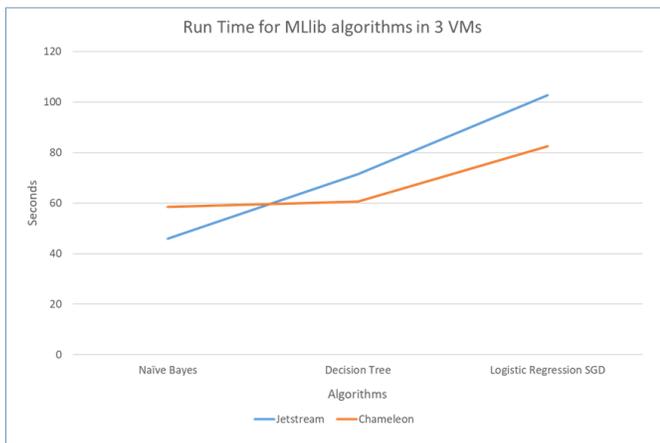


Fig. 6. Run-time in different clouds for 3 VMs

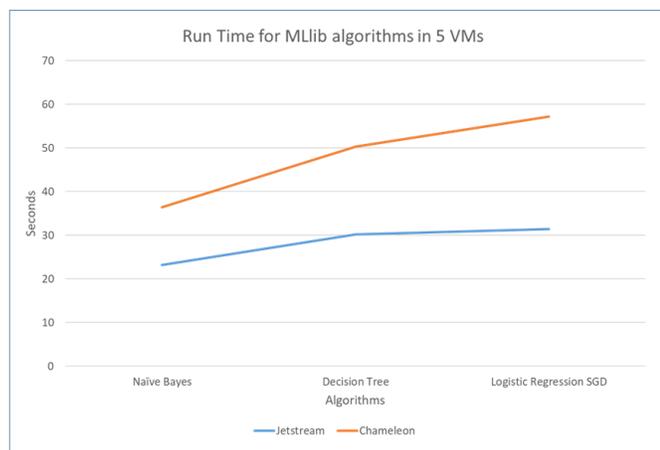


Fig. 7. Run-time in different clouds for 5 VMs

### 10.3. Accuracy comparison of multiple algorithms in Spark MLLib vs scikit-learn

We have recorded several metrics while running each of the four algorithms in different clouds. The four algorithms are SGD

Classifier, Gaussian Naïve Bayes, kmeans and Decision Tree Classifier. The variations in run-time and deployment time are caused due to factors like:

1. *The complexity of the algorithm:* For example, kmeans clustering has  $O(n \log n)$  time complexity which is worse than Gaussian Naïve Bayes and hence takes more time.
2. *The network latency between the hosts:* The VMs which are provisioned on clouds can be on different hosts spread across different racks of datacenters and even datacenters located in different geographies. This may result in network latency and affect the run-time of a program running in a distributed environment.

We compared the accuracies for different MLLib algorithms using pyspark.mllib package. We can see from Figure 8 the accuracies achieved for multiple algorithms in MLLib. While kmeans gave the lowest accuracy, rest of the algorithms gave similar higher accuracies.

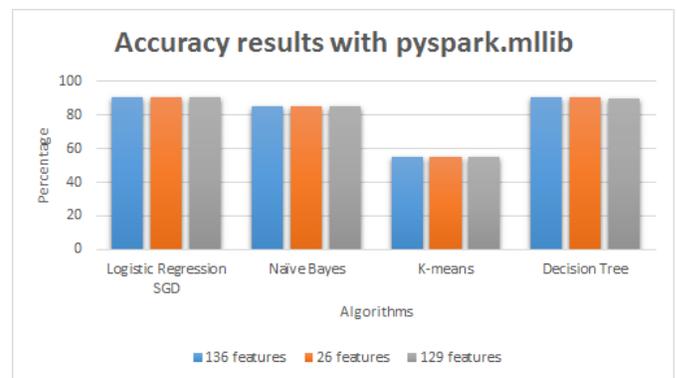


Fig. 8. Accuracy Results with pyspark.mllib

We compared the accuracies achieved from Spark MLLib and scikit-learn algorithms. Figure 9 shows accuracy results of multiple machine learning algorithms in scikit-learn vs MLLib.

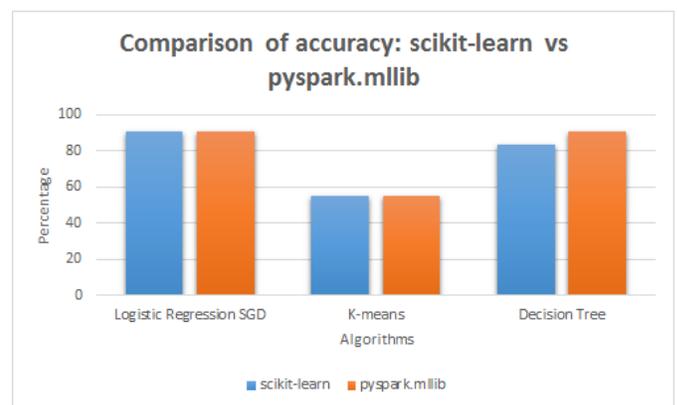


Fig. 9. Accuracy Results: scikit-learn vs pyspark.mllib

## 11. CONCLUSION

We demonstrated the implementation of a big data based predictive analytics solution using Hadoop, Spark and Spark's MLLib machine learning algorithms. We predicted the readmission

likelihood using MLlib with an accuracy of 90% by analyzing the medical data stored on HDFS. We also compared the results of Spark's MLlib [2] algorithms against scikit-learn's algorithms and found that both yielded similar results.

While Hadoop provided us a distributed file system for storing large amounts of data, Spark provided us big data processing capabilities and several libraries to accomplish several common processing and analytics tasks. We were successfully able to deploy the Spark-Hadoop cluster infrastructure on Chameleon, Jetstream and on-premise virtual box clouds. We developed several shell scripts and Ansible playbooks to automate the deployment. These technologies can be used to build similar solutions for real world scenarios requiring processing and analytics of big data. Our solution can also be extended to build analytics applications that process streams of data in real-time using Spark Streaming [29] and MLlib.

## 12. ACKNOWLEDGMENTS

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## A. APPENDIX: WORK DISTRIBUTION

- Kumar Satyam [S17-IR-2031]
  - Developed Ansible playbook for installation of cloudmesh client.
  - Developed Ansible playbook for automated deployment of Spark on different clouds.
  - Deployed the initial test of Spark cluster on 1 virtual machine of Jetstream cloud.
  - Deployed a Spark cluster on 5 and 7 virtual machines of Chameleon cloud.
  - Developed Ansible script for file transfer from local VM to Spark master node on different clouds.
  - Executed K-means python script for predicting readmission and recorded the runtime on Spark cluster on 1 VM on Chameleon cloud.
  - Developed python code for predicting readmission using Spark MLlib algorithm Decision Tree.
  - Developed python code for predicting readmission using Spark MLlib algorithm K-means.
  - Tested python code of predicting readmission using Spark MLlib algorithms on a single VM spark cluster deployed on Virtual Box.

- Executed Naive Bayes python script for predicting readmission and recorded the runtime on Spark cluster of 1, 3 and 5 VMs on chameleon cloud.
  - Executed K-means python script for predicting readmission and recorded the runtime on Spark cluster on 1 VM on Jetstream cloud.
  - Executed Decision Tree classifier python script for predicting readmission and recorded the runtime on Spark cluster on 1, 3 and 5 VMs on Jetstream cloud.
  - Benchmarked the algorithm runtimes of chameleon and Jetstream clouds.
  - Documented the sections: benchmarking, conclusion and references.
- Piyush Shinde [S17-IR-2035]
    - Performed preliminary data analysis.
    - Developed python code for preliminary analysis using sci-kit machine learning algorithm Gaussian Naive Bayes.
    - Developed python code for preliminary analysis using sci-kit machine learning algorithm SGD classifier.
    - Developed python code for preliminary analysis using sci-kit machine learning algorithm Decision Tree.
    - Developed python code for preliminary analysis using sci-kit machine learning algorithm K-means.
    - Developed Ansible playbook for configuration of cloudmesh client.
    - Performed initial test deployment of Spark cluster on 1 virtual machine of Chameleon cloud.
    - Deployed a Spark cluster on 2 and 3 virtual machines of Chameleon cloud.
    - Executed Naive Bayes python script for predicting readmission and recorded the run-time on Spark cluster of 1, 3 and 5 VMs on Jetstream cloud.
    - Documented the sections: introduction, technologies, architecture and preliminary data analysis.
    - Executed SGD classifier python script for predicting readmission and recorded the runtime on Spark cluster of 1, 3 and 5 VMs on Jetstream cloud.
- Srikant Ramanam [S17-IR-2028]
    - Performed data cleaning.
    - Installed cloudmesh client using developed Ansible playbook.
    - Configured cloudmesh client using developed Ansible playbook.
    - Performed initial test deployment of Spark cluster on 1 virtual machine of Virtual box.
    - Deployed a Spark cluster on 2 and 3 virtual machines of Jetstream cloud.
    - Deployed a Spark cluster on 5 and 7 virtual machines of Jetstream cloud.
    - Developed shell script for triggering spark deployment Ansible playbook.
- Benchmarked spark deployment on chameleon and Jetstream clouds using shell script.
  - Developed python code for predicting readmission using Spark MLlib's algorithm SGD classifier.
  - Executed Decision Tree classifier python script for predicting readmission and recorded the runtime on Spark cluster on 1, 3 and 5 VMs on chameleon cloud.
  - Developed python code for predicting readmission using Spark MLlib's algorithm Naive Bayes.
  - Executed SGD classifier python script for predicting readmission and recorded the runtime on Spark cluster of 1, 3 and 5 VMs on chameleon cloud.
  - Documented the sections: automated deployment using Ansible, Data cleaning and Pre-processing.

# Analysis Of People Relationship Using Word2Vec on Wiki Data

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project-1: Data mining for a wiki url , September 21, 2017

Wikipedia pages of famous personalities contain details like school, spouse, coaches, languages, alma-mater etc. This information is in free form text. In this project, we extract the people information from the Wikipedia page and to establish relationships between them. Specifically, we use the data of known relationships to derive the newer relationships. © 2017 <https://creativecommons.org/licenses/>. The authors verify that the text is not plagiarized.

**Keywords:** Cloud, I524, Chameleon, Word2Vec, Jetstream, Cloudmesh, RAM

Report: <https://github.com/cloudmesh/sp17-i524/blob/master/project/S17-IR-P005/report/report.pdf>

Code: <https://github.com/cloudmesh/cloudmesh.word2vec>

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## 1. INTRODUCTION

Word2Vec [1] is a group of related models that are used to produce word embedding. Word2Vec is used to analyze the linguistic context of the words. In this project, we created Word2vec model using Wikipedia data and news articles. Our focus is people names occurring in the Wikipedia data and to see if Word2vec can be used to understand relationship between people. Typically Wikipedia page for people and celebrities contain the entire family and friends, colleagues information. Our idea is to use Word2vec to see if using a smaller training set of known relationships whether we can derive similar relationship for anyone who has presence on Wikipedia. This mechanism can be then used to convert the data hidden in textual format to more structured data.

We used spark [2] to load the wiki data and create word vectors. We then used vector manipulations to derive the relationships.

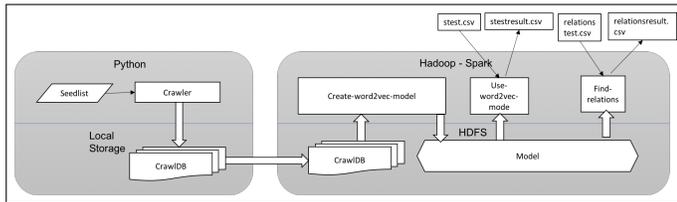
## 2. DESIGN

Figure 1 shows the overall data pipeline for the project. The data pipeline has three important stages:

- **Wiki crawler:** Wiki crawler runs in batch mode on a standalone machine. It can download wikipedia data as explained in section 2.1. Crawler creates CrawlDB which is a collection of text files. This crawler can be replaced or

Name	Purpose
spark [2]	data analysis
sparkML [3]	machine learning
python [2]	development
ansible [4]	automated deployment

**Table 1.** Technology Name and Purpose



**Fig. 1.** Data Pipeline.

augmented with any web-crawler which can download or create the text files.

- News crawler: News crawler is responsible for downloading the news articles.
- CreateWord2VecModel: This component is responsible for creating the Word2Vec model for the text files in the CrawlDB. This model runs on spark and stores the model on HDFS. Section 2.3 describes this component in detail.
- UseWord2VecModel and FindRelations: These two components use the pre-created Word2Vec model to find synonym of a word or find the relationships. Section 2.4 describes these components in detail.

**2.1. Wiki crawler**

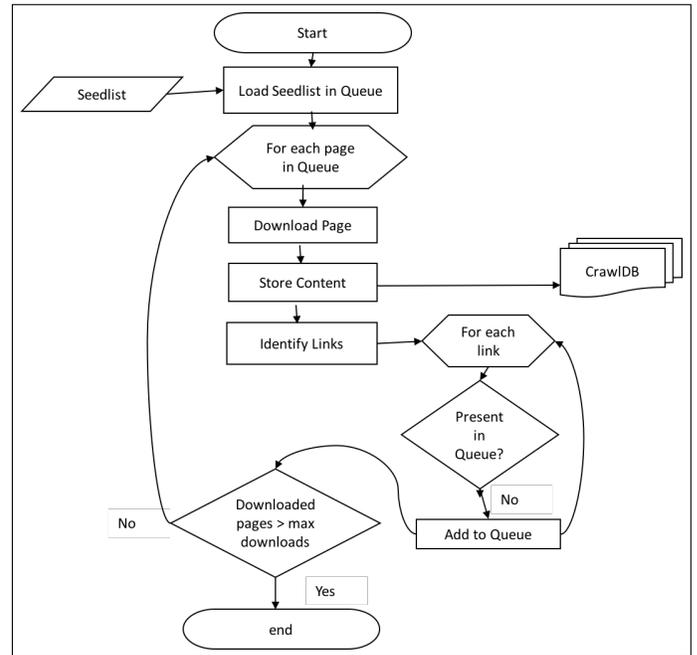
The Wiki Crawler component is useful to download the data from web. We implemented a simple crawler using Python which can deep traverse the wikipedia pages and download the text from it. In our crawler implementation, a user can specify the seed pages from wikipedia. User can also specify the maximum number of pages that are required to be downloaded. The crawler first downloads all the pages specified in the seedlist. It then extract the links from each wikipedia page and puts it in a queue which is internally maintained by the crawler. The crawler then downloads the the linked pages. Since this logic is implemented in recursive manner, the crawler can potentially download all the wikipedia pages which can be reached from the pages in the seedlist.

We followed the seedlist based crawler approach so that we can retrieve domain specific web pages. A well chosen seedlist can fetch large number of relevant web pages.

Figure 2 is the flowchart of the crawler implementation.

**2.2. News crawler**

News crawler is crawler implemented in Python. It executes in batch mode and download latest news article related to the topics configured in its seedlist. The news crawler uses Google APIs [5] to search the topics configured in the seedlist. Then it iterates over the result of each search, and downloads the



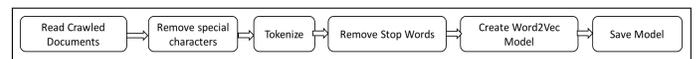
**Fig. 2.** Flowchart of crawler.

original HTML page contents. The textual portion of the HTML is extracted using goose python library [6]

**2.3. Word2Vec model creation**

CreateWord2VecModel is Spark application implemented in Python. This application is responsible for creating the Word2Vec model and storing it for later use. Figure 3 explains the steps involved in the Word2Vec model creation. We used Spark Feature Extraction [7] for implementing the steps involved in the Word2Vec model creation. These steps are explained below:

- Read crawled documents from HDFS
- For each crawled document, remove special characters from the text
- Tokenize text to create list of words
- Remove the stop words
- Create Word2Vec model
- Store the model on HDFS



**Fig. 3.** Steps involved in Word2Vec model creation.

**2.4. Using the Word2Vec model to find synonyms and relations**

The pre-created Word2Vec model can be queried to find the synonyms or relations between the words. In the context of Word2Vec, synonym of the word is the word that co-occur in similar context [8]. The *UseWord2VecModel* finds the synonyms

for the words provided in the *stest.csv* file. The results are stored in *sresults.csv* file.

The Word2Vec model is also used to find the relationships. [9] explains how the vector operations can be performed on word vectors to derive relationships. The *FindRelations* spark application performs the vector operations to find relationships. The *relationtest.csv* is input to the *FindRelations* application. The *relationtest.csv* has 3 words in each row. The application predicts the fourth word which has same relation to the third word as the second word related to first word. In the example below

*Sachin,Anjali,Sourav*

If *Anjali* is spouse of *Sachin*, then *FindRelations* application is expected to predict the first name of the person who is spouse of *Sourav*. The result of *FindRelations* is saved in *relationsresult.csv*.

### 3. DEPLOYMENT

The deployment on the cluster can be accomplished using 2 steps, assuming the cluster is up and running

- Step1: update hosts file *ansible-word2vec/hosts* with the IP of the master. The first node on the cluster becomes the master node.
- Step2: run the script *ansible-word2vec/run.sh*. This script will run the ansible playbooks to accomplish stage1 through stage4 of the deployment process.

Figure 4 shows the deployment stages. The two steps accomplish deployment in multiple stages as discussed in the sections below.

#### 3.1. Stage1

As pre-requisite, we need to create a cluster with 1 or more nodes. We created a 3 node cluster using Cloudmesh [10] command line interface(CLI). Cloudmesh[10] CLI allows you to orchestrate virtual machines(VM) in a cloud environment. For this project, we have used Chameleon and Jetstream cloud providers to orchestrate the VMs using cloudmesh[10] CLI. We can orchestrate a 3 node cluster using following CLI:

```
cm reset
pip uninstall cloudmesh_client
pip install -U cloudmesh_client
cm key add --ssh
cm refresh on
cm cluster define --count 3 \
--image CC-Ubuntu14.04 --flavor m1.medium
cm hadoop define spark pig
cm hadoop sync
cm hadoop deploy
cm cluster cross_ssh
```

We are using Ubuntu14.04 image with m1.medium which comes with 2 CPU, 4GB memory. Also, the nodes created are having hadoop and spark add-ons. We can test the deployment by checking hdfs and spark-submit CLI work fine.

```
ssh cc@<cluster-ip>
sudo su - hadoop
hdfs
spark-submit
```

At this stage our cluster is ready for further deployments.

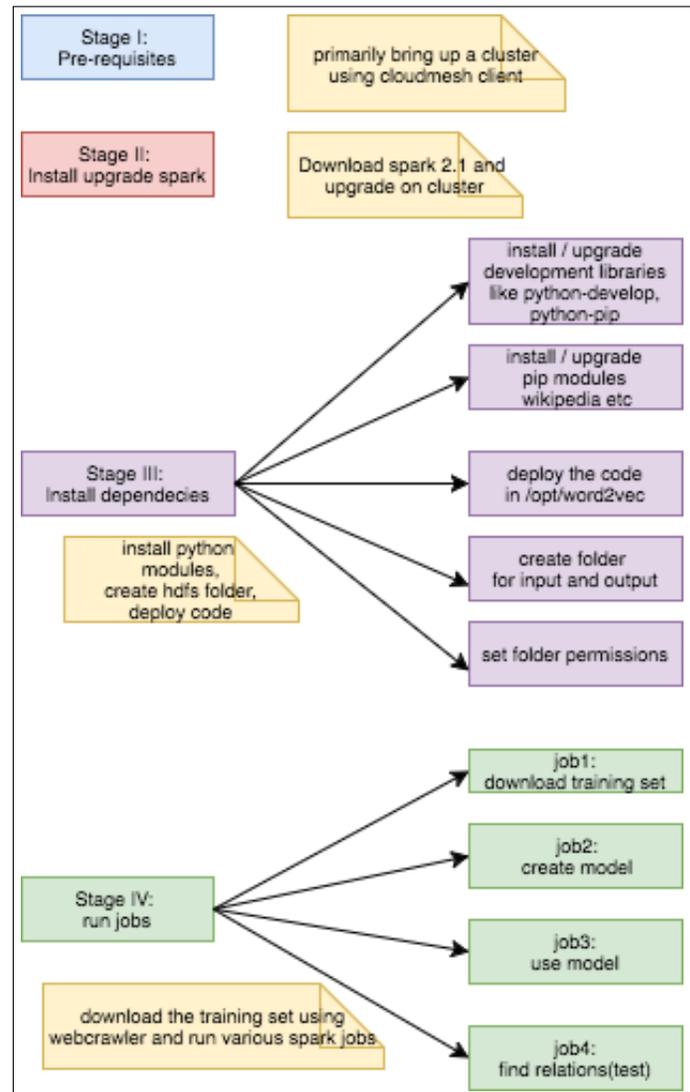


Fig. 4. Deployment stages.

### 3.2. Stage2

By default, cloudmesh installs spark 1.6 but our word2vec solution requires spark 2.1. We need to upgrade spark on the cluster. In order to do so we can run `install_upgrade_spark.yaml` ansible[4] playbook. This will download and unpack spark2.1 tar ball and further update the softlink to point to spark 2.1 folder.

### 3.3. Stage3

In this step, we upgrade the development libraries for python, and pip, install python modules like wikipedia, request etc, download the code from git repo and install it in `/opt/word2vec` folder, set the folder permissions for the `/opt/word2vec` folder so that it can be executed by hadoop user. These steps can be achieved using `word2vec_setup.yaml` playbook. After completing this stage, we are ready for running our word2vec solution on the cluster.

### 3.4. Stage4

This stage primarily deals with submitting the jobs for various purpose. Before we submit the jobs, we need to make sure input folder are created on hdfs. First, we run the crawler to download the training set and upload the data on hdfs. Further we run various jobs to created model and find relations. Along with these jobs we also run some monitoring jobs. The monitoring job queries spark metrics using

```
http://${spark_master}:4040
```

Stage4 steps can be accomplished using `word2vec_execute.yaml` playbook.

At the end of stage4 we also fetch the execution results from the cluster along with the metrics of execution times at various stages. The output files are fetched into `/tmp/word2vec_results`

```
ls -lt /tmp/word2vec_results
jobs.csv
executors.csv
app.csv
stest.csv
relationstest.csv
stestresult.csv
relationsresult.csv
```

Files `jobs.csv`, `executors.csv`, and `app.csv` collect the execution time for various jobs. File `relationsresult.csv` file collects the results for sample relations corresponding to `relationstest.csv`. Similarly `stestresult.csv` collects the results corresponding to `stest.csv`.

### 3.5. Execution

#### 3.5.1. Cleanup

We can execute the run from local system using `run.sh` located inside `ansible-word2vec`. Run script executes all stages sequentially on the remote system. To rerun word2vec, run the cleanup playbook `word2vec_cleanup.yaml` located inside `ansible-word2vec`. Cleanup remove the spark 2.1 binary and the soft link, remove `/opt/word2vec` folder as well as any temporary files created during setup step.

#### 3.5.2. Page size

The crawler downloads pages from wikipedia based on the config page count. To modify the page count, we can edit `ansible-word2vec/setupvariables.yml` and set the `max_pages` to desired page size. The crawler downloads individual pages and then combines the pages into a single file before submitting the spark jobs.

#### 3.5.3. Test Results

Test results are downloaded to local machine in `/tmp/word2vec_results` folder. Ansible execution log is saved in `/tmp/word2vec-logfile.txt`. The log gets appended each time you execute the run script.

#### 3.5.4. Troubleshooting

1. If the installation `run.sh` script fails in middle due to some reason, execute the cleanup script before re-triggering run script again. The run script may fail due to variety of reasons like failed to ssh, hadoop not available etc
2. If the run script fails due to spark memory errors, you can modify the spark memory setting in `code/config.properties` push the code to a git feature branch for example `spark_test`. Modify `word2vec_setup.yaml` git section `version=master` to point to `spark_test` branch and execute the run script.
3. If hadoop goes into safe mode, goto the cluster namenode and execute the following

```
/opt/hadoop$ bin/hadoop dfsadmin -safemode leave
```

This will remove the cluster from safe mode.

## 4. BENCHMARKING

We used datasets of 2 different sizes to perform the benchmarking of the application. Table 2 shows the details of the two datasets. The CreateWord2VecModel spark application is most complex and time consuming application. We used this application for the benchmarking. We deployed the application on Chameleon cloud and Jetstream cloud. Table 3 shows the details for the cluster configurations on Chameleon and Jetstream clouds.

**Table 2. Dataset Used for Performance Measurement**

Parameter	Dataset1	Dataset2
Size of crawldb	1.4MB	7.4MB
Count of files in crawldb	100	500
Source	Wikipedia	Wikipedia

**Table 3. Dataset Used for Performance Measurement**

Parameter	Chameleon Cluster	Jetstream Cluster
Cluster name	cluster-005	cluster-010
Nodes	2	2
OS	Ubuntu 14.04	Ubuntu 14.04
Flavor	m1.medium	m1.medium
Secgroup	default	default
Assign floating IP	True	True
Cloud	chameleon	ijetstream

Figure 5 shows the total time taken by CreateWord2Vec application for Dataset1 and Dataset2 on the Chameleon and Jetstream cloud environments.

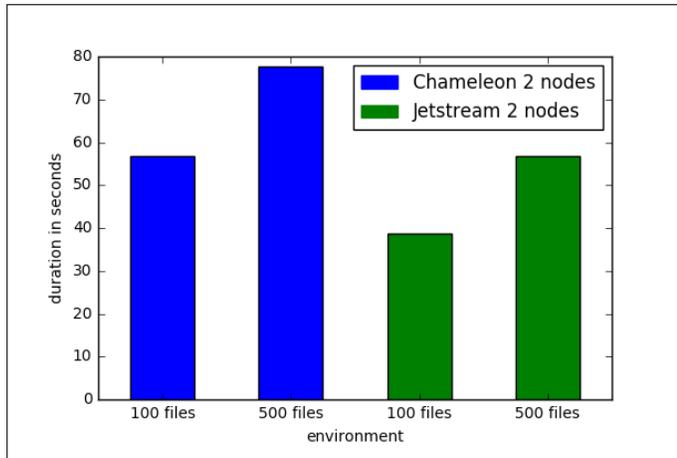


Fig. 5. Time taken by CreateWord2Vec

#### 4.1. Working with large dataset

There are several configuration parameters added in the application to fine tune the behavior of the spark applications. When working with larger datasets, the spark applications can go out of memory. Following parameters can be configured in the *ansible-word2vec/setupvariables.yml* to handle such situation.

```
spark_executor_memory = <memory given to executor>
spark_driver_memory = <memory given to driver>
max_result_size = <maximum result size>
```

Table 4 show cluster configuration of Chameleon cloud used for 1k files dataset

Table 4. Cluster configuration used for performance measurement

Parameter	Chameleon Cluster
Cluster name	cluster-006
Nodes	4
OS	Ubuntu 14.04
Flavor	m1.medium
Secgroup	default
Assign floating IP	True
Cloud	chameleon

We tried running out solution on a 4 node cluster as described in Table 4 with 1000 files on the crawlDB and the create model script failed with out of memory exceptions.

```
["OpenJDK 64-Bit Server VM warning:
INFO: os::commit_memory(0x00007ff67449f000, 12288, 0)
failed; error='Cannot allocate memory' (errno=12)",
"OpenJDK 64-Bit Server
VM warning: INFO:
os::commit_memory(0x00007ff6746a1000, 12288, 0)
failed; error='Cannot allocate memory' (errno=12)",
"#",
"# There is insufficient memory for the Java
Runtime Environment to continue.",
```

```
"# Native memory allocation (malloc) failed to allocate
12288 bytes for committing reserved memory.",
"# An error report file with more information is saved as:",
"# /home/hadoop/hs_err_pid25854.log"], "warnings": []]
```

We need to tune spark memory parameters here, since the words in model become too high and we need as much memory(RAM) to execute the solution or else it goes out of memory(OOM). For example for `min_word_count = 5`, the number of words in the model were 20839 and executor\_memory of 4GB was enough. But for `min_word_count` of 3 which resulted in 30194 words in model, we have to give 6GB RAM. After making these changes to spark executor and driver memory we were able to run the solution successfully with 1000 files.

Figure 6 shows the total time taken by CreateWord2Vec application varying min word count on the Chameleon cloud with 4 nodes

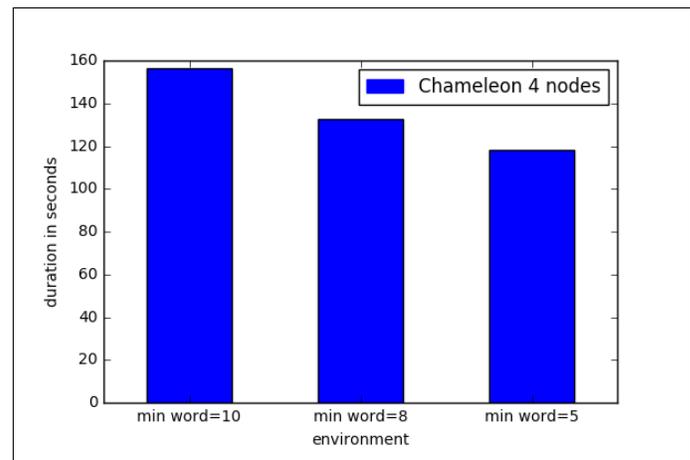


Fig. 6. Time taken on 4 node Chameleon cloud

## 5. DISCUSSION

The analysis of the results provided interesting insights. Section 5.1 provides key insights on our experiments with Word2Vec on Wikipedia data. Section 5.2 provide key insights on our experience of deployment and execution of Word2Vec application on Chameleon and Jetstream cloud.

### 5.1. Word2Vec app - key insights

We trained the Word2Vec model with the wikipedia data of Indian Cricket team members. We used *List of India ODI cricketers* as seedlist and downloaded 500 pages from Wikipedia. With this dataset, we observed that the *synonym* or correlated words were pretty accurate. Some interesting examples and its explanation:

```
sachin -> tendulkar
world -> cup
```

Sachin Tendulkar [11] is famous Indian cricket player. Naturally, the words *sachin* and *tendulkar* are highly correlated. The Word2Vec model was able to find this correlation.

Cricket World Cup [12] is one of the most viewed sporting event and considered as the flagship event of the international cricket. Hence the words *world* and *cup* are highly correlated in the context of cricket. The Word2Vec model was able to find this correlation.

However, when we tried to find the people relationships using the wikipedia dataset, we could not get good accuracy.

For example, *Anjali Tendulkar* is wife of *Sachin Tendulkar* while *Dona Ganguly* is wife of *Sourav Ganguly* who is another famous Indian Cricket player [13]. When we provided the test record of *sachin,anjali,sourav* we did not get good results.

After observing the wikipedia data, we concluded that there is lot of literature in wikipedia about the cricketers. However, there were very few mentions of their family members, coaches, schools etc. Due to this, we were not getting good results on the people relationships.

To augment the Wikipedia data, we decided to crawl news data which provide large amount of articles containing people and their relationships. We implemented the news crawler as explained in the section 2.2. After downloading about 200 news articles of 20 cricketers, our relationships discovery improved a lot. Some interesting examples are given below: *sachin,anjali,sourav,dona*

*sachin,anjali,dhoni,sakshi*  
*sachin,cricket,amitabh,hero*

In first two examples, the Word2Vec model was able to identify the people-people relationships, while in third example, the Word2Vec model was able to identify the people-profession relationships.

## 5.2. Deployment of Word2Vec app on Chameleon and Jetstream cloud - key insights

Both Chameleon and Jetstream run on openstack and work seamlessly using cloudmesh and ansible. There is a difference in the flavor for Chameleon and Jetstream, where m1.medium on Chameleon is different than m1.medium on Jetstream.

## 6. CONCLUSION

Using this project we conclude that we can use Word2Vec model on Wikipedia and news data to find the relationships between the people.

We further conclude that Word2Vec based analytics can be performed on public cloud systems like Chameleon cloud and Jetstream cloud. Our deployment automation, which is implemented using Cloudmesh and Ansible technology demonstrates the power of these technologies to achieve one touch deployment and execution of applications across multiple clouds.

## 7. ACKNOWLEDGEMENT

We acknowledge our professor Gregor von Laszewski and all associate instructors for helping us and guiding us throughout this project.

## 8. APPENDICES

Appendix A: Work Distribution The co-authors of this report worked together on the design of the technical solutions, implementation, testing and documentation. Below given is the work distribution

- Avadhoot Agasti
  - Implementation of wiki crawler and news crawler in Python.
  - Implementation of CreateWord2VecModel in Spark.
  - Implementation of UseWord2VecModel and FindRelations in Spark.

- Implementation of Python script MonitorSparkApp.
- Analyzing the Word2Vec model results.
- Testing of end to end flow on Chameleon cloud.
- Performance testing and bug fixing in the spark application.
- Writing related sections in this report.

- Abhishek Gupta

- Implementation of Ansible scripts for deployment of Spark 2.1 which is required for the spark application.
- Implementation of Ansible scripts for deployment.
- Implementing the changes in the spark applications to get it working on HDFS.
- Setting up and testing the end to end flow on Chameleon cloud.
- Setting up and testing the end to end flow on Jetstream cloud.
- Testing the crawler and Word2Vec applications for semantic correctness.
- Gathering the performance statistics for comparison.
- Writing related sections in this report.

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# Amazon Web Services Cloudmesh Extension

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Cloudmesh client provides an easy abstraction to gain access to hybrid clouds from the commandline. In contrast to other systems it provides a mechanism of adding plugins to the command. The command can not only be used as a commandline tool, but as a shell. Due to the swift developments in the area of cyber infrastructure such a convenient plugin allows us to integrate easily new services easily. This work uses our next generation cloudmesh shell and demonstrates the ease of integrating Amazon Web Services services into it. Hence Cloudmesh client can via other plugins achieve interoperability for virtual machine management by providing plugins for OpenStack, Azure, Comet Cloud Services and other frameworks including containers. Here we focus on extensions to bring its capability to work with Amazon EC2 services. As our integration demonstrates how to leverage libcloud as a backend, more than 30 other providers could easily be targeted.

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**Keywords:** Cloud, I524

Report: <https://github.com/cloudmesh/sp17-i524/blob/master/project/S17-IR-P006/report/report.pdf>

Code: <https://github.com/cloudmesh/cloudmesh.aws>

## 1. INTRODUCTION

Amazon provides a web service in a cloud (AWS) to deploy virtual machines (VM) with numerous operating systems environment available in different flavors. The images are called Amazon Machine Image (AMI) and are available as pre-configured for different applications. One can also create his own custom environment [1].

The Amazon EC2 drivers provides numerous functionalities to authenticate into the AWS, list available configurations and create and boot VMs. Many interfaces exist providing access to many different frameworks and platforms. Being able to utilize access through Web services allows developers to integrate AWS into their service offerings. Within Indiana University we have provided for the last seven years cloud services based on a variety of cloud services. While observing the evolution and practical use of these services it has become clear that in order to switch easily from one cloud to another we need a uniform interfaces that provides the most elementary service offerings of managing virtual machines. Our design offers the ability to switch easily between different cloud providers. Figure 1 demonstrates this convenient feature. Here we define in our cloudmesh client a cloud and set it to AWS, we then start a vm, we can do the same for OpenStack as demonstrated. Important to note is that all details of name assignment, flavor and image management, are abstracted out, but can be controlled and are provided as part of an easy to manage configuration framework.

This has advantages for university settings as we can distribute such configurations for particular classes and customize the use for many hundreds of non cloud experts. In fact using our abstractions allows non cloud experts easily to use clouds.

```
set default cloud=aws
vm boot
set default cloud=openstack
vm boot
```

**Fig. 1.** cms aws image refresh

## 2. GETTING STARTED

One needs to create an aws account first to be able to access its cloud. The instructions for it are available at [2]. A pair of access key and secret keys are required to be generated to authenticate into the cloud [3]. These keys are required to be kept confidential. They are to be specified in a yaml configuration file. Default vm image and flavor can also be specified in the configuration file. Following are some of the configuration entries:

```
cloudmesh:
clouds:
aws:
credentials:
EC2_ACCESS_KEY: 'ACCESS KEY'
```

```
EC2_SECRET_KEY: 'SECRET KEY'
```

```
.
```

```
default:
image: 'IMAGE ID'
size: 'SIZE ID'
location: 'LOCATION'
```

The user need to ensure that the combination of image, size and location is valid and that it's account has the required privileges for it. The instructions for installation of AWS client can be found at [4]. Once, the client has been installed and configurations settings enabled, the mongodb and the rest services to access the database can be started by following command from the root directory of the code:

```
make rest
```

The above services will be required by AWS client to store cloud related information locally. The user can now execute the client commands e.g.:

```
cms aws flavor refresh
```

This will fetch the list of image sizes available on Amazon EC2 cloud.

### 3. CLOUDMESH DESIGN

The cloudmesh client toolkit [5] is a lightweight client interface of accessing heterogeneous clouds, clusters, and workstations right from the users computer. The user can manage her own set of resources she would like to utilize. Thus the user has the freedom to customize the integration of a variety of cyber infrastructure resources into Cloudmesh. Cloudmesh client includes an API, a command-line client, and a command-line shell. It strives to abstract backends to databases that are used to manage the workflow utilizing different infrastructures and services. As explained earlier, switching to activate virtual machines from OpenStack clouds to Amazon is as simple as specifying the name of the cloud. Moreover, cloudmesh client can be installed on Linux, MacOSX, and in future Windows.

#### 3.1. General Requirements and Goals

Cloudmesh has from its inception followed the following general design goals and requirements.

**Technology agnostic.** An important aspect of cloudmesh is to offer access to useful services APIs and interfaces in a technology agnostic fashion. Thus it should be possible for example to switch easily between different IaaS providers. CM has excellently protected us during the changes of the OpenStack interfaces and libraries from the very first version of OpenStack and other IaaS frameworks [6].

**Easy to use.** Cloudmesh simplifies access of complex workflow to integrate with IaaS and deploy on them new platforms and software stacks. This advanced feature is not only to be performed by expert IT personal or programmers, but in fact by data scientists which we found in practice have less experience in such areas. As we deal often with many compute nodes it is often insufficient to just provide a graphical user interface or portal, but we need to provide APIs, REST interfaces and especially command-line and shell access in an easy comprehensible fashion.

**Expandable.** While working over the last years in the area it is obvious that the technology is rapidly evolving and new features need to be integrated, Thus it is important that cloudmesh is easy to expand and new features can be added while leveraging a core set of functionality and services.

**Documented.** It is important that we provide from the start documentation to existing and new features and make it easy for the developers to contribute documented add ons, but also allow users to have access to documentation including examples. This will include easy to follow documented installation and configuration steps to guarantee successful deployment and use

**Repeatable and automated deployment.** When we install software stacks an a variety of platforms it is expected that that can easily be replicated and repeated automatically.

**Portable.** It is important to provide services in cross platforms compatible fashion. It ensures working, executable software deployment on multiple platforms. This includes not only the installation of the software, but the integration of external services and tools such as DevvOps or workflow frameworks that could support the general mission of a data scientist.

**Abstractions.** To address some of the design issues our requirements implicitly asks for the existence of a number of abstractions and interfaces that can be used to enable portable and crossplatform services and tools.

#### 3.2. Architecture Requirements and Goals

In addition to the general requirements we set some specific architectural requirements and goals that have been growing from previous versions of cloudmesh and our earlier work in this area.

**Client based.** Cloudmesh client as the name indicates is a client based toolkit that is installed and run on the users computers. An add on component to use the client within a portal is available. Thus we distinguish the client that contains most of the functionality and the portal that can access the functionality through a locally maintain Web portal. Important to note is that the user manages its own credentials and thus security and credential management is done directly on the users machine instead through a hosted Web portal. This increases the security as access to any credential is managed by the user and is not part of a credential management system.

**REST.** Although Cloudmesh provides a client interface, it will provide a REST interface to many of its services in order to support service based deployments. The basic APIs developed for the client can easily be reused to implement such interfaces.<sup>1</sup>

**Layered Architecture.** Cloudmesh client has a layered architecture that allows easy development of new features. This also allows contribution by the community while developing integrated and smaller sub components. Figure ?? depicts the various layers. A resource abstraction layer allows the integration of a multitude of resources spanning

<sup>1</sup>we have demonstrated that cloudmesh APIs can be used to implement REST interfaces in a variety of frameworkks such as Flask, Django, and Cherypy

HPC, Containers, and Cloud resources. (At this time we focus on OpenStack and Slurm resources. We are working on reintegrating resources such as Azure, AWS, Maui, Moab, and others which we previously supported, as well as new resources such as docker).

**Management Framework.** Cloudmesh client contains a management framework, and its components are depicted in Figure B. cloudmesh allows easy management of virtual machines, containers, and the data associated with them. We are currently developing a choreography framework that leverages Ansible, chef, and heat. All of the functionality is easily usable through a comand-shell that also can be used from the command-line, and a Python API. IN future we will be providing a REST API.

**Database Agnostic.** Cloudmesh contains some state about the resource and environment that a user may want to use. The information is managed in an database abstraction that would allow storing the data in a variety of databases such as SQL and MongoDB. At this time we have chosen SQLite to be the default database as it does not require any additional setup and is universally available on all operating systems without change.

**Command-shell and Command-line.** Cloudmesh contains a comand-shell allowing scripts to be developed and run. However we designed the comand-shell in such a way that each command can also be called from the command-line. Through the cloudmesh state machine the state between comand-shell, command-client, and the portal is shared.

**Cloudmesh Client Portal.** Previously, we distributed cloudmesh with client, server, and a portal components in one package. This however turned out to be to complex to be installed for some of our less technically skilled user community. Thus we split up the install into two independent packages. The cloudmesh client and the cloudmesh portal. The portal provides some elementary features to manage virtual machines and HPC jobs. At this time the portal is considered to be alpha technology. Just as the client the portal is to be run on the local user machine in oredr to allow increased security by managing the credentials locally rather than on a server.

**Cloudmesh Two Factor Authentication.** We have an exploratory project in place that looks at the use of Yubikeys for cloudmesh, client and cloudmesh portal.

**Cloudmesh Comet.** We are actively developing the client interface for SDSC’s comet supercomputer allowing bare metal provisioning. The interface reuses cloudmesh components and technologies while interfacing with the comet cloud REST interface. The goal here is to manage virtual clusters.

3.3. Architecture

4. IMPLEMENTATION CONSIDERATIONS

The AWS client is based on cloudmesh.cmd5 [7] and cloudmesh.common [8]. It uses mongodb in the back-end to store the cloud information such as list of available images or instances running on the cloud. Requests library [9] is used to connect to the back-end through rest services. The rest service is deployed using cloudmesh REST framework [10].

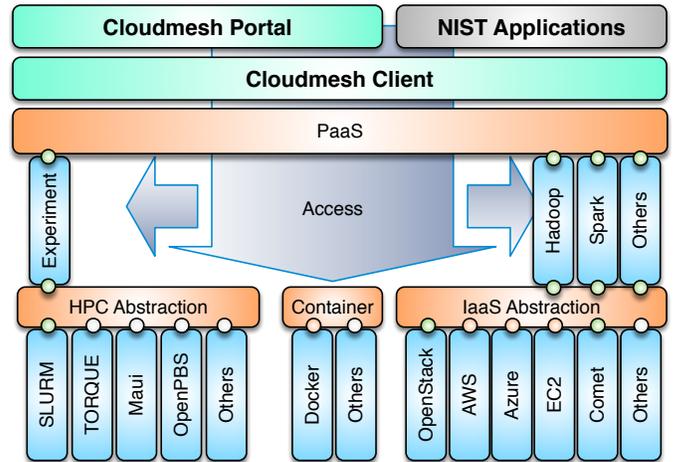


Fig. 2. Cloudmesh layered architecture.

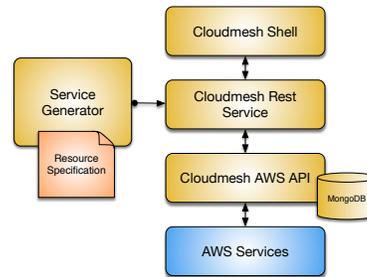


Fig. 3. Cloudmesh AWS REST Service.

```
client -> rest (eve) -> database (nosql)
    ~ object definitions
```

5. ARCHITECTURE

The commands are implemented as methods of a class *AwsCommand* which is based on *PluginCommand* from cloudmesh shell. Depending on the arguments passed, corresponding routine is called from *Aws* client API which acts as a wrapper around the *libcloud* EC2 drivers [11] and is also responsible to connect with back-end database apart from reading the configuration from *yaml* file. The entire code is written in Python.

5.1. Technologies Used

To adhere to the principal of code reuse we are using a number of core technologies that allow us to keep the overall developed new code small. This includes leveraging our previous *cloudmesh* efforts, the reuse of *mongodb* and the automatic creation of a REST service based on example objects with *evengine*. Particularly the following software components have been leveraged:

**Libcloud EC2 driver [11]:** The driver provides a number of functions for various functionalities such as listing the available nodes, generating a key pair and deploying a VM.

**MongoDb [12]:** MongoDB is an open source document store database. It’s used by AWS client to store information about various VM configuration options available on the Amazon

EC2 cloud. It's also used to store information regarding the VMs that are running on the cloud. The information in the database is refreshed whenever it's fetched from the cloud.

**Cloudmesh.common [8]:** A library of many commonly useful functions and classes shared among all cloudmesh projects.

**Cloudmesh.cmd5:** The cmd5 is a dynamically extensible CMD based command shell [7].

**Cloudmesh.evegenie [13]:** The schema for the collections are specified in json files which are then converted to Eve syntax using evegenie. It creates the configuration file for starting up the rest services using cloudmesh rest framework.

**Cloudmesh.rest [10]:** The cloudmesh rest framework is used to deploy and start the mongodb and rest services. The schema for the objects to be stored in the database is collectively specified in json file called *all.json*. The schema defined in the file is closely associated with the code in *awsclient.py* which is responsible for fetching the information from cloud and passing it to mongodb through rest services. From our experience during the development of this project, we observed that rest services required the schema to be precise and didn't handle null values for collection fields. There's another file *all.settings.py* which contains the configuration information for rest services such as port mongodb is running on along with the database name. It contains the schema for the collections and the list of methods to be provided by the rest services. The database connectivity was initially developed using pymongo library. However, during the review it was suggested that the code based on pymongo is quite low level and does not have adequate security features. This led to the use of Python Requests library.

## 6. USAGE

One needs to create an AWS account first to be able to access its cloud. The instructions for it are available at [2]. A pair of access key and secret keys are required to be generated to authenticate into the cloud [3]. These keys are required to be kept confidential. They are to be specified in a yaml configuration file. Default vm image and flavor can also be specified in the configuration file (see Figure 4).

```
cloudmesh:
  clouds:
    aws:
      credentials:
        EC2_ACCESS_KEY: 'ACCESS KEY'
        EC2_SECRET_KEY: 'SECRET KEY'
        . . .
      default:
        image: 'IMAGE ID'
        size: 'SIZE ID'
        location: 'LOCATION'
```

Fig. 4. Configuration

The user need to ensure that the combination of image, size and location is valid and that it's account has the required privileges for it. The instructions for installation of AWS client can be found at [4]. Once, the client has been installed and configurations settings enabled, the mongodb and the rest services to

access the database can be started by following command from the root directory of the code:

```
make rest
```

The above services will be required by AWS client to store cloud related information locally. The user can now execute the client commands e.g.:

```
cms aws flavor refresh
```

This will fetch the list of image sizes available on Amazon EC2 cloud.

## 7. CLOUDMESH REST SERVICE

```
{
  "aws_flavor": {
    "id": "t1.micro",
    "name": "Micro Instance",
    "ram": 627,
    "disk": 15,
    "price": 0.025
  }
}
```

Fig. 5. Specification for flavor.

```
{
  "aws_image": {
    "id": "ami-0180d261",
    "name": "ubuntu/images-testing/ubuntu-....-server-20170123",
    "driver": "string"
  }
}
```

Fig. 6. Specification for image.

```
{
  "aws_keypair": {
    "name": "AWSTEST",
    "fingerprint": "e7:db:fe:a6:5e:...:d2:d3:f8:79"
  }
}
```

Fig. 7. Specification for keypair.

## 8. AWS COMMANDS

### 9. BENCHMARKING CLOUDMESH AWS

We benchmarked the aws commands that fetch information either from the cloud over the network or from the local database. The information is then displayed to the user. The informations that is fetched over the network is also updated in the database. The performance statistics observed give us the overview of the difference in execution time of the two kind of commands. Each command was run 50 times with its execution time recorded. The mean and standard deviation of the timings were calculated using statistical methods in R. Table 3 shows the observed values in seconds.

The commands that fetch the information from local database are on an average 85% faster than the commands that fetch information from the cloud and also have lesser variation in their timings. The difference in performance tends to decrease when the information to be fetched is more. This may be due to the limitation of the machine on which it was tested.

**Table 1.** Cloudmesh AWS Commands

Function	Description	Command
Refresh	Whether to always fetch the information from the cloud over the network or display it from the local database when asked can be configured by setting the configuration variable <i>refresh</i> to either <i>on</i> or <i>off</i> . When the value is set to <i>on</i> , the information will always be fetched from the cloud. This functionality is implemented for only some of the commands as of now.	<code>aws refresh on</code>
Image refresh	The images available on the cloud could be listed using this command. The database will also be updated with the newly fetched list. The command may take up to minutes to run as the list contains more than 24,000 images.	<code>aws image refresh</code>
Image list	Depending on whether the value of <i>refresh</i> is set to <i>on</i> or <i>off</i> , the list is either fetched from the cloud or from the local database.	<code>aws image list</code>
Flavor refresh	This will list the different sizes of VMs that are available on the cloud. The information is fetched from the cloud and stored locally.	<code>aws flavor refresh</code>
Flavor list	The flavor list is either fetched from the cloud or from the local database depending on whether the value of <i>refresh</i> is set to <i>on</i> or <i>off</i> . <code>aws flavor list</code>	
Start/Boot vm	It creates a new node instance and start that node automatically. The required parameter is <i>IMAGE_ID</i> . This command assumes user has created keypair with name <i>AWS1</i> . The default values; flavor and location are taken from <i>cloudmesh.yaml</i> . Those values are required to be set before executing this command. Once it has been created, it can be seen using <i>vm list</i> .	<code>aws vm boot IMAGE_ID</code>
Reboot vm	This command is used to reboot a running vm instance. The state of the node gets changed from <i>RUNNING</i> to <i>REBOOTING</i> while its restart. The rebooting time of node depends on the configuration the configuration that was selected while its creation. <i>vm reboot</i> requires <i>NODE_UUID</i> of the node to be rebooted which can be retrieved using either <i>vm list</i> or <i>vm refresh</i> .	<code>aws vm reboot NODE_UUID</code>
VM delete	It destroys the instance of a node and all the data associated with it including backup. It takes few seconds to terminated the instance. At first, the state of the node changes to <i>TERMINATED</i> which can be observed using <i>vm refresh</i> . The node gets removed from the list subsequently.	<code>aws vm delete UUID</code>
VM list	It lists out all the nodes along with their status as stored in the database.	<code>aws vm list</code>
Keypair create	To create the node, one of the essential component is <i>key pair</i> . Amazon EC2 uses public key of the user to encrypt the password and then recipient uses private key to decrypt it. These public and private keys are know as a <i>key pair</i> . They are required to be given a name.	<code>aws keypair create NAME</code>
Keypair delete	It allows user to delete a created <i>key pair</i> which is no longer in use.	<code>aws keypair delete NAME</code>
Keypair refresh	It refreshes the list of created <i>key pairs</i> in the database and also displays it on the screen.	<code>aws keypair refresh</code>
Keypairs list	It lists out all the <i>key pairs</i> information stored locally in the database.	<code>aws keypair list</code>
Keypair get	It returns the key pair object, which has the name of <i>key pairs</i> , driver and hash key.	<code>aws keypair get NAME</code>

**Table 2.** Cloudmesh AWS Commands

Locations refresh	It will show all the available locations associated with Amazon EC2 account. For free tier, user will get two locations. More locations will be available in paid service. The database records are also updated with this command.	<code>aws location refresh</code>
Locations list	It lists the locations information stored in the database.	<code>aws location list</code>
Volume create	It creates the volume for vm. The size of volume is specified in GB, the default value is set to 1 GB. The maximum number of volumes that can be attached to a vm will depend on its operating system.	<code>aws volume create VOLUME_NAME</code>
Volume refresh	This command shows the created volumes with the id, size and the driver name. It also updates the database.	<code>aws volume refresh</code>
Volume list	This command displays the volume information stored in the database.	<code>aws volume list</code>
Volume delete	User can delete the unwanted volumes using the <i>VOLUME_NAME</i> .	<code>aws volume delete VOLUME_NAME</code>

```
{
  "aws_location": {
    "region_name": "us-west-1",
    "availability_zone": "us-west-1a",
    "country": "USA",
    "zone_state": "available",
    "id": 1,
    "name": "us-west-1a"
  }
}
```

**Fig. 8.** Specification for location.

```
{
  "aws_node": {
    "state": "RUNNING",
    "provider": "provider",
    "uuid": "e257efd0e6763e9fdc04b79a00f5147fcc21ee7a",
    "name": "test1"
  }
}
```

**Fig. 9.** Specification for node.

**10. USE CASE: CREATE AN AWS NODE**

The following are the pre-requisites to be able to create an EC2 node.

**10.1. Prerequisite**

1. User should have a valid AWS account.
2. users Create a IAM [14] user for which the access and secret key will have to be generated [15]. The keys will have to be added to the yaml cloudmesh configuration file.
3. The required permissions are needed to be granted to the user.
  - visit IAM home [16]

```
{
  "aws_volume": {
    "id": "vol-0c30e77f6ca2a263a",
    "size": 1,
    "driver": "Amazon EC2"
  }
}
```

**Fig. 10.** Specification for volume.

**Table 3. Banchmarking of AWS commands**

Commands	Mean	Standard Deviation
flavor refresh	0.612	0.059
flavor list	0.207	0.024
keypair refresh	1.967	0.964
keypair list	0.240	0.062
location refresh	1.933	1.246
location list	0.172	0.039
vm refresh	2.342	1.876
vm list	0.160	0.023
volume refresh	2.184	1.878
volume list	0.170	0.020

- select **policies** in left hand menu
  - create **administrator policy** from amazons existing policies
  - select **administrator checkbox** and **attach** to your user
4. Open the `../cloudmesh.yaml` configuration file and update with `EC2_ACCESS_KEY`, `EC2_SECRET_KEY`, you just copied. Now set default flavor, image and location, as `t2.micro`, `ami-0183d861` and `us-west-1` respectively in same file.
  5. MongoDB server should be up and running (please refer section 2. Getting started)

**10.2. Create Node**

1. Create keypair name using command

```
cms aws keypair create AWS1
```

It will create the *keypair name*, it is essential to create the *node*. To verify it, `cms aws keypair list` command will list down all created *keypairs* so far.

2. Now create the node

```
cms aws vm boot ami-0183d861
```

Above command will create a node instance with the image of ami-0183d861.

**Table 4. cms aws image refresh**

id	name	driver
aki-02b79b47	pv-grub-hd00_1.03-i386	627
aki-033c6d46		<libcloud.compute.drivers.ec2.EC2NodeDriver object at 0x105898a90>
aki-037a5e46	ubuntu/kernels-testing/ubuntu-lucid-i386-linux-image-2.6.32-347-ec2-v-2.6.32-347.52-kernel	<libcloud.compute.drivers.ec2.EC2NodeDriver object at 0x105898a90>
.	.	.

**Table 5. aws flavor refresh**

id	name	ram	disk	price..
t1.micro	Micro Instance	627	15	0.025
m1.small	Small Instance	1740	160	0.047
m1.large	Large Instance	3840	410	0.095
.	.	.	.	.

**Table 6. cms aws vm boot ami-0183d861**

uuid	name	states ..
eec0cb8ddb3a17764c665827816249681cec1f67	test1	running

**Table 7. cms aws vm list**

uuid	name	states ..
eec0cb8ddb3a17764c665827816249681cec1f67	test1	running

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 [2] Web Page. [Online]. Available: <http://docs.aws.amazon.com/AmazonSimpleDB/latest/DeveloperGuide/AboutAWSAccounts.html>

**Table 8. cms aws keypair create AWSCLI**

name	fingerprint
AWS1	17:20:41:93:1d:b1:e1:a6:84:44:99:0d:87:d2:ab:72:3d:a1:f0:a7
AWS2	72:31:87:fc:2b:0f:93:1a:24:f7:9a:01:91:29:f7:eb:27:6a:2d:fa

**Table 9. cms aws location refresh**

id	name	country	availability_zone	zone_state ..
0	us-west-1a	USA	us-west-1a	available
1	us-west-1b	USA	us-west-1b	available

**Table 10. cms aws volume create VOL\_TEST\_1**

id	size	driver
vol-009775889a2d50154	1	Amazon EC2

**Table 11. cms aws volume refresh**

Id	Size	Driver
vol-009775889a2d50154	1	Amazon EC2
vol-0c30e77f6a2a263a	1	Amazon EC2

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**Piyush Rai** received his BE (Computer) in 2011 from The University of Pune. His research interests also include Big Data analytics for military intelligence and financial markets.

**Gregor von Laszewski** has written more than 100 publications in the area of Grid and Cloud computing. He obtained a Ph.D. from Syracuse University and has worked at Argonne National Laboratory. His team is providing with cloudmesh a client interface to XSEDE SDSC comet virtual clusters.

# Deploying a spam message detection application using R over Docker and Kubernetes

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Application containerization and automated deployment allows developers to focus on writing code without worrying about the environment in which their software is supposed to run. This paper aims to containerize a standalone R application and deploy it on a multi node kubernetes cluster and benchmark application performance on different clouds. Email spam messages are a nuisance to the web community. If not filtered accurately, they may work like an email-bomb attack where a stream of spam messages shall make a user to accidentally omit a legitimate message. We use several established data mining algorithms to classify messages as legitimate or not, and compare their classification accuracy. Application and cluster performance is benchmarked and compared across Chameleon and Kilo clouds. © 2017

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**Keywords:** Docker, Ansible, Kubernetes, R, Pandas, Spam

Report: <https://github.com/cloudmesh/sp17-i524/tree/master/project/S17-IR-P007/report/report.pdf>

Code: <https://github.com/cloudmesh/cloudmesh.kubernetes>

## 1. INTRODUCTION

Email and text messaging are the most formal means of communication for internet users. Web mining helps any organization to discover identities of users that it can target to advertise their business by sending them emails, and at times without their consent. The ease with which content can be generated and published has also made it easier to create spam. Spam can be stated as any information which does not add value to a user of the web. Messages which are inappropriate, unsolicited, repeated and irrelevant can be all classified as spam. In this report, we are using data mining algorithms like SVM (Simple Vector Machine), KNN (K-Nearest Neighbor) and AdaBoost over an SMS collection dataset of 5574 messages to differentiate spam messages from legitimate ones. R shall be used to develop the code as it provides supporting text mining libraries to implement these algorithms.

To automate application deployment such that it can be tested on any environment, docker is used to containerize the application along with the application dependent libraries. The cluster management tool - *Kubernetes*, is used to auto deploy the application on a multi-node cluster. Scripts are written in *Ansible* [1] to automate the deployment process. As Kubernetes itself scales the application container according to our specification, a deployment engineer shall only be responsible to write a yaml specification file that is read by the kubernetes engine. Application benchmarking results are achieved by running the ansible scripts to deploy the application on Chameleon cloud and Kilo cloud.

## 2. ELEMENTS OF THE PROJECT

### 2.1. Ansible

No one likes repetitive tasks, with Ansible, IT admins can begin automating away the drudgery from their daily routine tasks. Ansible is a simple automation language that can perfectly describe an IT application infrastructure. Ansible is an open source automation engine which can be used to automate cloud provisioning, configuration management, and application deployment. It can also perform more advanced IT tasks such as continuous deployment or rolling out updates with zero downtime.

A major difference in Ansible and many other tools in the space is its architecture.

#### 2.1.1. Architecture

Ansible is an agentless tool, it doesn't require any software to be installed on the remote machines to make them manageable. By default it manages remote machines over SSH or WinRM, which are natively present on those platforms [?].

Like other configuration management software, Ansible distinguishes between two types of servers: one being the controlling machines and other being the nodes. Ansible uses a single controlling machine where the orchestration begins. Nodes are then controlled by a controlling machine over SSH [?]. The location of the nodes are described by the inventory of the controlling machine.

Ansible modules are deployed by Ansible over SSH. These

modules are temporarily stored in the nodes and communicate with the controlling machine through a JSON protocol over the standard output

### 2.1.2. Playbooks

Playbooks [2] are Ansible's configuration, deployment, and orchestration language. They let us control the remote systems with a policy which we might want them to enforce. If Ansible modules act as tools in your workshop, then playbooks are your instruction manuals, and your inventory of hosts are your raw material. Playbooks can be used to manage configurations of and deployments to remote machines. They can sequence multi-tier rollouts involving rolling updates, and can delegate actions to other hosts, interacting with monitoring servers and load balancers.

### 2.1.3. Ansible Galaxy

## 2.2. R

R is a language and environment for statistical computing and graphics [3]. Pandas does not provide a significant statistical modeling environment as it is still a work in progress. R provides a variety of statistical model analysis, classification, clustering and graphical techniques to provide this environment. Integrating Python's efficiency with R's capability allows us to build a highly desirable analysis model for our application.

## 2.3. Docker

*Docker* is an open-source project that automates application deployment by packaging the application in *containers*. Containers provide application portability by bundling together an application and its needed resources in a package so that they can be deployed on different platforms without worrying about resource dependencies. Application containerization is an OS (Operating System) level emphvirtualization for deploying and running an application instance without launching a virtual mahine for each application [4]. A container has its own environment variables, filesystem and libraries that is needed by the application, thus eliminating OS or hardware dependency. Containers abstract the OS kernel while a *VM (Virtual Machine)* hypervisor abstracts an entire device.

Docker allows application developers to package their applications into isolated containers. Docker automates the repetitive tasks of setting up and configuring development environments thus allowing developers to focus only on building software. A dockerized application can simply ship between platforms as the complexity of software dependencies is handled by the container. Docker standardizes container creation and can be used to pack, ship and run an application as a lightweight container that can run in any environment. Docker can be integrated with other devops applications like Puppet, Chef, Vagrant, Ansible and Kubernetes. We shall use Docker with Ansible and Kubernetes in our project.

### 2.3.1. Dockerfile and DockerImage

To package an application and its dependencies in a single file, docker introduces the concept of a *docker image*. The docker engine creates a docker image by parsing contents of a *dockerfile*. A dockerfile is a script composed of various commands to build a container in a step-by-step, layer-by-layer manner [5]. Once an image has been built it can be shared with other users by pushing it to a public repository on *DockerHub* or *GoogleCloudPlatform*. In this manner, an image once built by the docker engine can be used across the organization by making a docker pull request.

## 2.4. Kubernetes

Kubernetes is an open-source platform for automating deployment, management and scaling of containerized applications across a cluster [6]. The more granular an application is, the more components it consists of and thus requires management of these components. Kubernetes helps in faster deployment of applications and scaling them on the fly. Moreover it optimizes the use of hardware by using the resources which are needed. Kubernetes provides container management features like component replication, load-balancing, service-discovery and logging across components [7]. A Kubernetes cluster can be deployed on either physical or virtual machines. We shall be deploying a kubernetes cluster using *kubeadm* - the kubernetes command line tool and *Minikube* which is a lightweight Kubernetes implementation which creates a VM on the local machine and deploys a simple cluster containing only one node. The Minikube CLI provides basic bootstrapping operations for working with the cluster, including start, stop, status, and delete commands.

## 2.5. Kubernetes Terminologies

Kubernetes defines the following set of primitives which provide mechanisms for deploying and scaling applications.

### 2.5.1. Pods

A pod is the smallest unit of a kubernetes cluster and has a unique ip-address within the cluster. A pod consists of one or more containers that can share resources and can be controlled as a single application [6] [8]. Thus all the involved containers in a pod are scheduled on the same host. A pod can be thought of as a single virtual machine in terms of resource sharing and scheduling. Pods can be managed manually using the *Kubernetes API* or can be managed by a controller.

### 2.5.2. Services

A kubernetes service is a collection of pods that perform the same function and are presented as a single entity. This way a service can be emphasized as a one tier of a multi-tier application. Service act as an interface to a group of containers so that service-consumers need only reference the single access location. Kubernetes facilitates service discovery by assigning a stable IP address and a namespace to a service. This idea abstracts the change of IP addresses of pods within a service that result due to pod failure or pod rescheduling.

### 2.5.3. Replication Controllers

A replication controller is a framework for horizontal scaling of pods. Semantics of a pod are defined in a `<pod_name>.yaml` file which also defines the replication details that need to be done. The replication controller performs replication by scaling a number of pods across a cluster based on the pod definition file [6]. The replication controller has to make sure that a certain number of copies of a pod are always up and running. Thus, in event of a pod failure it replaces the failed pod with a new replica.

### 2.5.4. Labels and Selectors

Kubernetes allows users or internal components to assign a key-value pair tag to any API object in the system. An object can have one or more labels associated with it, but each with a unique key. eg: `appversion = 1.0`, `development_stage = 4`. Label selectors are queries against labels that return matching objects [8]. This way each object in the system can be referenced with a single label or a combination of multiple labels for fine grained control.

## 2.6. Kubernetes architecture

Kubernetes exhibits the master-slave architecture. The components can be split into those that manage an individual node(slave) and those that manage the master or control plane.

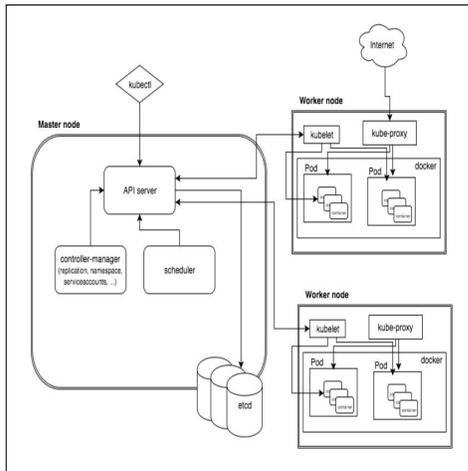


Fig. 1. Kubernetes architecture [7]

### Kubernetes Master Node/Control plane

The Kubernetes master node is responsible for managing the kubernetes cluster and orchestrating the worker nodes, where the actual pods are scheduled. The master node can work as a single node cluster where it can schedule pods to work on the master node itself by tainting the schedule policy rule on the node. The master node also referred as the control plane consists of several components:

#### 2.6.1. API Server

The API server is the most fundamental component of the Kubernetes master and serves as the entry point for all the REST commands used to control the cluster. The API server serves up the Kubernetes API using JSON over HTTP, providing both internal and external interface to the cluster [8] [9]. It validates the REST requests, executes them and updates the status of the objects in the *etcd* storage.

#### 2.6.2. etcd storage

*etcd* is a simple, distributed and consistent key-value store that stores configuration data of the cluster and represents the state of the cluster at any point of time [6]. Kubernetes uses *etcd* for service discovery and provides a simple HTTP/JSON API as an interface for setting or retrieving values from the store. Other components watch the state of the *etcd* store to bring themselves up to the desired state. Data being stored in the *etcd* store are deployed services, pods, replication information etc.

#### 2.6.3. Scheduler

The scheduler component is responsible for the deployment of pods and services on the cluster nodes. The scheduler has the information about the availability of resources on a node and schedules unscheduled pods on the nodes accordingly. Along with scheduling, the scheduler also tracks resource utilization of each node and ensures that workload scheduled is not in excess to the resources available [6].

#### 2.6.4. Controller-manager

The controller manager is the process embedding the different types of controllers like the Replication Controller or the Dae-

monSet Controller on a kubernetes master. The controllers query the API Server to manipulate the resources like pods, services etc. which they manage.

## 2.7. Worker Node

The worker node also called as minion node is where the containers are actually deployed. The worker contains all the necessary services needed to manage the networking between containers, communicate with the master node and assign resources to the scheduled containers [7]. Every worker node must run the container runtime i.e docker and other components stated below to ensure proper communication with the master.

### 2.7.1. Docker

Docker runs on each of the worker nodes. It is responsible for downloading the docker images and running the configured pods by starting the container.

### 2.7.2. Kubelet

*Kubelet* gets the pod definition from the api-server and is responsible for maintaining the pod in the desired state. *Kubelet* is the worker service that monitors the health of each pod and communicates the status of each node via a heartbeat message to the master. If the pod is not in the desired state, it is redeployed to the same node [6]. *Kubelet* is also responsible for communicating with the *etcd* storage to get information about the services and update the storage about newly created ones.

### 2.7.3. Kube-Proxy

*Kube-proxy* acts as a network proxy and a load balancer. It is responsible for networking of TCP and UDP packets to the appropriate container based on the IP address of each packet [6] [7].

### 2.7.4. Kubectl

*kubectl* is a command line tool that communicated with the API server to fetch important information about the nodes, pods, services and events in the cluster.

## 3. DESIGN

## 4. ABOUT THE APPLICATION

We are using a series of machine learning algorithms and shall compare their performance in terms of classifier accuracy. To build our classifier and check its accuracy, we shall partition the data into 2 subsets - training data and classification data. We shall choose one of the subsets for training and other for testing and predicting classifier accuracy.

### 4.1. The dataset

We are using the SMS Spam Collection dataset from UCI's public machine learning repository to build our classifier. The dataset consists of 5574 text messages, with each classified as a spam or ham message [10].

### 4.2. Algorithms Used

#### 4.2.1. SVM

SVM (Support Vector Machines) are discriminative classifier models that classify the data as belonging to one of the two possible classes, in our case class ham and class spam. The SVM algorithm attempts to categorize data by drawing a hyperplane among the data points such that points on either end of the hyperplane belong to one of the two possible classes. An SVM

model is representation of given data points in space such that the division between the classes of data is as clear as possible [11]. The aim of the algorithm is to find the optimum hyperplane that defines the largest possible margin between the classes of data.

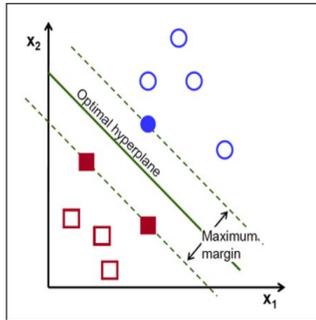


Fig. 2. The maximum margin hyperplane for SVM [12]

#### 4.2.2. SVM Kernels

A simple SVM transformation works for data with linear decision boundaries, where the different data points lie on either side of the decision boundary. But for scenarios where a linear boundary is efficient to classify data, we need to transform the data from its original coordinate space into new space so that a linear decision boundary can be drawn to separate the data in this transformed space [13]. The kernel is a similarity function. It is a method to compute similarity between attributes in the transformed attribute space. We shall use svm kernel methods as they eliminate the curse of dimensionality problem as they perform the computations in the original attribute space [13]. We shall avoid mathematical details about SVM and the kernel as they are beyond the scope of this report.

**Polynomial kernel** - Polynomial kernel, as the name suggests, looks not only at the given features of the input samples but at their combination [14]. If a pair of words give interesting information rather than the individual words alone, we can use a quadratic kernel. Similarly, for occurrences of triplets of words, we can use a cubic kernel. Linear kernels are special case of polynomial kernels where the quadratic factor is 1.

**Radial kernel** - Radial basis kernel maps the data into infinite dimensional space to extract relations between the variables. It helps us to draw a circular decision boundaries to pick dependent features.

#### 4.2.3. K - Nearest Neighbor

The k-nearest neighbor algorithm classifies a data point as belonging to either output class by taking a majority vote amongst its k-nearest neighbors. The algorithm computes distances between the test data point and all the stored data points or neighbors. *Euclidean distance* [15] is used to compute distance metrics between attribute values of the neighbors. A sample figure explaining the algorithm is given below.

There are 2 classes of data items in the figure - circles and squares. We have an unknown data point - the star and wish to find its real class using k-nearest neighbor algorithm. For  $k=3$ , the 3-nearest neighbours according to the distance metrics are all circles. Hence, the unknown data point is then classified as a circle. This assumption changes for higher values of k. To eliminate the effect of noise and outliers on the classification result, a weight is associated with each data point, with closer

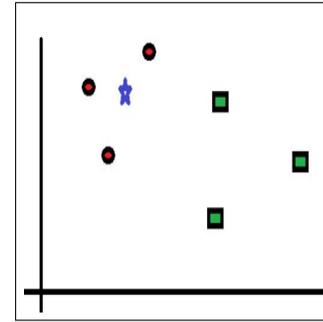


Fig. 3. An example for the K-Nearest Neighbor algorithm [16]

neighbors having higher weight over the distant neighboring points.

#### 4.2.4. Naive Bayes Classifier

Naive Bayes classifier works on the principle of conditional probability. Bayes classifier assigns each sample a probability of belonging to one class or another. The classifier shall maintain a bag of words along with the count of each word occurring in the spam messages. This word count shall be used to calculate and store the word probability in a table that shall be cross-referenced to determine the class of the record on classification data [17].

A selected few words have more probability of occurring in a spam messages than in the legitimate ones. Eg: The word "Lottery" shall be encountered more often in a spam message. The classifier shall correlate the bag of words with spam and non-spam messages and then use Bayes Theorem to calculate a probability score that shall indicate whether a message is a spam or not. The results shall be verified with the results available on the training dataset and the classifier accuracy shall be calculated. The classifier shall use the Bayesian theorem over the training dataset to calculate probabilities of such words that occur more often in spam messages and later use a summation of scores of the occurrence of these word probabilities to estimate whether a message shall be classified as spam or not. After working on several samples of the training dataset, the classifier shall have learned a high probability for spam based words whereas, words in legitimate message like family member or friends names shall have a very low probability of occurrence.

Once the training process has been completed, the posterior probability for all the words in the new input email is computed using Bayes theorem. A threshold value shall be defined to classify a message into either class. A message's spam probability is computed over all words in its body and if the sum total of the probabilities exceeds the predefined threshold, the filter shall mark the message as a spam [18].

### 4.3. The Classification process

#### 4.3.1. Building the classification model

To address the problem of incoming spam messages, a model shall be developed using the various classification techniques to correctly classify each incoming email/text message as a spam or a legitimate one. The training dataset to build the model consists of 5574 message records.

To develop an efficient training model, we shall partition the data into 2 subsets - the training data and testing data. We shall choose one of the subsets for building a classification model and the other to evaluate the model's performance. The training process involves creating a document term matrix for the

occurrence of each word in the spam marked messages. This matrix describes the frequency of terms in each of the messages, with the rows corresponding to documents in the dataset and columns corresponding to the terms. Using the document term matrix, we find highly repeated words in spam messages across the training set. We vectorize the training and the test data set using these word frequencies and provide this vectorized data as input to the various algorithms in our program.

#### 4.3.2. Testing the model

Each algorithm used in the application uses its own strategy to build a classification model from the training set examples. The model's performance is evaluated by using it to classify the test dataset. Using the classification results, a confusion matrix is built to analyze the algorithm's performance on the test dataset. The confusion matrix specifies what number of spam messages were correctly classified as spam or incorrectly classified as ham and vice-versa. Based on these results, we calculate the accuracy of classification by dividing the number correct results by the total records in the dataset.

Further, a higher classification accuracy shall be achieved through filtering by looking at the message header i.e the sender's number/name. Thereby if a message from a particular sender is repeatedly marked as spam by the user, the classifier need not evaluate the message body if it is from the same sender.

## 5. DEPLOYMENT

Our application will be deployed using Ansible [1] playbook. Automated deployment should happen on two or more nodes clouds or on multiple clusters of a single cloud. Deployment script should install all necessary software along with the project code to Kubernetes cluster nodes using the Docker image.

### 5.1. Deployment process - Ansible

<TODO - describe the ansible deployment and scripts>

### 5.2. Dockerizing the application

To containerize our application, we need to create a docker image for it. To create a docker image we need to create a docker file that describes the semantics to create the docker image. Docker version used for this process is 1.12.6.

#### 5.2.1. The Dockerfile

Docker can build images automatically by reading instructions from a Dockerfile. A dockerfile is a series of text commands that a user can run on a command line to build an image [? ]. Instructions within a Dockerfile have the following format:

```
INSTRUCTION arguments
```

**Fig. 4.** Syntax of every command in a dockerfile

Docker reads the instructions from a dockerfile in the order they are written. The very first line of a docker file must be a 'FROM' clause which specifies the base image from which the image is being built. As our application works with R, we need to specify the base package as one that shall help us run our R application. *DockerHub* has a r-base package that binds the latest version of R and its libraries together that we shall use [? ]. The argument following the FROM clause is a repository/tag name that the docker engine automatically looks up on <http://hub.docker.com>.

Following the FROM statement, we can specify all actions we need to perform like specifying the work directory for building the image or copying files into our work directory so that every resource is available under a single folder. Our application needs several text mining packages to be available as a part of the installation and thus we use the docker RUN command to download these dependencies and make them part of the docker image. The R library in the docker container shall pre-install all the dependencies as the image is built and we shall only care about running the application logic. Lastly, our docker file ends with a CMD statement that specifies the command that the container is supposed to execute on successful instantiation. CMD accepts an array of command names followed by the parameters. Since we want our image to execute our R application we shall specify the command as stated in the dockerfile below.

```
FROM r-base
COPY . ~/myscripts
WORKDIR ~/myscripts
RUN Rscript -e "install.packages('tm')"
RUN Rscript -e "install.packages('e1071')"
RUN Rscript -e "install.packages('RWeka')"
RUN Rscript -e "install.packages('ada')"
RUN Rscript -e "install.packages('rbenchmark')"
CMD ["Rscript", "spamdetection.r"]
```

**Fig. 5.** Dockerfile of the application

#### 5.2.2. Creating a docker image

Once the Dockerfile is built, we can build the image using docker build command as follows :

```
cc@rahpsing-055:~/dockerDirectory$ sudo docker build
-t spamdetectionapplication ~/dockerDirectory/

Sending build context to Docker daemon 12.8 kB
Step 1 : FROM r-base
latest: Pulling from library/r-base
c560cd7bd403: Pull complete
b190a5321f19: Pull complete
3933674049c0: Pull complete
99d11fb944ea: Pull complete
34522f7c3788: Pull complete
c2a798388711: Pull complete

Digest: sha256:e192edf861d61caff0b329436...
Status: Downloaded newer image for r-base:latest
----> 16fe32463daa

Step 2 : COPY . ~/dockerDirectory/
----> a6717da2ec47
Removing intermediate container 8fb4aaaec0d8

Step 3 : WORKDIR ~/dockerDirectory/
----> Running in 0220b193ed11
----> a3c4d57e23c9
Removing intermediate container 0220b193ed11

Step 4 : RUN Rscript -e "install.packages('tm')
.
. <installation_logs>
.

Step 9 : CMD Rscript spamdetection.r
----> Running in 4edb44f2ffb6
----> a4814eeadf35
Removing intermediate container 4edb44f2ffb6
Successfully built a4814eeadf35
```

**Fig. 6.** Building an image line by line from a dockerfile

The built image is placed in our machine's local docker registry and can be viewed with the 'docker images' command.

```
$ docker images
REPOSITORY          TAG          IMAGE ID          SIZE
spamdetectionapplication  latest      a4814eeadf        646.1 MB
r-base              latest      16fe32463d        645.6 MB
```

**Fig. 7.** Listing images in the local repository

### 5.2.3. Running the application

We shall run our application using the docker run command.

```
docker run spamdetection
```

**Fig. 8.** Running a docker image

We can check the container id of our application along with other important information using the 'docker ps' command.

### 5.2.4. Sharing the docker image

By default, the docker CLI points to docker's public registry which is located at <http://hub.docker.com>. We need to create

a docker account to upload our application image so that it could be directly referenced by kubernetes later. Once a docker account is registered, create a public repository and give it a name. The repository shall be accessible by the format '<username>/repositoryname'.

To tag the current docker image that we created on our system we need to inform the docker engine to point to our registry. To do so, we shall use login command provided by the docker CLI.

```
docker login
```

**Fig. 9.** Linking a dockerhub account to the local registry

The login request shall ask for a valid docker account userid and password. Once authenticated, the docker engine shall establish a link with the registry associated with the username. To upload our docker image to the repository, we need to tag the image. Docker provides the 'tag' command to do so.

```
docker tag image_name <username>/<repository_name>:
<tag>
```

**Fig. 10.** Tagging a local docker image

The <tag> can be any name given by the user to uniquely identify the image. Once tagged, we need to push the image to the repository using the command line 'docker push' command.

```
docker push rahpsing/kubernetesi524:spamdetection
```

**Fig. 11.** Pushing an docker image to a registry

As the image is now publicly available on the repository, we can do a simple 'docker pull' from any machine to deploy the container with no dependencies. This is possible as the image wraps together the application code file, the data file and dependent r-base package from the latest version of R available on dockerhub's library.

## 5.3. Deployment via Minikube

TODO

## 5.4. Deployment via kubeadm

Kubeadm is a part of kubernetes 1.4 distribution that allows users to install and set up a Kubernetes cluster. Kubeadm works with local VM's, cloud servers or physical servers [19].

### 5.4.1. Creating a cluster

To create a kubernetes cluster, it is essential to install docker, kubelet, kubectl and kubeadm on all the machines that are to be a part of the network. Kubelet shall help to start pods and containers on all the machines of the network. kubectl allows us to monitor the activities of the cluster once it is up and running. Primarily, it is used only on the master node. Kubeadm is used to setup the cluster by allowing multiple worker nodes to bind with the master on a unique network identifier token.

Once the mentioned components are installed, we need to initialize the master so that it can accept requests from other service nodes to join the cluster. Master initialization is done with the 'init' command.

```
kubeadm init
```

**Fig. 12.** The master initialization command

Executing the above command tells kubernetes that the host machine shall serve as the master in the cluster. Kubeadm initializes all the other dependent components like the API server and generates a unique key that identifies the master in the network. Client nodes can issue a join request with the master by using the unique identifier as a part of the join command.

```
kubeadm join <unique_token>
```

**Fig. 13.** Syntax of the join command

A few seconds after running the join command we can query the master to list the available nodes in the cluster using 'kubectl get nodes' command.

```
kubeadm join --token 87ce11.50ab6a5eea 192.168.0.204
$ kubectl get nodes
NAME          STATUS    AGE
rahpsing-056  Ready    2m
rahpsing-057  Ready    2m
```

**Fig. 14.** Registering nodes to the cluster

Before the master is ready to schedule pods, it is imperative that the API server and the kubedns service are up and running. We can check the status of all the services of the system using the '-all-namespaces' argument along with the "get nodes" command.

The kubedns service is responsible for networking with its client nodes. Without the kubedns service, the kubernetes master shall be unable to schedule pods on the worker nodes as pods cannot communicate with each other. To get the service up and running, we need to install a pod network. Kubernetes provides many addon services that can be used to setup the cluster network policy and enable networking. Of the list of available addons we shall use 'weave-net' as it provides us with a network policy and does not require an external database [?].

```
kubectl apply -f https://git.io/weave-kube
```

**Fig. 15.** Creating the weave-net pod-network

```
$ kubectl get pods --all-namespaces
NAME                                READY    STATUS
etcd-rahpsing-056                   1/1     Running
kube-apiserver-rahpsing-056         1/1     Running
kube-controller-manager-rahpsing-056 1/1     Running
kube-discovery-2849056221-5xws4    1/1     Running
kube-dns-2247936740-m9198          3/3     Running
kube-proxy-amd64-d91cy              1/1     Running
kube-proxy-amd64-ycg5e              1/1     Running
kube-scheduler-rahpsing-056        1/1     Running
weave-net-1sk03                     2/2     Running
weave-net-p9cpd                     2/2     Running
```

**Fig. 16.** Services running in the cluster

#### 5.4.2. Creating a pod

A pod as described initially is the smallest unit of work in a kubernetes cluster. Semantics of a pod are defined in a pod.yaml file which is then passed to the kubectl CLI to initialize the pod and maintain its desired state.

The pod.yaml file specifies the containers that compose a pod. Each container works on top of a docker image that it runs once instantiated. We shall use the spamdetection image for our container that we created by dockerizing our application and pushing the image to the repository. By default, kubernetes searches for image tags specified in the pod.yaml file on docker's public repository. If the matching image is found, the pod is created successfully or it results in a pod failure.

Once the semantics of a pod are fixed we can use kubectl to instantiate the pod. We can also use 'kubectl apply' if we wish to make changes to the definition of the pod and want the implementation to reflect it.

```
kubectl create -f pod.yaml
```

**Fig. 17.** Creating a pod

kubectl provides 'get XXX' commands to query status of any type of object in the system. We can check the status of our pods by using the API's get pods command.

```
$ kubectl get pods
NAME                READY    STATUS    AGE
spamdetectionimage  0/1     Running   46s
```

**Fig. 18.** Status of pods in the cluster

To get a detailed view of each element we can use the 'describe <element\_name>' command where <element\_name> is unique under each type of component in the system.

#### 5.4.3. Creating a deployment

Similar to creating a pod, a deployment can be created in Kubernetes using the same yaml file syntax. The only notable difference in this case is the value of the 'type' and the 'apiVersion' field in the yaml file. The 'type' field is set to 'deployment' in case of creating a deployment while the apiVersion field is set to 'extension/v1beta1' as version 'v1' which was used for pod creation does not support deployments. With the deployment file, we have the flexibility of specifying the number of replicas we want to deploy. We set the number of replicas to 2, which

means that kubernetes will ensure that at any given point in time the system will have 2 replicas of our application running. After defining the number, we define the containers whose replicas we wish to maintain.

```
apiVersion: extensions/v1beta1
kind: Deployment
metadata:
  name: spamdetectionapplication
spec:
  replicas: 2
  template:
    metadata:
      labels:
        app: echo
    spec:
      containers:
      - name: container2
        image: rahpsing/kubernetesi524:spamdetection
          application
        ports:
        - containerPort: 80
```

**Fig. 19.** Deployment file of the application

kubectl command to create a deployment is the same as the one we used to create a pod. The Kube Control API parses the yaml file and understands the type of object it is expected to create.

As with pods, the command to list the deployments running on the cluster is 'kubectl get deployments'. Now that our deployment is created we can check its status by using various kubectl commands. As we set the number of replicas to be 2, there should be atleast 2 pods running our application which can be verified as below.

```
$ kubectl get pods
NAME                                READY   STATUS
spamdetectionapplication-1         1/1     Running
spamdetectionapplication-2         1/1     Running
```

**Fig. 20.** Deployment with 2 replicas

**5.4.4. Fetching the application output**

As stated previously, a pod is a collection of multiple related containers. Our application executes in of the containers within the pod. Since our application prints output to the console, we shall be able to view it by accessing logs of the relevant pod.

```
kubectl get pods | grep spamdetectionapplication*

kubectl logs <pod_name>
```

**Fig. 21.** Fetching logs for the application

As each pod is hosted on a separate node with a unique ip address, we can issue a curl or a wget request to the node to fetch the output. Since our application output spans over multiple lines we shall redirect and save the output to a file so that it can be referenced at any point of time with ease.

```
curl https://<node_ip>:<node_port>/containerLogs/
default/<pod_name>/spamdetectionapplication
--insecure > output.txt
```

**Fig. 22.** Saving container logs to a file

Following the above steps, the application output shall be available in the file 'output.txt' in the current directory.

**5.4.5. Scheduling pods on the master**

By default, kubernetes does not allow pods to be scheduled on the master node for security purposes. However, this setting can be overridden by removing the taint on the master node and allowing pod execution.

```
kubectl taint nodes --all node-role.kubernetes.io/
master-
```

**Fig. 23.** Command to schedule pods on the master

Execution of the above statement shall remove the taint 'node-role.kubernetes.io/master' from all the nodes in the network including the master node and thus allowing the scheduler to schedule pods across the network [19]. This feature also allows us to create a single node cluster.

**6. CLASSIFICATION RESULTS**

After running all the algorithms on our data file the following results were achieved.

Algorithm	Classification Accuracy (%)
SVM Linear Kernel	93.58
SVM Polynomial Kernel	92.12
SVM Radial Kernel	93.72
Naive Bayes Classifier	91.76
Ada Boost	93.9

**Fig. 24.** Classification results

**7. ISSUES TACKLED WITH KUBERNETES SETUP AND DEPLOYMENT**

**7.1. ImagePullBackOff**

```
$ kubectl get pods
NAME            READY   STATUS             RESTARTS
myapplication   0/1     ImagePullBackOff   21
```

**Fig. 25.** The ImagePullBackOff error

The ImagePullBackOff error indicates that the container was unable to fetch the desired image from the repository specified. This happens in case of improper tag names associated with the application image or reference to a repository that doesnt exist. By default, any text specified against the 'image' key in the pod or deployment file makes a direct lookup on dockerhub. Thus

any docker image that has been built on the system cannot be referenced by the kubernetes engine unless it is tagged and uploaded to a public repository on dockerhub. Dockerhub allows users to create public repositories for no charges. Thus, the only way to use your custom created image is to register for an account on dockerhub, create a public repository, upload your local image with a unique tag name and use the repository and tag name in the yaml file. This issue took a lot of our development time as there is no clear documentation which explicitly describes the kubernetes interpretation of the value of the 'image' key specified in the pod yaml file.

### 7.2. CrashLoopBackOff

```
$ kubectl get pods
NAME          READY   STATUS             RESTARTS
myapplication 0/1     CrashLoopBackOff 49
```

Fig. 26. The CrashLoopBackOff error

Kubernetes allows us to execute instructions after a container has been deployed successfully. The output of these instructions is visible in the container's logs which can be accessed by using the 'get logs' primitive of the kubectl CLI. Commands to be executed can be specified under the 'args' key of the container specification in the pod definition file. However, kubernetes defines strict parsing for those arguments with no pointers to indicate where the execution failed. Any issues with the yaml file shall trigger a crashloopbackoff error with no traces of line numbers or clear log messages to guess what went wrong. It was after considerable research and trial and error that we figured out that an extra space between arguments to the sleep command was causing the error.

### 7.3. Kube DNS service not working

```
$ kubectl get pods --all-namespaces
NAME                                     READY   STATUS
etcd-rahpsing-056                       1/1     Running
kube-apiserver-rahpsing-056              1/1     Running
kube-controller-manager-rahpsing-056    1/1     Running
kube-discovery-2849056221-5xws4         1/1     Running
kube-dns-2247936740-m9198               0/3     Container
                                           Creating
```

Fig. 27. Failure of the kube-dns service

Kubedns is an integral part of the kubernetes master setup as it enables pods to communicate with each other. Before creating any pods or deployments we need to setup a pod-network. The pod network defines security policies and establishes networking within the cluster. Kubernetes provides various addons to be used as its pod network. We tried to use *flannel* but were unable to bind it to our network and get the dns service working. After numerous attempts we figured out that *weave-net* is the best pod-network that we could use as its network was updated to work with the CNI networking policy introduced in Kubernetes 1.4. Also, using *weave net* as our pod network allows us to use the *weave-kube* service where we can observe our cluster components and their configurations on a GUI accessible by a web browser.

### 7.4. Unsuccessful download requests from within a kubernetes pod

Initially, our R application program started with many download and install-package statements as we needed several text mining packages to implement the respective algorithms. Even after successful deployment, we couldn't find the application output in the container logs. It took us a fair amount of time to figure out that something wasn't working correctly as the pod logs failed to highlight the issue. To debug in deeply, we started deploying applications with simple print statements to check their behavior. After several attempts, we could draw a conclusion that deployment would result in a failure if the program included package import statements that needed to be downloaded from an external repository. We ran the same application image with docker only to find it working perfectly. Thus, we could state that, from within a kubernetes pod, an application is unable to reach the network and download the desired packages. We could find no precise explanation of this behavior on the kubernetes forum or issues opened on stack overflow or kubernetes git page.

As a workaround, we segregated the download statements from the R program and included it within our docker file. This modification would download and install the R libraries and packages as a part of the build process of the docker image, eliminating the need to install it post deployment. With the dependent libraries as a part of the docker container, the application program would run successfully and generate the output as a part of the logs for the pod it is associated with.

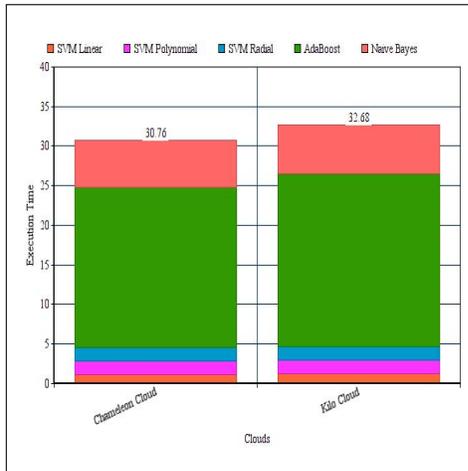
## 8. BENCHMARKING RESULTS

Application benchmarking was accomplished by executing the application on a kubernetes cluster with two nodes on both chameleon and kilo clouds. To observe execution time of different algorithms, we inserted checkpoints in the R application to measure time taken by each algorithm on different clouds. We referred to the application output file to get the runtime of all 5 algorithms on our dataset.

Algorithm	Chameleon cloud execution time (seconds)	Kilo cloud execution time (seconds)
SVM Linear Kernel	1.15	1.22
SVM Polynomial Kernel	1.68	1.72
SVM Radial Kernel	1.75	1.78
Ada Boost	20.25	21.75
Naive Bayes	5.93	6.21

Fig. 28. Algorithm execution time on Chameleon and Kilo cloud

Further, the stopwatch command on CMD5 module was used to benchmark execution time of kubernetes cluster creation, software deployment and installation on both chameleon and kilo cloud. By segmenting the all-round application runtime into software installation, cluster creation and code deployment



**Fig. 29.** fig: Graph plot of algorithm execution time on chameleon and kilo clouds

we can clearly observe the performance of the cluster on each cloud.

## 9. DISCUSSION

TBD

## 10. CONCLUSION

TBD

## 11. ACKNOWLEDGEMENT

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## 12. APPENDICES

TBD

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# Big data Visualization with Apache Zeppelin

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**Apache Zeppelin is an open source notebook for data analytics and visualization. In this project Apache Zeppelin is used to deploy and do visual data analytics by taking advantage of parallel computing capabilities of Spark in multiple cloud environments.**

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**Keywords:** Zeppelin, Apache, Big data, Visualization

<https://github.com/cloudmesh/sp17-i524/blob/master/project/S17-IR-P008/report/report.pdf>

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## 1. INTRODUCTION

Interactive browser-based notebooks enable data engineers, data analysts and Data scientists to be more productive by developing, organizing, executing, and sharing data code and visualizing results without referring to the command line or needing the cluster details. Notebooks allow these users not only allow to execute but in order to interactively work with long work-flows There are a number of notebooks available with Spark. Although IPython remains a mature choice and great example of a data science notebooks, it has certain limitations when used for visualizations with spark which are fulfilled by Apache Zeppelin.

Apache Zeppelin[1] is a upcoming web-based notebook which brings data exploration, visualization, sharing and collaboration features to Spark. It supports Python and also has a growing list of programming languages such as Scala, Hive, SparkSQL, shell and markdown.

It is a completely open web-based notebook that enables interactive data analytics used for data ingestion, discovery, analytics, visualization and collaboration. It has built in Spark integration and supports multiple language backends like Python, Hadoop HDFS, R etc. Multiple languages can be used within same Zeppelin script and share data between them. In this project we deployed Zeppelin along with in built Spark and backend languages R and Python across cluster using Ansible. Then installed additional visualization packages provided by Apache Zeppelin Helium[2] APIs.

We also loaded a data set into Spark across cluster and perform data analytics and visualization in cloud using Zeppelin. However since the goal of this class project is focus on deployment of Big data software across multiple machines and benchmarking the time for deployments, we focused more on that through out the paper and gave less importance to the analytics that are performed after the deployment.

## 2. INFRASTRUCTURE

The deployment of Apache Zeppelin is done on two clouds. The clouds selected for the purpose of this project are

1. Chameleon Cloud
2. JetStream Cloud

### 2.1. OpenStack

OpenStack[3] is a cloud operating system that controls large pools of compute, storage, and networking resources throughout a data center, all managed through a dashboard that gives administrators control while empowering their users to provision resources through a web interface. It was created as joint project between NASA and Rackspace that is currently managed by OpenStack Foundation. It is open source software released under the Apache 2.0 license.

Both Chameleon cloud and JetStream use OpenStack. OpenStack is a free, open source cloud computing platform primarily deployed as IaaS.[4]

### 2.2. Chameleon Cloud

Chameleon Cloud[5] provides a large-scale platform to the open research community allowing them to explore trans-formative concepts in deeply programmable cloud services, design and core technologies. It is funded by the National Science Foundation. The testbed of Chameleon Cloud is hosted at the University of Chicago and Texas Advanced Computing Center and the University of Chicago. Chameleon provides resources to facilitate research and development in areas such as Infrastructure as a Service, Platform as a Service, and Software as a Service. Chameleon provides both an OpenStack Cloud and Bare Metal High-level Performance Computing Resources[6].

### 2.3. JetStream Cloud

Jetstream is led by the Indiana University Pervasive Technology Institute (PTI), will add cloud-based computation to the national cyberinfrastructure. Researchers will be able to create virtual machines on the remote resource that look and feel like their lab workstation or home machine, but are able to harness thousands of times the computing power. Jetstream will provide the following core capabilities use Virtual Machines interactively, Researchers and students can move data to and from Jetstream using Globus transfer[7], use virtual desktops and publish VMs with a Digital Object Identifier(DOI)[8].

### 2.4. Virtual Machine Specifications

A brief comparison of multiple attributes of the clouds discussed above are shown in the table 1.

Clouds	Chameleon	Jetstream
CPU	Intel Xeon X5550	Dual Intel E-2680v3 "Haswell"
RAM	4 GB	2 GB
Number of CPU's	1	1
CPU Cores	1	1
CPU Speed	2.3 GHz	2.3 GHz

Table 1. Comparison of cloud vendors

## 3. APACHE ZEPPELIN

Apache Zeppelin is Apache project under open-source license Apache 2.0. It aims to provide a web interface to analyze and format large volumes of data processed via spark in a visual and interactive way. It is a notebook style interpreter that enables collaborative analysis sessions sharing between users. Zeppelin is independent of the execution framework itself. Current version run on top of Apache Spark but it has pluggable interpreter APIs to support other data processing systems. More execution frameworks of type SQL-like backends such as Hive, Tajo, MRQL can also be added.

### 3.1. Background

Large scale data analysis workflow includes multiple steps like data acquisition, pre-processing, visualization, etc and may include inter-operation of multiple different tools and technologies. With the widespread of the open source general-purpose data processing systems like Spark there is a lack of open source, modern user-friendly tools that combine strengths of interpreted language for data analysis with new in-browser visualization libraries and collaborative capabilities.

Zeppelin initially started as a GUI tool for diverse set of SQL-over-Hadoop systems like Hive, Presto, Shark, etc. It was open source since its inception in Sep 2013. Later, it became clear that there was a need for a greater web-based tool for data scientists to collaborate on data exploration over the large-scale projects, not limited to SQL. So Zeppelin integrated full support of Apache Spark while adding a collaborative environment with the ability to run and share interpreter sessions in-browser.

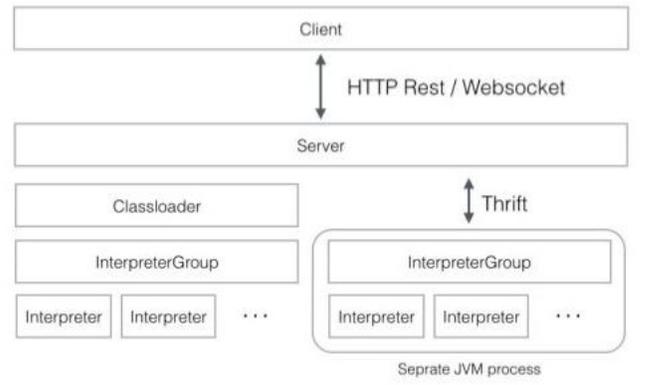


Fig. 1. Zeppelin Architecture

### 3.2. Zeppelin Features

Currently, Apache Zeppelin multipurpose notebook supports the following functionalities.

1. Data Ingestion
2. Data Discovery
3. Data Analytics
4. Data Visualization
5. Collaboration

### 3.3. Zeppelin Architecture

#### 3.3.1. Client

Apache Zeppelin is a client based application. Analytics can be done with latest version of modern browsers. Anyone with details of the host details, port on which zeppelin is listening and access to the zeppelin interpreter can execute or view the notebooks.

#### 3.3.2. Server

Apache Zeppelin is a web-server based application. Zeppelin listens on a port and application communicates to server through this port. This server-client based architecture facilitates sharing of notebooks and collaboration.

#### 3.3.3. Classloader

Classloader loads the essential classes and configuration for running of Zeppelin. This also loads spark context as base interpreter. This loads additional interpreter and their classes when the new interpreters are configured and saved.

#### 3.3.4. Multiple Language Backend

Apache Zeppelin interpreter concept allows any language/data-processing-backend to be plugged into Zeppelin. Currently Apache Zeppelin supports many interpreters listed below

1. Apache Spark
2. Python
3. JDBC
4. Markdown
5. Shell

Adding a new language backend is simple and shown in the next sections

### 3.3.5. Apache Zeppelin Interpreter

Apache Zeppelin interpreter is a language backend. For example to use python code in zeppelin, it is needed to have a python interpreter. Every interpreter belongs to an InterpreterGroup. Interpreters in the same InterpreterGroup can reference each other. For example SparkSqlInterpreter can reference SparkInterpreter to get the SparkContext from it while they're in the same group.

InterpreterSetting is configuration of a given InterpreterGroup and a unit of start/stop interpreter. All interpreters in the same InterpreterSetting are launched in a single, separate JVM process. The interpreter communicates with Zeppelin engine via Thrift.

### 3.3.6. Create your own Interpreter

To create a new interpreter we need extend `org.apache.zeppelin.interpreter` class and implement some methods. We can also include `org.apache.zeppelin:zeppelin-interpreter:[version]` artifact in our build system and put the jars under the interpreter directory with a specific directory name. Zeppelin server reads interpreter directories recursively and initializes interpreters including the new interpreter that is recently added.

There are three locations where you can store your interpreter group, name and other information. Zeppelin server tries to find the location below. Next, Zeppelin tries to find `interpreter-setting.json` in your interpreter jar.

```
zeppelin_interpreter_dir/your_own_interpreter_dir/
interpreter-settings
```

## 4. DEPLOYMENT

Zeppelin works with Spark deployed across clusters. To deploy Zeppelin and Spark across clusters, Ansible and cloudmesh client integrated with python CMD is used. Refer our code for implementation. Each component and their brief usage is explained in this section.

### 4.1. Cloudmesh Client

Cloudmesh client is a command line based tool to access and manage multiple cloud environments. Cloudmesh client can also be used to define security group and monitor cloud environments. Cloudmesh client is used in the project to boot, delete and define security group to enable firewall settings.

### 4.2. Ansible

Ansible is an automation tool to automate application deployment, maintenance and configuration management. Ansible is used to deploy jdk, openssh, spark and zeppelin across instances that are boot using cloudmesh client.

Ansible playbook is used to write and execute automated deployment. To deploy zeppelin and spark, playbooks are created with different roles like zeppelin, spark, ssh, jdk, start and stop tasks for each cloud with different variable files. Each variable file have cloud specific environment variables like cloud user, home folder and permissions for directory etc. Along with the variable files and separate role files, an individual playbook that calls start and stop tasks for zeppelin and spark. This is required to launch individual roles like start and stop to be executed through command line.

The playbook developed for deploying spark and zeppelin is configured to install pre-built version of spark and zeppelin instead of building from the code. Ansible downloads the prebuilt version and extract it. Then the extracted version is configured

for cluster by setting the IP values of master and slaves of the cluster.

Version of Zeppelin and spark is configured in a variables file to make it easy to customize any version of spark or zeppelin. Ports on which zeppelin and spark listens could be configured in the same along with the locations in which the spark and zeppelin need to be installed.

### 4.3. Security - Cross SSH

In order for spark master and slaves to communicate, zeppelin to communicate with spark master cross SSH need to be enabled between all nodes in the cluster. This is achieved by creating a SSH public and private keys. The private key is encrypted using 'Ansible-valut' and stored in code repository. Then at deployment time same private and public key are distributed across cluster using ansible with decryption.

### 4.4. Putting to gether with CMD

### 4.5. Accessing applications

Python CMD is used to build a command line like interface to put cloudmesh client and ansible together. This interfaces with cloudmesh client to boot cloud instances with required security group and deploy applications using ansible.

Python CMD interface takes number of instances required to boot and launches the number of instances by using cloudmesh client. Once the instances are booted, the details of the instances are stored into an inventory file and config files. Now using the generated inventory and config file ansible playbook is launched. The interface has options to set cloud and user details.

This interface also has capability to deal with local network ip and floating IP based deployment. This enables in-network deployment by using less scarce resources without creating floating IP address. To do this we could set master ip through interface and cloud based spark-zeppelin infrastructure with master-slave using only one floating IP.

The interface also can be used to start and stop zeppelin and/or spark. It calls respective ansible playbooks to execute the task by using the inventory files created earlier.

Zeppelin Notebook is accessible via latest version of browsers like Firefox or Chrome. Zeppelin is configured to listen on port 8080 and Spark UI is available on port 8082 of master instance. By launching the master ip and port 8080, Zeppelin is launched and Spark master instance can be configured in Zeppelin. Now Zeppelin is ready to do visual analytics by taking advantage of Spark parallel computing capability.

Spark applications can also be launched using the command line interface created. This invokes start-all utility of spark to launch master and worker nodes. It is useful in the instances where spark need to run as application instead of using Zeppelin for only analytics.

### 4.6. Boot and Deployment Time

The interface prints time taken to boot the instances and time taken to deploy the application across all the nodes. The time printed are used for benchmarking the deployment. Booting happens in sequence as Chameleon cloud supports sequential booting operations only. Once booting is completed the deployment is done in parallel across different machines in cluster. Refer to the benchmarking section for the time took to deployment time on different clouds.

## 5. DATASET DESCRIPTION

This is real-world dataset[9] collected from a Portuguese marketing campaign related with bank deposit subscription. The business goal is to find a model that can explain success of a contact, i.e. if the client subscribes the deposit. Such model can increase campaign efficiency by identifying the main characteristics that affect success, helping in a better management of the available resources (e.g. human effort, phone calls, time) and selection of a high quality and affordable set of potential buying customers.

The increasingly vast number of marketing campaigns over time has reduced its effect on the general public. Furthermore, economical pressures and competition has led marketing managers to invest on directed campaigns with a strict and rigorous selection of contacts. Such direct campaigns can be enhanced through the use of Business Intelligence (BI) and Data Mining (DM) techniques.

In the benchmarking section we have used three codes to benchmark the Zeppelin software that we have deployed on the Chameleon and Jetstream clouds. All the codes run on the same data set and written in SQL. The code is explained in more detail in the visualization section below

## 6. BENCHMARKING

There are 2 different approaches used in benchmarking which are used for the deployments on clouds where the deployment has been done. They are as follows

1. Deployment Benchmarking
2. Analytical Benchmarking

### Deployment Benchmarking

This benchmarking deals with the time taken for deploying Apache Zeppelin across machines. Graphs are plotted to visualize the time taken for deployment of Apache Zeppelin with number of machines on x-axis and time taken on the y-axis. The command line script also includes code to record the time taken for the deployment. When the VM's are booted inside the command line wrapper the results also include the amount of time taken to deploy Apache Zeppelin on the virtual machines. The time taken for deploying Apache Zeppelin on different number of machines can be recorded and plotted on a graph to show analyze the increase in amount of time as the number of machines increases. Ideally it is expected that the graph in the curve flattens out as with increase in the number of machines.

Various factors that influence the deployment benchmarking are as follows.

1. The dependencies that need to be installed on all machines in order to deploy the software.
2. The network traffic can effect the time taken for deployment. For example a bad network might introduce delay in downloading the software on to the machines.
3. The number of machines the software has to be deployed on.

### Analytical Benchmarking

This benchmarking deals with the time taking for running the analytics on clouds. The same analytics are performed on all clouds on which Apache Zeppelin was deployed and the performance is plotted on graphs

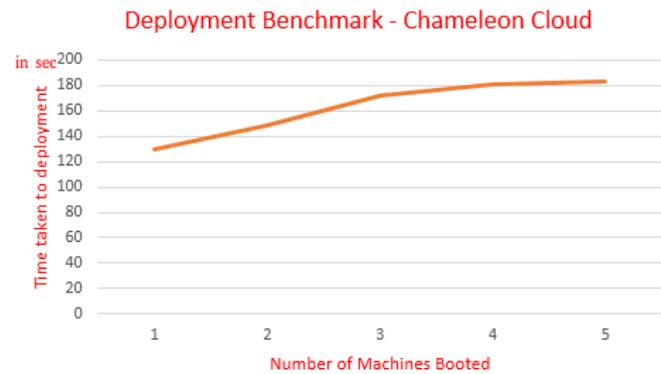


Fig. 2. Jetstream Deployment Benchmarking

Various factors that influence the analytical benchmarking are as follows.

1. The size of the data set that the scientist is working on. As the size of the data set it take more time to download the data set and split it across machines.
2. The way the machines are configured. If all the machines lie on the same hardware then the network over head is largely reduced decreasing delays in processing.
3. The complexity of the algorithm. A highly complex algorithm can take longer time time than a simpler algorithm.
4. The size of data set can also effect the running as the algorithm time complexity will increase with the size of the dataset.

Since Cloudmesh client doesn't allow parallel boot of virtual machines the boot time is neglected in the deployment benchmarking

### 6.1. Chameleon Cloud

The Benchmarking for on Chameleon Cloud is done and explained in detail the below 2 sections. The benchmarking is only performed after all the machines are successfully booted and ready for deployment.

#### 6.1.1. Deployment Benchmarking

Once all the machines are boot the ansible-playbook script is started automatically and the time taken to deploy Apache Zeppelin on the machines is clocked before the start of the deployment and after the end of the deployment. The difference of the end time and start time is the total deployment time. The graph for deployment benchmarking on chameleon cloud explains the various times taken to deploy Apache Zeppelin across machines with changes in the number of machines on Chameleon Cloud.

The time taken for deployment on a single machine is the lowest of all and the time taken for deploying more machines increases with the number of machines. However the graph also starts to flatten out after five machines. Since the deployment is done using ansible playbook the process is parallelized and all the softwares are installed at the same time across all the machines. This process is reflected in the deployment graph shown for chameleon cloud.

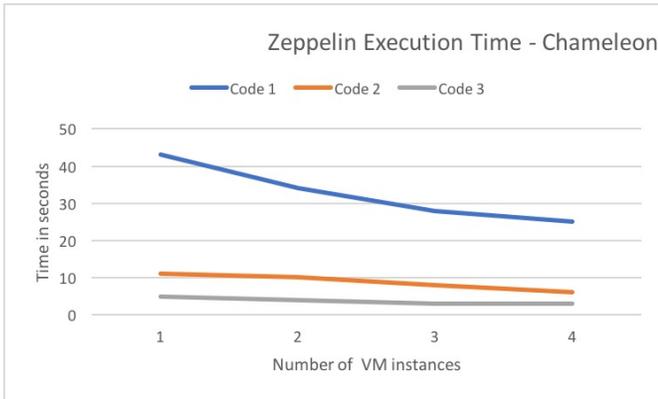


Fig. 3. Chameleon Analytics Benchmarking

6.1.2. Analytical Benchmarking

After the deployment of Apache Zeppelin on Chameleon Cloud, the code for the analytics is run on the Apache Zeppelin and the run time is clocked. The run time to process and generate the visualizations is plotted on the y-axis and the number of VMs in the cluster is given on the x-axis. The table below explains this in detail.

Table 2. Analytical Benchmarking Chameleon Cloud  
Time taken to run codes Vs Machines Count

VM Count	Code#1	Code#2	Code#3
1	43	11	5
2	34	10	4
3	28	8	3
4	25	6	3

6.2. Jetstream Cloud

Similar to Chameleon Cloud, in Jetstream also cloudmesh allows only serial booting of VMs. Hence the boot time of the VMs is ignored in the process of benchmarking the deployments on the Jetstream Cloud.

6.2.1. Deployment Benchmarking

The benchmarking in the Jetstream case is similar to that of the deployment in the Chameleon cloud. The same ansible-playbook script is started automatically and the time taken for deployments are recorded similarly. The below graph explains the amount time taken to deploy Apache Zeppelin on Jetstream cloud when the number of machines are varied.

From the Jetstream deployment benchmarking figure it can be seen that the time taken for deploying zeppelin across virtual machines stops to grow and flattens out as the number of virtual machines start to increase. It can also be noted that there is an increase in the number time taken for deployment the number of virtual machines is less than 4. The primary reason for this initial increase due the additional overhead the master node has to handle for setting up communication with the worker nodes

6.2.2. Analytical Benchmarking

Similar to the analytical benchmarking in the chameleon we also performed the same experiment on Jetstream cloud. The results

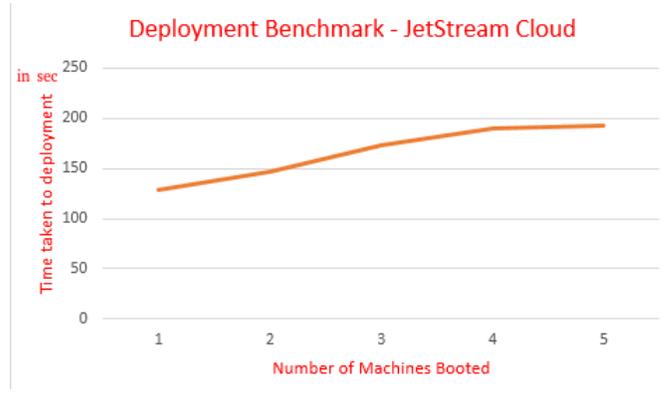


Fig. 4. Jetstream Deployment Benchmarking

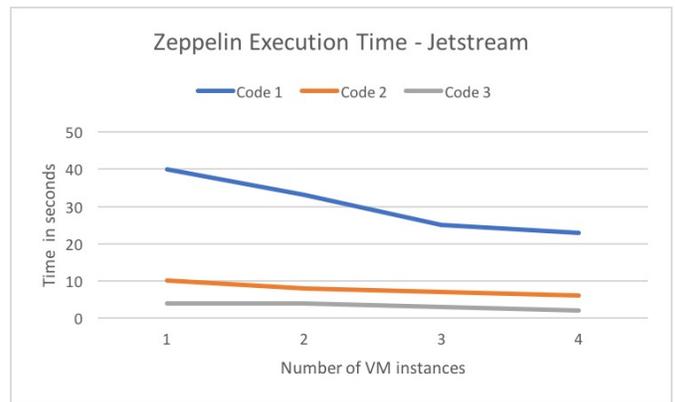


Fig. 5. Jetstream Analytics Benchmarking

are presented in the table below.

Table 3. Analytical Benchmarking Jetstream Cloud  
Time taken to run codes Vs Machines Count

VM Count	Code#1	Code#2	Code#3
1	40	10	4
2	33	8	4
3	25	7	3
4	23	6	2

Analytics deployment shows a slight decrease in time as number of nodes increased.

7. VISUALIZATION WITH ZEPPELIN

All the codes for visualization are written in SQL on Zeppelin. Zeppelin has options to change the type of plots in a click and better present the results. The basic features of zeppelin are presented below through the code examples.

7.0.1. Code 1

This piece of code counts all the people who are below the age of 30, groups them age and then orders the counts by age. The plot below shows this in detail.

```
select age, count(1) value
```

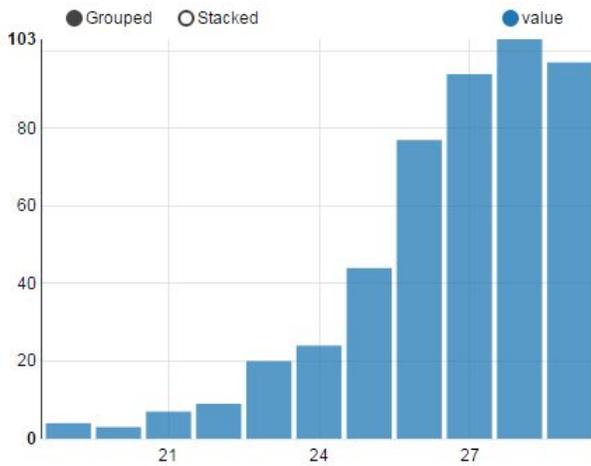


Fig. 6. Histogram/ Bar Chart

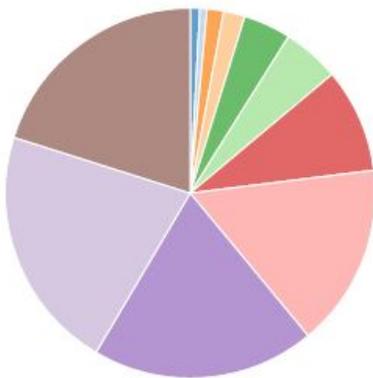


Fig. 7. Pie Chart

```
from bank
where age < 30
group by age
order by age
```

A few of the different Types of Visualizations on the same code can be seen the figures below and many others can be explored at on Zeppelin basic tutorials available inbuilt in the Zeppelin notebook. The figures 4, 5 and 6 show how Zeppelin plots Bar Chart, Pie Chart and Line Charts on the Bank data described above.

**7.0.2. Code 2**

```
select age, count(1) value
from bank
where age < ${maxAge=30}
group by age
order by age
```

In this code above the maxAge parameter acts as an place holder and accepts an user input which is an integer. After the system process the user input then the place holder is replaced

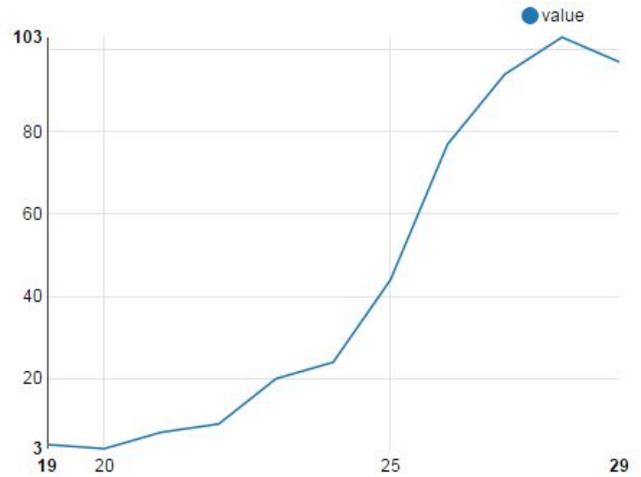


Fig. 8. Line Chart

by the input values and Zeppelin executes the code and presents the results.

**7.0.3. Code 3**

The user input can also be a string and it shown in the code below. Below code takes a string as input and processes the query based on the input received

In the below query the records are picked based on the marital status column, grouped by the age column and then ordered by age to show the count of people on who and their age given their marital status.

```
select age, count(1) value
from bank
where marital=${marital=single,single|divorced|married}
group by age
order by age
```

**8. SUPPLEMENTAL MATERIAL**

Apache Zeppelin is Quick start tutorials are available on the Apache Zeppelin webpage[10] and can be accessed for free of cost. There are also other Zeppelin works available in the form of notebooks on Zeppelin hub[11].

**9. CONCLUSION**

We are successfully able to deploy Apache Zeppelin across clouds with varying number of machines. The deployment time flattens out after four clusters in both Chameleon and Jetstream clouds. The time taken to run similar zeppelin analytic queries on both clouds are almost similar when the other parameters are fixed.

**10. EXECUTION PLAN**

The following subsections act as a timeline regarding how we broke the project up week-by-week in order to complete the entire project by the desired deadline. This project execution plan is a final draft of the project was implemented during the second half of the semester.

### 10.1. March 6,2017 - March 12,2017

This week we discussed about the planned how to implement the project in and came up with approximate deadlines for tasks. We have also revisited the tutorials on the class webpage and referred to official documentation of Apache Zeppelin and came up with a workflow for implementing this project.

### 10.2. March 13,2017 - March 18,2017

This week we have installed Cloudmesh on our local machines, completed the tutorials on Cloudmesh present on the class website. We have also accessed on chameleon cloud accounts to boot Virtual Machines on cloud and logged in successfully into the Virtual Machines.

We have discussed about building a command shell through which we can deploy the clusters with less effort. Hence we looked completed the tutorials on CMD and CMD5 available on the class website. This tutorials have helped us in coming up with a basic outline of the shell that we should develop in order to meet the requirements for deploying Apache Zeppelin on various clouds. We have made a decision to use CMD module in python for this purpose.

### 10.3. March 19,2017 - March 26,2017

During this week we have completed the development of the command shell which can start a given number of virtual machines are return their details like the machine name, floating IPs, Static IPs to a file. Other methods like delete, setCloud, getStaticIps, getFloatingIps are also included in the command shell developed over the week. The description for all methods is documented and can accessed from with the shell.

We have discussed the over the deployment of Apache Zeppelin and came up with the dependencies that need to installed on the machines before zeppelin in deployed on to them. We have revisited the ansible tutorials on the class website as we will using ansible to deploy Apache Zeppelin on various clouds

### 10.4. March 27,2017 - April 2,2017

Developed and tested code to deploy the Apache Zeppelin on the clusters. Upon successful deployment we have opened ports so that Apache Zeppelin can be accessed through web-interfaces.

### 10.5. April 10,2017 - April 16,2017

Integrated the deployment code into the command shell developed previously and tested the deployment chameleon cloud. We have ran into issues with security and VM accessibility. We have fixed the below issues over the week.

1. Fixed deployment issues that might arise to lack of availability of floating point IPs on the chameleon cloud.
2. Fixed security issues and checked if the notebook is accessible through the external web-browsers.

During the week we have also worked on analytics which can be performed on the Apache Zeppelin that has been previously installed on the cloud from a web-page on in external machine. More details about the analytics are discussed in the analytics section below.

### 10.6. April 17,2017 - April 23,2017

Review of deployment and developing the final draft of the report for submission.

## ACKNOWLEDGEMENTS

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**Veera Marni** received his Bachelors in Technology in Electronics and Communication from SRM University, India and will be receiving his Masters in Data Science from Indiana University in Dec 2017. His research interests are Machine Learning and Big Data. He will be working as Data Scientist intern at Proteous Digital

Health during the summer 2017.

## 11. WORK BREAK DOWN:

**Naveenkumar Ramaraju** is responsible for the following

- Ansible scripts for deployment
- Benchmarking on Jetstream

**Veera Marni** is responsible for the following

- Python wrapper using CMD
- Benchmarking on Chameleon
- Zeppelin notebook

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# Cloudmesh Docker Extension

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S17-IR-P009, September 21, 2017

Cloudmesh client is a simple client to enable access to multiple cloud environments from a command shell and command line. The users can manage their set of resources right from their workstation. Currently, cloudmesh client supports managing Virtual Machines across multiple clouds. In this project, we have added the capability to manage/provision docker and swarm containers to the cloudmesh client through a simple and extensible command line interface.

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**Keywords:** Cloud, I524

Report: <https://github.com/cloudmesh/sp17-i524/blob/master/project/S17-IR-P009/report/report.pdf>

Code: <https://github.com/cloudmesh/cloudmesh.docker>

## 1. INTRODUCTION

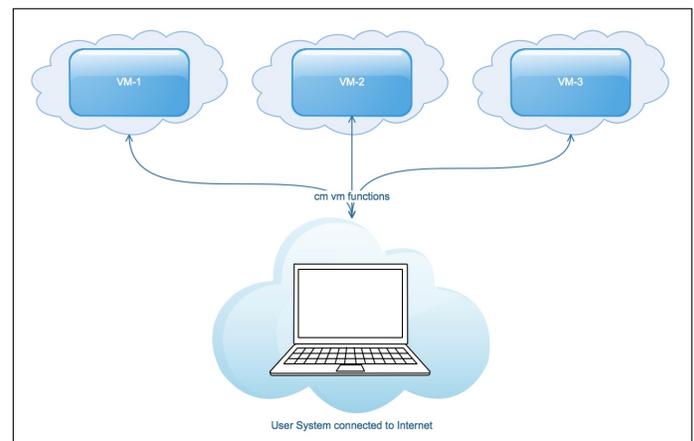
Docker is an open platform for developing, shipping, and running applications. Docker enables to separate the applications from infrastructure so that we can deliver software quickly. With Docker, one can manage the infrastructure in the same ways we manage our applications[1].

Docker provides the ability to package and run an application in a loosely isolated environment called a container. The isolation and security allow running many containers simultaneously on a given host. Containers are lightweight because they don't need the extra load of a hypervisor, but run directly within the host machine's kernel. This means we can run more containers on a given hardware combination than if you were using virtual machines. We can even run Docker containers on host machines that are virtual machines.

Cloudmesh Client[2] capability is detailed in Figure 1, it aims at managing vm instances in multiple heterogeneous clouds remotely via a command line interface. In this project we have added the capability to provision and manage docker[1] containers and swarm[3] services to cloudmesh client[2].

### 1.1. Docker Mode

The key objects of Docker engine are images, containers and networks. An image is a read-only template with instructions for creating a Docker container. A container is a runnable instance of an image. The Docker Module built in cloudmesh docker application has the capabilities to manage Docker hosts and the underlying objects running on multiple remote VM's as shown in Figure 2.



**Fig. 1.** Cloudmesh client

### 1.2. Swarm Mode

A swarm[3] is a cluster of Docker engines, or nodes, participating in a cluster where we deploy services. The Swarm Mode of Docker orchestrates swarm services in standalone containers on Docker instances.

#### 1.2.1. Node

A node is an instance of the Docker Engine participating in the swarm. We can run one or more nodes on a single physical computer or cloud server.

To deploy the application to a swarm, we submit a service definition to a manager node. The manager node dispatches units of work called tasks to worker nodes.

Manager nodes also perform the orchestration and cluster

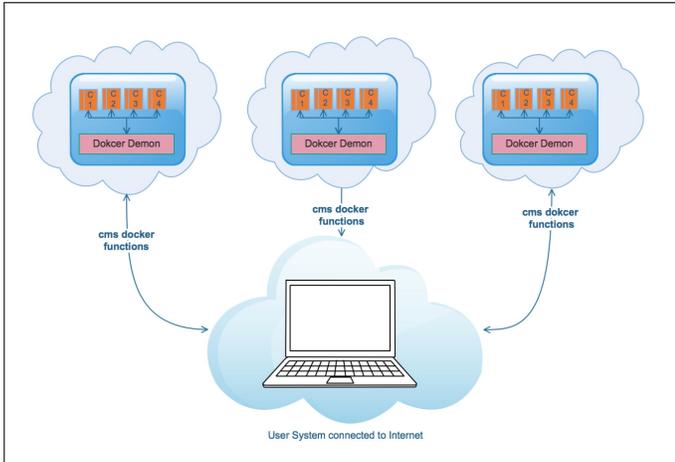


Fig. 2. Docker Module

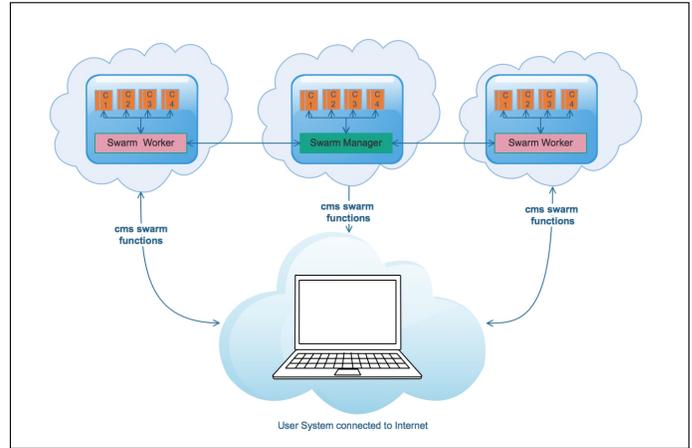


Fig. 3. Swarm Module

management functions required to maintain the desired state of the swarm. Manager nodes elect a single leader to conduct orchestration tasks.

Worker nodes receive and execute tasks dispatched from manager nodes. By default manager nodes also run services as worker nodes, but we can configure them to run manager tasks exclusively and be manager-only nodes. An agent runs on each worker node and reports on the tasks assigned to it. The worker node notifies the manager node of the current state of its assigned tasks so that the manager can maintain the desired state of each worker.

1.2.2. Services and Tasks

A service is the definition of the tasks to execute on the worker nodes. It is the central structure of the swarm system and the primary root of user interaction with the swarm. When we create a service, we specify which container image to use and which commands to execute inside running containers.

In the replicated services model, the swarm manager distributes a specific number of replica tasks among the nodes based upon the scale we set in the desired state.

For global services, the swarm runs one task for the service on every available node in the cluster.

A task carries a Docker container and the commands to run inside the container. It is the atomic scheduling unit of swarm. Manager nodes assign tasks to worker nodes according to the number of replicas set in the service scale. Once a task is assigned to a node, it cannot move to another node. It can only run on the assigned node or fail.

The Swarm Module built in cloudmesh.Docker application has the capabilities to create and manage a swarm cluster running of multiple remote VM's as shown in Figure 3.

1.3. Remote vs Local use

Users can choose to use cloudmesh docker application from a remote terminal outside the network of the data centre as in Figure 2 or locally from a provisioning or configuration server inside the data centre as in Figure 4. We have analysed this difference in the application usage in depth in the project and have provided detailed benchmark results for both modes of use.

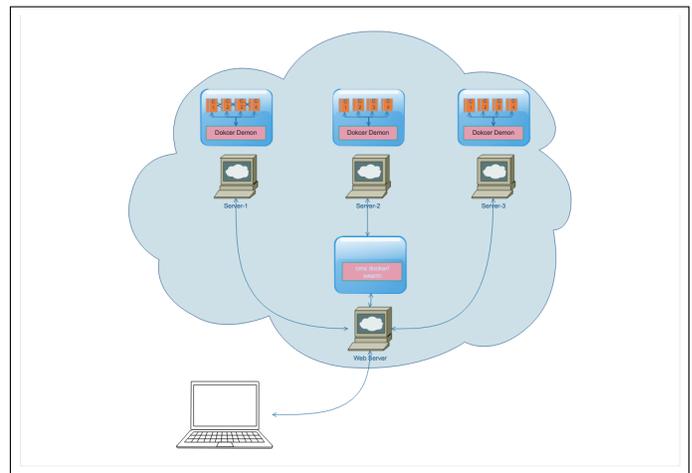


Fig. 4. Docker/Swarm Remote

2. CLOUDMESH DOCKER APPLICATION ARCHITECTURE

The architecture of the application is depicted in Figure 5. The commands developed can be broadly classified as 'action commands', 'Inquiry commands'. The action commands are which would create or alter an entity. The entity can be a host/container/node. We use the corresponding API call to get the latest values for the changed entity. Docker API module is developed for addressing the docker commands, and Swarm API module is used for swarm commands. The Inquiry commands have two flavours a list and refresh mode. The list commands fetch the data locally from the Database and the refresh command will refresh the current state of the corresponding entity from the hosts.

### 2.1. Technologies Used

Name	Purpose
docker [1]	Docker Server and Api for managing containers and services
mongodb [4]	Nosql DBMS
Python-eve [5]	Restful webservice interface to mongoDB
python [6]	Development
ansible [7]	Automated deployment

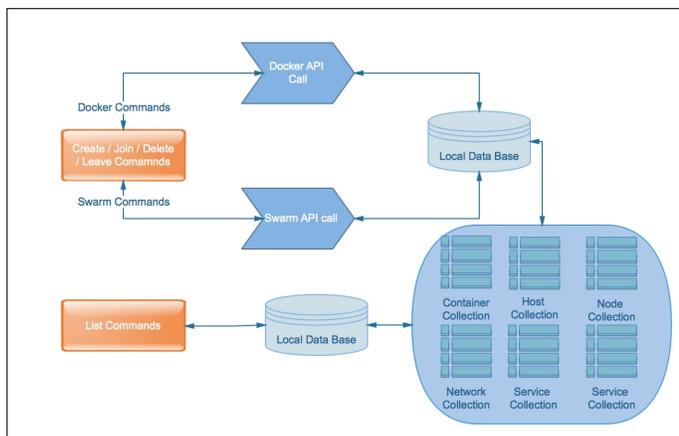
**Table 1.** Technology Name and Purpose

### 2.2. MongoDB and Python-eve

The cloudmesh docker application uses MongoDB[4] for data storage. The access to the database is all through restful services supported through Python-eve[5]. The following are the entities for which collections are defined in Eve and MongoDB.

1. Host
2. Image
3. Container
4. Network
5. Service
6. Node

A key benefit of using a NoSQL database like MongoDB is that it allowed us to store the data in the DB in the native form as returned by the Docker API without the need for much marshalling of the data.



**Fig. 5.** cloudmesh docker application architecture

### 2.3. Security

We have not yet fully baked in security aspects into the client. We propose that security between the various aspects of the application will be handled as below

1. The docker daemon on the remote Hosts / VM are to be exposed to be accessed by cloudmesh Docker application. We envision that there would be separate configuration machines either within the network of the user's infrastructure or outside which will have a secure access. The docker daemons will be configured to accept connections only from this remote host. Alternatively, if there are multiple configuration machines, then specific security groups need to be created between the client machine and each docker host for secure access.
2. The Python-eve client currently runs on a local machine and will accept connections only from the localhost from where the client is run. We also envision adding a user access control to the Python-eve services which will facilitate making the service and the Mongo DB to be deployed on a remote central server different from the client and allowing only authenticated users to use the application.

### 2.4. Cloudmesh Common

The application makes extensive use of common functions and tightly integrated into common functions available in the cloudmesh common repository for display formatting, YAML config management and timers

### 2.5. Ansible

As part of the project we have built Ansible[7] scripts to automate the installation of Docker in remote hosts and also deployment of Docker images in these remote docker hosts. Below is the list of Ansible scripts that are built and used in the project

1. Install Docker in remote hosts and enable them for remote API access
2. Install Docker images in Docker hosts. As part of the script, the local docker files are synced with remote hosts, and the images are built.
3. Setup /etc/hosts for remote hosts. This script allows to setup host names in remote hosts which allow the applications running on these hosts to be configured to access other applications on the network by the standard host names instead of the IP address.

### 2.6. Project Repository

The source code and the detailed deployment and use instructions are available at [8]

## 3. DOCKER COMMANDS

1. **Host Set/Add** This command will Set/Add the docker host on which the user wants to operate. The host details will be captured in the database with this command.
 

```
cms docker host docker1 docker1:4243
```
2. **Host List** This command will list the hosts available. The output would display the Ip, Name, Port, and if the host is swarm manager and the swarm manager Ip. Please note the Swarm manager Ip will be blank if the host is manager or not part of swarm.

```
cms docker host list
```

**Table 2. cms docker host list**

Ip	Name	port	Swarmmode	SwarmManagerIp
docker1	docker1	4243	Manager	
docker2	docker2	4243	Worker	docker1
docker3	docker1	4243	Host	

3. **Host Delete** This command will delete the host from the setup. This would also delete the host details from the database. User can do a host list to see the updated host details.

```
cms docker host delete docker1:4243
```

4. **Image List** This command will display the images available on the hosts available in the database. It would display the Ip of the host, the Image Id, repository and the size of the image. Please note that this command would display the results from the local dB.

```
cms docker image list
```

**Table 3. cms docker image list**

Ip	Id	Repository	Size(GB)
docker1	5545f4e3b27e	cloudmesh:docker	5.59
docker2	45f4e3b2799e	elasticsearch:swarm	0.45

5. **Image Refresh** This command would refresh the images across the hosts available. The results are updated to the local data base.

```
cms docker image refresh
```

6. **Container Create** This command will create a container on a given host. The arguments for this command is the name of the container and the image from which the container needs to be created. The image in the argument must be available through image list command above on the given host.

```
cms docker container create test1 \
elasticsearch:docker
```

7. **Container Start** This command will start a container. The container should have been already created using the create command.

```
cms docker container start test1
```

8. **Container Stop** This command will stop and container which is running.

```
cms docker container stop test1
```

9. **Container List** This command will display the list of containers running across the hosts. The output contains the Ip, Container Id, Name, Image, status and start time of the container. The details would be shown from the local database maintained.

```
cms docker container list
```

**Table 4. cms docker container list**

Ip	Id	Name	Image	Status	StartedAt
docker1	5545f4e3b27e	test1	image1	exited	12.00PM

10. **Container Refresh** This command will refresh the current state of the containers across the hosts. This application will connect to all the hosts available in the database and run the native Docker container list to get the latest information and update the local database for refreshing the data.

```
cms docker container refresh
```

11. **Container Delete** This command will delete the container on the host. The argument required is the container name. The updated container list can be viewed by running cms docker container list command.

```
cms docker container delete test1
```

12. **Container Run** This command will create and run a container in one step. The arguments for the function are the name of the container and the image from which it needs to be run.

```
cms docker container run test1 /
elasticsearch:docker
```

13. **Container Pause** This command will pause the container which is currently running.

```
cms docker container pause test1
```

14. **Container Unpause** This command will unpause the container which is currently paused.

```
cms docker container unpause test1
```

15. **Network Refresh** This command will refresh the network details across all the available hosts in the database and update the results to the local database.

```
cms docker network refresh
```

16. **Network List** This command will display the network details available in the local database. The output would display the host Ip where the network is established, the network Id , name and containers on the network.

```
cms docker network list
```

**Table 5. cms docker network list**

Ip	Id	Name	Containers
docker1	5545f4e3b27e	network1	test1

#### 4. SWARM COMMANDS

1. **Host Set/Add** The command will add or set the input host to the current host. The swarm commands following this command will be executed on the host setup in this step. The host details will also be captured in the database as part of this command.

```
cms swarm host docker1 docker1:4243
```

2. **Host List** This command will list the hosts available. It displays the Ip, Name, Port, and if the host is swarm manager and the swarm manager Ip. Please note the Swarm manager Ip will be blank if the host is manager or not part of swarm.

```
cms swarm host list
```

**Table 6. cms docker host list**

Ip	Name	port	Swarmmode	SwarmManagerIp
docker1	docker1	4243	Manager	
docker2	docker2	4243	Worker	docker1
docker3	docker1	4243	Host	

3. **Host Delete** This command will delete the host from the database and also the associate container, service, network and image objects of the host.

```
cms swarm host delete docker1:4243
```

4. **Image List** This command will display the images available on a host. It would display the Ip of the host, the Image Id , repository and the size of the image. Please note that this command would display the results from the local dB.

```
cms swarm Image list
```

5. **Swarm Create** This command will initialise the swarm mode on the current host. There are no arguments required for this command. After this command is run the current host would become the swarm manager.

```
cms swarm create
```

6. **Swarm Join** This command will join the current host to a swarm node either as a manager or a worker. User needs to setup a new current host with cms swarm host command and run cms swarm join so that current host would be joined with the swarm created. User needs to pass the address or host name of the swarm manager and the mode in which the current node will operate in the swarm.

```
cms swarm join docker3 docker4:4243 worker
```

( assuming docker3 is already a swarm manager)

7. **Swarm Leave** This command is applicable for the swarm manager or worker, this would remove the host from the swarm. If a manager has multiple workers, workers need to be removed (leave) before the manager can leave.

```
cms swarm leave
```

8. **Network Create** This command will create the network which can be used by the swarm containers later. The argument it needs is the name of the containers.

```
cms swarm network create network1
```

9. **Network List** This command will display the network details from the local database. The output will display the host Ip where the network is established, the network Id, name and containers on the network.

```
cms swarm network list
```

**Table 7. cms swarm network list**

Ip	Id	Name	Containers
docker1	5545f4e3b27e	network1	test1

10. **Network Refresh** This command will refresh the network details across the Docker hosts available in the database and update the results in the local database.

```
cms swarm network refresh
```

11. **Network Delete** This command will delete an existing network. The input required for this command is just the network name.

```
cms swarm network delete network1
```

12. **Service Create** This command will create a service, the arguments required are the image name and the name of service. This command will record the service details into the local database. This command also takes several configurable options such as Replica Count, Replica Mode and Network which can be passed as advanced options as detailed in Section 5.

```
cms swarm service create elasticsearch \
elasticsearch:swarm
```

13. **Service List** This command will list the current services running, the data displayed is from the local database, if the most current details are required user can run service refresh command below.

```
cms swarm service list
```

The number of replicas below indicates the number of containers which are running the services.

**Table 8. cms swarm service list**

Ip	Id	Name	Image	Replicas
docker1	5545f4e3b27e	elasticsearch	elastic:swarm	3

14. **Service Delete** This command will delete a running service, the argument required is the service name. This command will also delete the service details into the local database.

```
cms swarm service delete elasticsearch
```

15. **Service Refresh** This command will refresh the services status for all the hosts available in the database and refresh the service details in the local database.

```
cms swarm service refresh
```

16. **Node List** This command will display the list of the nodes across the hosts available. The results come from the local database. The command will display the node Id, node Ip, Role, Status and Manager Ip.

```
cms swarm node list
```

**Table 9. cms swarm node list**

Id	Ip	Role	Status	Manager Ip
5545f4e3b27e	docker3	Manager	Ready	
7645f4f4b27e	docker2	Worker	Ready	docker4

17. **Image Refresh** This command will refresh the images details across the hosts available in the database and store the results in the local database.

```
cms swarm image refresh
```

18. **Image List** This command will display the images available on a host. It would display the Ip of the host, the Image Id, repository and the size of the image. Please note that this command would display the results from the local dB.

```
cms swarm image list
```

**Table 10. cms swarm image list**

Ip	Id	Repository	Size(GB)
docker1	5545f4e3b27e	cloudmesh:docker	5.59
docker2	45f4e3b2799e	elasticsearch:swarm	0.45

19. **Container Refresh** This command will refresh the current state of the containers across the hosts available in the local database. This command would connect to the host and run the native Docker container list to get the latest information and update the local database refreshing the data.

```
cms swarm container refresh
```

20. **Container List** This command will display the list of containers running across the hosts. This would return the Ip, Container Id, Name, Image, status and start time of the container. The details would be shown from the local database maintained.

```
cms swarm container list
```

**Table 11. container list**

Ip	Id	Name	Image	Status	StartedAt
docker1	5545f4e3b27e	test1	image1	exited	12.00PM

## 5. DOCKER AND SWARM COMMANDS ADVANCED OPTIONS

All the commands in the docker and the swarm module support optional advanced parameters that allow customising the docker containers, services and networks that are created. A detailed list of these arguments is available at [9]. The advanced options can be added to commands as simple name value pairs.

## 6. USE CASE - ELASTICSEARCH CLUSTER

Elasticsearch[10] is an open-source, broadly-distributable, readily-scalable, enterprise-grade search engine. Accessible through an extensive and elaborate API, Elasticsearch can power extremely fast searches that support your data discovery applications[2]

Using Cloudmesh client, Ansible and Cloudmesh Docker application we deployed and provisioned an Elasticsearch cluster on remote hosts in Chameleon cloud in Docker and swarm

mode. We benchmarked the cluster using esrally[11] have compared the results between the elastic search clusters in Docker and swarm mode.

The hardware specifications used on both the clouds is detailed in Table 12

**Table 12.** Deployment Hardware Specification

	Chameleon	Aws
<b>VM</b>	3	3
<b>Containers</b>	5	5
<b>OS</b>	Ubuntu 16.04	Ubuntu 16.04
<b>Flavor</b>	m1.large	t2.large
<b>VCPU</b>	4	2
<b>Memory</b>	8 GB	8 GB
<b>Storage</b>	80 GB	80 GB

### 6.1. Elasticsearch Cluster Docker Mode

For provisioning, the Elasticsearch cluster in Docker hosts below are the steps done

1. Created 3 Virtual Machines using Cloud Mesh Client .2 of the Virtual Machines are to be used for the docker Elasticsearch cluster, and 1 Virtual machine is the Benchmark server for the Kibana and esrally docker images
2. Using Ansible scripts Install Docker in 3 Virtual Machines and enable the docker daemon for remote access.
3. Using Ansible scripts Install Images of Elasticsearch on hosts for Docker cluster and the Image of Esrally in the Benchmark server.
4. Using the Cloudmesh Docker application we start four containers 2 in each of the virtual machines. To enable clustering of Elasticsearch applications running in the docker containers, we need set the below parameters in container creation.

```
network_mode=host
environment=
["http.host=0.0.0.0",
"transport.host=0.0.0.0",
"discovery.zen.ping.unicast.hosts=/
docker1,docker2"]
```

The network mode set to host allows the Elasticsearch containers use the underlying Virtual Machines network for networking and leveraging the Elasticsearch unicast discovery find and form a cluster along with the other Elasticsearch instances running in other containers either on the same host or different hosts.

### 6.2. Elasticsearch Cluster Swarm Mode

For provisioning, the Elasticsearch cluster in Docker hosts in swarm mode below are the steps done

1. Created 3 Virtual Machines using Cloud Mesh Client .2 of the Virtual Machines are to be used for the docker Elasticsearch cluster, and 1 Virtual machine is the Benchmark server for the esrally docker image.

2. Using Ansible scripts Install Docker in 3 Virtual Machines and enable the docker daemon for remote access.
3. Using Ansible scripts Install Images of Elasticsearch on hosts for Docker cluster and the Images of Kibana and Esrally in the Benchmark server.
4. Using the Cloudmesh Docker application we first create a swarm cluster with the two docker hosts. Then we create a service in the Swarm Manager Node. Along with the creation of the service we pass parameters to specify the number of replicas, the network to be used, the mode of replication and the service name.

```
ServiceMode.mode="replicated"
ServiceMode.replicas=4
EndpointSpec.ports=["9200:9200"]
networks=["elastic_cluster"]
env=["SERVICE_NAME=elasticsearch"]
```

Swarm mode containers cannot use the underlying host network as in the docker mode to enable the communication between the swarm containers we created an "overlay" network in the swarm manager. This network is passed in the service creation. So every container that is created by the swarm mode Manager will run on this network. In the swarm mode to enable elastic search unicast discovery on the start of the elastic search cluster using the Service name environmental variable we identify other containers available in the cluster and dynamical set the

```
discovery.zen.ping.unicast.hosts
```

parameter to enable elastic search to find and form a cluster with other Elasticsearch applications in the swarm.

### 6.3. Elasticsearch cluster Docker and Swarm mode benchmark results

Table 13 summarises the benchmark results between the clusters in the docker and swarm modes. The results indicate that barring minor differences the clusters in both the docker and swarm modes have similar results. So we can conclude that the docker swarm mode in spite of having the additional overhead need for networking and cluster management has nearly nil impact on the performance of the application deployed on it. The above finding combined with the benefit of the inbuilt scalability and fault tolerance capabilities of the docker swarm mode make it a clear winner.

## 7. BENCHMARKING CLOUDMESH DOCKER

We performed benchmarking of the cloudmesh docker application for Docker and swarm commands. The benchmark was performed both in remote mode (Cloudmesh docker client is run on a network outside the cloud data centre) and local mode (Cloudmesh Docker client is run from a VM inside the cloud data centre). We performed the benchmarking for both the options on both the Amazon Webservices[12] and Chameleon cloud[13]. The results are plotted and tabulated as below

Each of the benchmark runs were performed 100 times for a defined set of operations similar to the steps performed for setting up an elastic search cluster in Docker and swarm. The results were gathered as a CSV file and plotted using Ipython[14].

The hardware specifications used on both the clouds is detailed in Table 14

**Table 13.** Elastic search Benchmark Results Docker Vs Swarm

Operation	Unit	Docker	Swarm
Flush time	min	0.9709	1.34333
Indexing time	min	117.888	136.951
Merge throttle time	min	75.5648	87.8035
Merge time	min	146.693	179.403
Refresh time	min	27.4014	32.6458
articles_monthly_agg_cached	ops/s	20.0178	20.0175
articles_monthly_agg_uncached	ops/s	20.0085	20.0093
default	ops/s	20.0133	20.007
force-merge	ops/s	1.75528	0.943048
index-append	docs/s	535.527	461.233
index-stats	ops/s	49.8993	50.2674
node-stats	ops/s	49.6913	50.2767
phrase	ops/s	20.0127	20.0129
scroll	ops/s	1.31822	0.457152
term	ops/s	20.0126	20.011

**Table 14.** Cloud Hardware Specification

	Chameleon	Aws
VM	3	3
Containers	5	5
OS	Ubuntu 16.04	Ubuntu 16.04
Flavor	m1.large	t2.large
VCPU	4	2
Memory	8 GB	8 GB
Storage	80 GB	80 GB

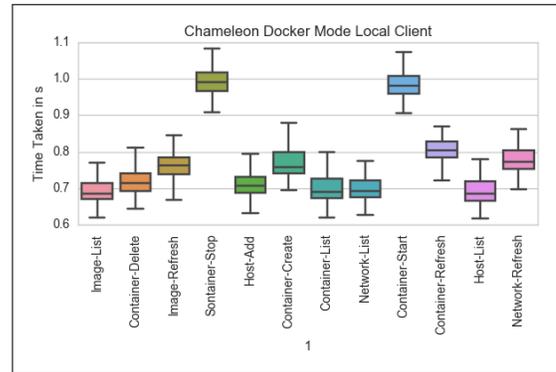
**7.1. Docker Mode - Results**

Below are the categories of the bench mark results

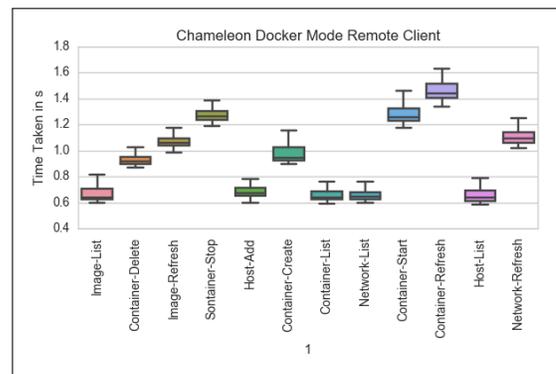
1. Chameleon Docker Mode Local Client Figure 6
2. Chameleon Docker Mode Remote Client Figure 7
3. Aws Docker Mode Local Client Figure 8
4. Aws Docker Mode Remote Client Figure 9

Based on the benchmark results we can infer the below details

1. In the battle of the clouds, Aws is around 20 percent faster than Chameleon cloud in docker mode
2. Cloudmesh docker operations for the docker command performed in a local network are between 25 and 30 percent faster. We also noticed some network issues when performing the test from a remote network, however, we chose to ignore those outliers in the plot.



**Fig. 6.** Chameleon Docker Mode Local Client



**Fig. 7.** Chameleon Docker Mode Remote Client

3. The standard deviation of the response times is significantly lower for Aws than Chameleon indicating that Aws is much more stable and reliable in performance than the chameleon cloud
4. The mean container create times range between 0.5 to 1 s which is significantly faster than normal VM boot times on the cloud.

**7.2. Swarm Mode - Results**

Below are the categories of the Benchmark results

1. Chameleon Swarm Mode Local Client Figure 11
2. Chameleon Swarm Mode Remote Client Figure 10
3. Aws Swarm Mode Local Client Figure 12
4. Aws Swarm Mode Remote Client Figure 13

Based on the benchmark results we can infer the below details

1. In the battle of the clouds, Aws is around 20 percent faster than Chameleon cloud in swarm mode
2. Cloudmesh swarm operations for the swarm command performed in a local network are between 25 and 30 percent faster.
3. The standard deviation of the response times is significantly lower for Aws than Chameleon indicating that Aws is much more stable and reliable in performance than the chameleon cloud

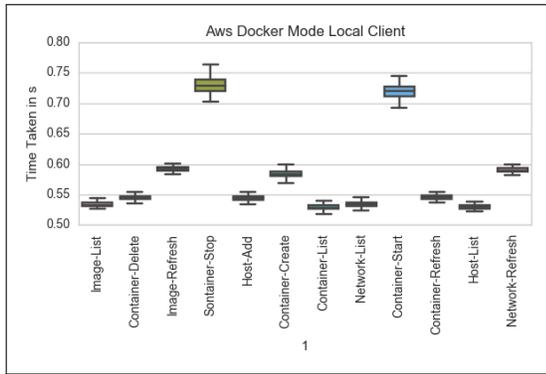


Fig. 8. Aws Docker Mode Local Client

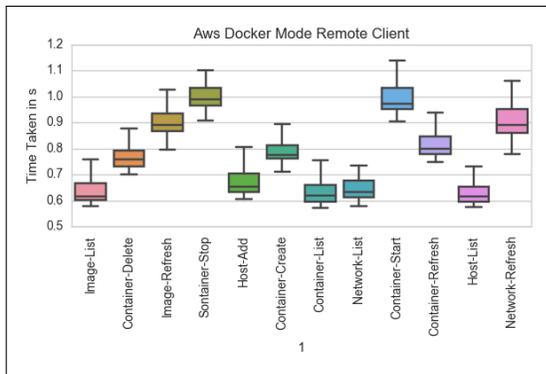


Fig. 9. Aws Docker Mode Remote Client

- The mean service create times range between 2 to 1.6 s for four replicated containers which is significantly faster than normal boot times for a similar number of VM on the same cloud.

Table 15. Docker Mode AWS VS Chameleon Local Vs Remote

		Aws		Chameleon	
		Local	Remote	Local	Remote
<b>Image-List</b>	mean	0.534	0.661	0.695	0.704
<b>Image-List</b>	std	0.004	0.128	0.039	0.197
<b>Container-Delete</b>	mean	0.545	0.785	0.721	0.951
<b>Container-Delete</b>	std	0.004	0.090	0.040	0.115
<b>Image-Refresh</b>	mean	0.592	0.925	0.763	1.139
<b>Image-Refresh</b>	std	0.005	0.109	0.040	0.298
<b>Sontainer-Stop</b>	mean	0.730	1.017	0.992	1.299
<b>Sontainer-Stop</b>	std	0.014	0.122	0.041	0.113
<b>Host-Add</b>	mean	0.544	0.691	0.710	0.727
<b>Host-Add</b>	std	0.004	0.114	0.038	0.194
<b>Container-Crete</b>	mean	0.584	0.798	0.767	1.007
<b>Container-Crete</b>	std	0.006	0.075	0.042	0.164
<b>Container-List</b>	mean	0.529	0.655	0.697	0.689
<b>Container-List</b>	std	0.004	0.110	0.038	0.141
<b>Network-List</b>	mean	0.534	0.668	0.700	0.679
<b>Network-List</b>	std	0.005	0.098	0.035	0.115
<b>Container-Start</b>	mean	0.720	1.018	0.985	1.310
<b>Container-Start</b>	std	0.011	0.145	0.044	0.169
<b>Container-Refresh</b>	mean	0.546	0.824	0.805	1.509
<b>Container-Refresh</b>	std	0.004	0.070	0.033	0.208
<b>Host-List</b>	mean	0.530	0.659	0.693	0.708
<b>Host-List</b>	std	0.004	0.125	0.042	0.273
<b>Network-Refresh</b>	mean	0.591	0.946	0.780	1.137
<b>Network-Refresh</b>	std	0.005	0.171	0.043	0.151

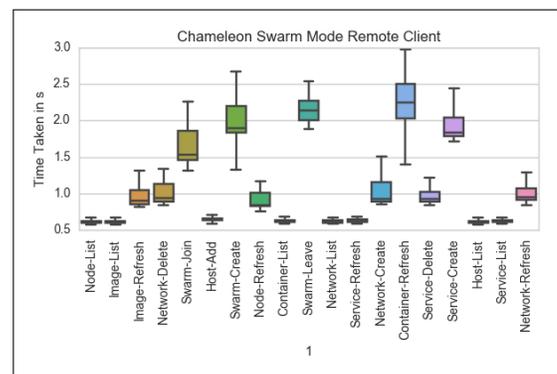


Fig. 10. Chameleon Swarm Mode Remote Client

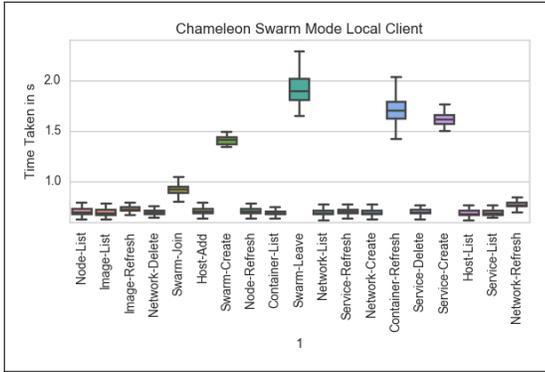


Fig. 11. Chameleon Swarm Mode Local Client

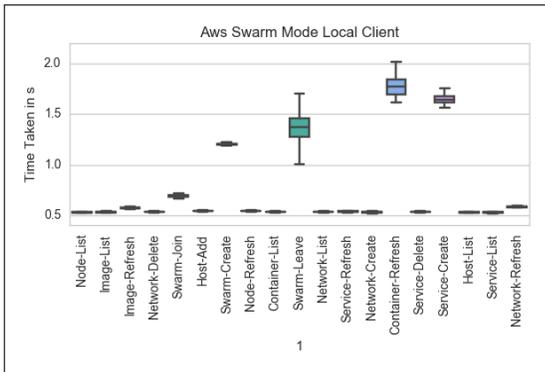


Fig. 12. Aws Swarm Mode Local Client

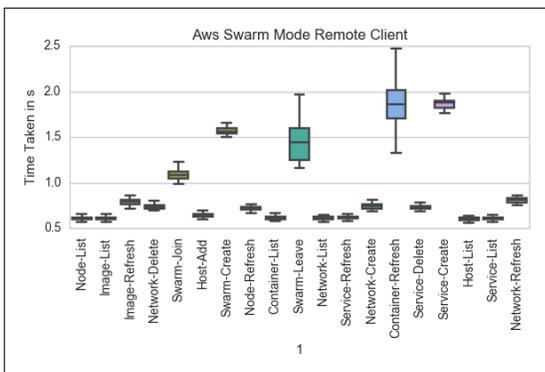


Fig. 13. Aws Swarm Mode Remote Client

Table 16. Swarm Mode AWS VS Chameleon Local Vs Remote

		Aws		Chameleon	
		Local	Remote	Local	Remote
Node-List	mean	0.529	0.612	0.704	0.631
Node-List	std	0.004	0.022	0.037	0.056
Image-List	mean	0.532	0.614	0.696	0.626
Image-List	std	0.004	0.041	0.039	0.053
Image-Refresh	mean	0.571	0.818	0.732	0.981
Image-Refresh	std	0.006	0.139	0.035	0.220
Network-Delete	mean	0.536	0.822	0.701	1.024
Network-Delete	std	0.005	0.280	0.035	0.247
Swarm-Join	mean	0.690	1.178	0.925	1.666
Swarm-Join	std	0.015	0.345	0.053	0.270
Host-Add	mean	0.542	0.653	0.714	0.665
Host-Add	std	0.005	0.062	0.035	0.076
Swarm-Crete	mean	1.201	1.640	1.320	1.963
Swarm-Crete	std	0.046	0.342	0.213	0.340
Node-Refresh	mean	0.542	0.738	0.714	0.911
Node-Refresh	std	0.004	0.107	0.039	0.127
Container-List	mean	0.533	0.622	0.696	0.638
Container-List	std	0.004	0.039	0.033	0.050
Swarm-Leave	mean	1.419	1.460	1.932	2.143
Swarm-Leave	std	0.275	0.288	0.241	0.186
Network-List	mean	0.532	0.625	0.698	0.625
Network-List	std	0.004	0.050	0.035	0.027
Service-Refresh	mean	0.536	0.631	0.710	0.645
Service-Refresh	std	0.004	0.089	0.039	0.099
Network-Crete	mean	0.531	0.781	0.698	1.009
Network-Crete	std	0.005	0.156	0.035	0.162
Container-Refresh	mean	1.666	1.846	1.693	2.273
Container-Refresh	std	0.374	0.348	0.181	0.386
Service-Delete	mean	0.535	0.781	0.704	0.991
Service-Delete	std	0.004	0.205	0.039	0.140
Service-Crete	mean	1.661	1.905	1.636	1.938
Service-Crete	std	0.071	0.164	0.115	0.273
Host-List	mean	0.529	0.608	0.693	0.629
Host-List	std	0.004	0.030	0.033	0.083
Service-List	mean	0.528	0.617	0.698	0.639
Service-List	std	0.005	0.052	0.035	0.075
Network-Refresh	mean	0.583	0.834	0.776	1.009
Network-Refresh	std	0.005	0.145	0.039	0.126

## 8. CONCLUSION

In this project, we have successfully integrated docker and swarm capabilities into the cloudmesh client. We have also demonstrated its use for a practical use case of Setting up an Elastic search cluster in Docker and swarm modes. We have also benchmarked the commands for multiple clouds (AWS and Chameleon) in both local and remote modes and detailed the results and insights. The Ansible scripts as part of the project along with the capabilities built in the cloudmesh docker application provide for a seamless capability in deploying and provisioning applications in Docker and swarm containers.

## 9. ACKNOWLEDGEMENT

We acknowledge our professor Gregor von Laszewski and all associate instructors for helping us and guiding us throughout this project.

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## A. APPENDICES

### A.1. Appendix A: Work Distribution

The co-authors of this report worked together on the design of the technical Solutions, implementation, testing and documentation. Below given is the work distribution

- Karthick Venkatesan
  - Design and Implementation of Docker and Swarm Commands.
  - Integration of Docker and Swarm Commands to Docker API.
  - Integration to cloudmesh.common,cloudmesh.rest, cloudmesh.cmd5 repositories.
  - Framework definition and wrapper class built for Python-eve
  - Ansible scripts for Docker image installation and setup of etc hosts
  - Test scripts for Docker and Swarm command
  - Dockerfile for installation of cloudmesh.docker
  - Create Benchmark scripts for Local and Remote Benchmarking on Chameleon and AWS
  - Execute Benchmark scripts for Chameleon and Aws and plot the results in Ipython
  - Scripts for setup of Elasticsearch Docker cluster
  - Benchmark Elastic search swarm cluster using ESRally and document results
  - Writing related sections in this report.
- Ashok Vuppuda
  - Design of Docker and Swarm Commands.
  - Integration into cloudmesh.rest
  - Python-eve integration and implementation for Docker and Swarm Modes
  - Ansible scripts for Docker installation
  - Test application on Aws and Chameleon clouds
  - Execute Benchmark scripts for Chameleon and Aws and plot the results in Ipython
  - Benchmark Elastic search Docker cluster using ESRally and document results
  - Writing related sections in this report.

# Deployment of Vehicle Detection application on Chameleon clouds

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Project: S17-IR-P010, September 21, 2017

**This project focuses on the deployment of Vehicle Detection application on multiple Chameleon clouds using Ansible playbook. It also focuses on the benchmarking of the deployment results and its analysis.**

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**Keywords:** Vehicle detection, Ansible, Cloudmesh, OpenCV, Haar Cascades, Cloud, I524

Report: <https://github.com/cloudmesh/sp17-i524/tree/master/project/S17-IR-P010/report/report.pdf>

Code: <https://github.com/cloudmesh/cloudmesh.vehicle>

## 1. INTRODUCTION

Vehicle Detection forms an integral part of the development of new technologies like fully self-driving cars, etc. One of the techniques to perform such detection is by using Haar Cascades [1]. This technique has been applied to vehicle detection by creating a haar-cascade cars.xml file which has been trained using 526 rear-end images of cars. In this project, we would be extending this vehicle detection approach to enable it to run on multiple clouds. This deployment would initially be done on the local host, followed by deployment on the cloud. Cloudmesh client would be used for cloud management and Ansible scripts would be used for software stack deployment. The vehicle detection application would then run remotely onto the clouds. The result would be an image (a .jpg file) with all the vehicles in it detected with a red rectangle around it and sent back to the local host. Appropriate benchmarking would be carried out at each iteration using some benchmarking technique.

## 2. REQUIREMENTS

The requirement was to deploy the Vehicle detection application onto the cloud's Virtual Machines (VMs). The processing, which included detection of vehicles by drawing a red rectangle around them, had to be carried out on the cloud VMs. The output image that was generated had to be then resent back to the local machine.

## 3. SOFTWARE STACK

For this project, we have used the following software/applications:

- Ansible [2]:  
Ansible is an open source platform that is used for automa-

tion. Configuration management, task automation and application deployment can be carried out using Ansible. In our project, we have used Ansible to manage the configuration and automate the deployment of the software stack onto the clouds. We run Ansible scripts via localhost entering the IP addresses of the cloud's VMs and the software/applications are installed in those VMs. Thus, we are using Ansible to orchestrate the software deployment via playbooks using the inventory.txt file containing the IP addresses.

Ansible forms connections to our cloud VMs and then pushes 'Ansible modules', which are nothing but small programs, to them. Ansible executes these modules and then removes them upon completion. Ansible thus helped us in lightweight development, in the sense that other than an editor and the terminal, it did not require any other components to be installed. Although we used SSH keys for the connections and with Ansible, Ansible also supports the use of passwords.

- Cloudmesh client [3]:  
Cloudmesh is basically used for cloud VM management. It provides easy access to different cloud environments via a command shell and command line. In our project, we have used Cloudmesh client for dynamic management of the cloud VMs. Cloudmesh client enabled us to boot up the virtual machines on the clouds, assign floating IPs, etc. Thus, we have used it to carry about these activities as well as add our SSH keys to a local database and then SSH to the remote VMs on the clouds using various cloudmesh client commands and utilities.
- Python [4]:  
Python is an object oriented, high level programming lan-

guage. It is an interpreted language and provides built-in data structures with dynamic typing and binding. It has an easy and simple yet intuitive syntax. In our project, we are using Python (and Pip [5]) for the installation and management of software written in Python.

- Git [6]:  
Git is a version control system that can be used for tracking and change management when multiple people are involved in a project. It helps control and coordinate the working among a group of people. We have used Git to manage our work within our team. It has helped us by providing a central place wherein we could commit our work and make it easily accessible to others. Also, the Vehicle Detection Application (outlined below) application that we are using in our project has been developed and hosted on Github by the creator Andrews Sobral. We have forked his repository and using his application for the detection of vehicles.
- OpenCV [7]:  
OpenCV is a collection (library) of various functions used to execute computer vision related applications. The Vehicle Detection Application runs on OpenCV. OpenCV includes both, a trainer as well as a detector. It also has many pre-trained classifiers. We are using the Haar classifier [1].
- Vehicle Detection Application [8]:  
The Vehicle Detection Application has been developed by Andrews Sobral. It basically uses a haar-cascade cars.xml for vehicle detection. The haar-cascade was trained using 526 rear-end images of the cars. The video size used is 360x240 pixels. In our project, we are running this application on the clouds.
- Bash script [9]:  
Bash typically helps us in the automatic execution of various Linux commands by creating a .sh file. We have used a file myScript.sh in order to carry out the benchmarking of the project. It should be noted that once a shell script is created, appropriate permissions (or privileges) must be set so that it is executable. We call the ansible script to be executed within this shell script. We can thus say that the Bash script is the starting point of our project - we just have to run this script and then the software stack including the Vehicle detection application would be deployed, the application would be run and the generated image file would be rerouted to our local machine. In order to carry out benchmarking, we just did a minor modification to this routine (edited the inventory.txt file).

#### 4. DEPLOYMENT

For successful project deployment, the first step was gaining access to the clouds. Cloudmesh client was used for gaining this access. In order to set up this cloudmesh client, we had to configure the cloudmesh.yml file with our credentials and other details. We mainly used Chameleon clouds in our project so we only edited the cloudmesh.yml file parts that corresponded to chameleon clouds. If we were to use Jetstream, we would have required to edit the Jetstream part as well. We had to edit the values in such a way as to ensure that the info command did not yield any To Be Decided (TBD) values. In case it did, then it meant that there were possibly some errors and we had to revisit

the cloudmesh.yml file and correct those. If there were no TBD values at all, then it meant that we were good and could now access the clouds. Once we had access to the clouds, we booted a VM and then assigned a floating IP to it. Post this, we used the SSH command to log in into the VM. Once we were within the VM, we could use it as a normal local Ubuntu machine. Although we didn't require it in this project, cloudmesh also provided the functionality to use a different image on the cloud VMs.

When we need a new VM, we simply booted a new VM and assigned a new floating IP address to it. This resulted in allocation of a new VM which we could then use as a new additional machine. By proper set up in the Ansible scripts, one of these machines could be used as a master and the other one(s) as slaves, if there is a need in some project.

The second step was the identification of the software stack that would be required. In order to understand this, we first deployed the software and application on the local machines and then on the clouds. This step helped us understand the software needed as well as the dependencies amongst them. Once we identified the software, we developed an ansible script to deploy the software and applications dynamically in an automated way.

Ansible is an open source automation platform. It mainly uses .yml files for its working. The file 'inventory.txt' contains the details of the hosts (their IP addresses) wherein the software stack is to be installed. Similarly, we can also mention the ansible username in this file. Thus, in our case, the entry in the inventory.txt file is as below:

---

```
129.114.110.83 ansible_ssh_user=cc
```

---

The 'playbook.yml' file lists the hosts, variables and the roles. The hosts contains the details of the machine where the software are to be installed. The variables section lists the variables that are being used elsewhere, for e.g., 'download\_dr' denoting the download directory. The advantage of using variables is that the values do not need to be hard coded and thus they can be changed everywhere with a minor update. The roles section lists the various software that need to be installed, in order. In our case, the entry of the playbook.yml file is as below:

---

```
---
- hosts: all
  vars:
    download_dr: ~/downloads
    ocv_ver: 2.4.13.2
    repository: {{ repository }}
    tmp: /tmp/vehicledetection
  roles:
    - git
    - python
    - upgrade
    - opencv
    - vehicledetection
```

---

The 'roles' directory contains the details about all the software that are to be installed. Since we have installed four software, we have four directories within it. Each of these four directories is named after the software that it is supposed to install. Thus, the directory 'git' installs git, 'python' installs python and so on. Each of these directories in turn contain two directories - 'defaults' and 'tasks'. The 'defaults' directory contains a file 'main.yml' that lists the temporary variables like the download directory to be used, the version to be downloaded, etc that is specific to its software. The 'tasks' directory contains a file

named 'main.yml' that lists the tasks (i.e., the activities) that need to be carried out step-by-step. These activities are executed in a sequential order. A snapshot of one of the main.yml files used in our project is as below:

```
---
- name: install Git on Ubuntu machine
  become: yes
  apt: name=git state=present
```

Thus, the first statement says that we are installing Git on the Ubuntu. The next statement says that sudo privileges would be required for installation of Git. The last statement specifies the package name and its state. Ansible thus enabled us to dynamically deploy the software stack and configure the system as required for proper installation.

## 5. EXECUTION

For the execution of this project, we had set the tasks as below:

### 5.1. Week 1

In the first week, we deployed the vehicle detection application on the localhost by using bare commands. The main aim of this step was to ensure that the application worked. This step was critical in the sense that it helped us understand the various dependencies among the various software in the software stack. It also helped us understand the environmental variables like `OpenCV_FOUND` and `OpenCV_DIR` that we had to setup, since they are specific to the local system on which the application is run. This step in reality took us more than a week to find out about `OpenCV_DIR`, `OpenCV_FOUND` and their specific expected values. Once this step was executed successfully, we wrote down an Ansible script to carry out the software deployment. Since we spent substantial amount of time in debugging the `OpenCV_FOUND` and `OpenCV_DIR` errors, we could not write the scripts for the entire software stack. We wrote it only for Git; but it provide us with a good start.

### 5.2. Week 2

In this week, our aim was to reserve and access a Chameleon cloud using cloudmesh client. We then planned to carry out software stack deployment on it, and carry out benchmarking. However, we spent more than four days in trying to debug the `OpenCV_DIR` and `OpenCV_FOUND` errors that we encountered in the first week. Nonetheless, we found out a solution and tested that the application works as expected. As a consequence of the error we faced, we could not spend much time in developing ansible scripts for further software stack deployment. However, by the end of second week, we had configured our cloudmesh.yml file. We were yet to test it, though.

### 5.3. Week 3

For week 3, we tested our configuration of the cloudmesh.yml file by actually gaining access to the Chameleon clouds. For this, we learned about the various commands that cloudmesh had to offer and booted up a VM in the clouds. Later, we assigned a floating IP address to it and then logged in into the remote VM via SSH. Once we were into the VM, we could operate on it just like a local normal VM. We spent the next couple of days in writing down ansible scripts for software stack deployment. Once this was complete, we ran those scripts on the local host to test if they worked as expected, or if they needed any changes.

### 5.4. Week 4

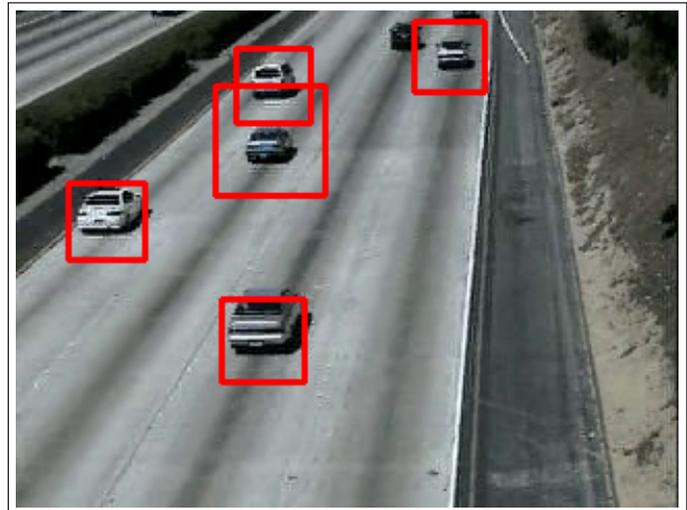
In this week, we carried out minor changes to the ansible scripts that we had written. We booted up a cloud VM using cloudmesh client and logged in into it. We then ran the ansible scripts from our local hosts by entering the floating IP of our cloud VMs in the inventory.txt file. While the scripts for git ran successfully, the script for OpenCV failed. After much debugging and testing, we found a solution which involved updating the cache (running an equivalent of `sudo apt-get update`) which resulted in OpenCV being installed successfully on the clouds. We faced another challenge when cloning the Vehicle detection project from github. We circumvented this problem by making the ansible script run the command as a sudo user.

### 5.5. Week 5

In the final fifth week, we aimed to carry out benchmarking and write a report about our observations. We first carried out benchmarking by deploying the software stack on the local machine and taking the readings. Then, we deployed it onto the Chameleon clouds and noted down the observations. Finally we noted down all these observations in a detailed report.

### 5.6. Week 6

By this week, the majority of our project was ready. We, however, still had one significant change to make - re-factor the code in order to make it suitable to be deployed on the clouds. Since we were interested in *saving* the image so as to send it back to the local machine, we replaced the `cvShowImage()` attribute to `cvSaveImage()`, passing it similar parameters. This method created a snapshot of the video and placed the output video file in the same directory as that of the main programs. In our case, the image file denoting the detected vehicles looks as shown in Figure 1.



**Fig. 1.** Image showing the detected vehicles sent back to local machine from the cloud VM

Other than this, we were also getting a warning "Gtk - Could not open display". After some debugging, we found out that the reason for this error was that within the vehicle detection application, the algorithm was trying to create a new window. As per our requirement, we didn't have any need to open a window and display the contents there. Hence we simply removed this

call that the algorithm made and instead added some other code due to which the image would be re-routed to the local host.

Post these two changes, the application ran successfully on the clouds, carrying out all the processing on the remote VMs. Once the required output file was created on the remote VM, it would create a directory on the host machine with the name as the floating IP address assigned earlier. Within this directory, another directory named dev containing the vehicledetection folder was created. The final image was placed within this vehicledetection folder. Thus, as can be seen, ansible provides a robust and very secure way to access the systems (local as well as remote).

## 6. BENCHMARKING RESULTS AND ANALYSIS

For benchmarking, we first deployed the software stack onto the local machine and then deployed it on the clouds. We noted down the observations in each case. The parameters for benchmarking as well as the observed values have been noted below. In order to reduce any errors, we have considered average values. Thus, we installed each software (from scratch) 3 times on the local machine and 3 times on the clouds. Then, we took the average of all these values in order to find out the exact time needed for its deployment on the platform.

Also, for measuring the time, we used a shell script Setup.py. This script displays the current time and then calls onto the Ansible playbook. This Ansible script then installs all the software on the software stack and then final comes to an end. Once the Ansible script ends, the shell script again denotes the latest time. The difference between these two timings displayed at the beginning and at the end give us the total software installation time required. While testing it for different software, we had edited the playbook.yml file to contain only the single software under consideration. In this way, we understood the time required for the installation of just a single software.

### 6.1. Deployment benchmarking

Deployment benchmarking included observing the software deployment times for each of the software in the software deployment stack. We started off with the first software, Git. On the local machine, it was installed in 2.57 seconds, while it took 10.45 seconds to be installed on the clouds. The next command, upgrade, took 35.84 seconds on the local machine and 155.03 seconds on the clouds. Python took 4.55 seconds to be installed on the local machine and 30.75 seconds to be installed on the clouds. OpenCV, is a heavy software having lots of dependencies on other software. We thus had to install its dependencies first before we could compile and install it. Due to all this, OpenCV took 1420.37 to be installed on the clouds and 276.01 seconds on the local machine. Vehicle detection is a lightweight application and as such, it took 11.99 to install on the clouds and just 2.04 seconds to be installed on the local machine. All these values have been tabulated in Table 1.

### 6.2. Elasticity benchmarking

Elasticity metric aims to test the dependency of one software on the other ones. In other words, it aims to test a software's sensitivity to changes in another software. In our project, we noticed that some of the software had a high dependency (and sensitivity), while others had relatively low (or no) dependency. For benchmarking the software elasticity, we referred its ansible script. We counted the number of tasks that had to be successfully executed before the software in question could be

**Table 1.** Deployment Benchmark

	Local VM avg time	Cloud VM avg time
Git	2.59	10.49
Upgrade	35.53	155.59
Python	4.29	30.58
OpenCV	277.03	1419.53
Vehicle Detection	2.18	11.72

**Table 2.** Elasticity benchmark

Software/Application	Dependency count
Git	0
Upgrade	NA
Python	4
OpenCV	14
Vehicle Detection	3

considered to be successfully installed. For e.g., in case of the Vehicle Detection application, before running the 'make' command, we need to carry out 3 steps - getting the Vehicle detection package source, changing the directory and running cmake. Thus, the elasticity factor associated with the Vehicle Detection project is 3. We carried out a similar analysis of the other software from the software stack. Table 2 lists these observations.

### 6.3. Re-installation benchmarking

Ansible scripts do a good job of installing the software. However, even before the software/applications are installed, ansible first tests to make sure that the software is not already installed on the system. In case it is, then it simply skips over the installation process of that software and then continues with the next one. This is important, since it does not try to update/reinstall the existing software since that would lead to conflicts with the existing package versions or features. Also, since the re-installation of packages is just skipped, in case of failures, there is no need to edit the inventory.txt file to deploy only the failed software - it can be kept as it is and the ansible scripts can be run from scratch. Only the failed software would be installed. This also helps in reducing the installation time.

### 6.4. Workload benchmarking

For Workload benchmarking, we found out the disk utilization of the various software from the software stack. While software such as Git were pretty light, others like OpenCV were pretty heavy. They not only required a long time to install, but also consumed a lot of disk space. The output of the 'df -h' command on the cloud VMs has been shown. We, thus, had used only 1.3 GB of system space before installing OpenCV while we ended up consuming 4.4 GB of it after its installation. The usage thus increased from 7 percent to 24 percent.

```
cc@abhinaik-011:~$ df -h
Filesystem
udev
tmpfs
/dev/disk/by-label/
```

```
Size Used Avail Use% Mounted on
997M 12K 997M 1% /dev
201M 340K 200M 1% /run
20G 1.3G 18G 7% /
```

none	4.0K	0	4.0K	0%	/sys/fs/cgroup
none	5.0M	0	5.0M	0%	/run/lock
none	1002M	0	1002M	0%	/run/shm
none	100M	0	100M	0%	/run/user

```
cc@abhinaik-011:~$ df -h
Filesystem      Size  Used Avail Use% Mounted on
udev            997M  10M 987M   2% /dev
tmpfs           201M  340K 200M   1% /run
/dev/disk/by-label/
none            4.0K   0 4.0K   0% /sys/fs/cgroup
none            5.0M   0 5.0M   0% /run/lock
none           1002M   0 1002M   0% /run/shm
none            100M   0 100M   0% /run/user
```

## 6.5. Security and trust factors

In our project we have used cloudmesh client which in turn uses the SSH protocol to make secure connections to the VMs on the clouds [10]. SSH is a cryptographic network protocol used for establishing secured connections over the network. It is thus used for access to shell accounts on Unix like operating systems. Since SSH is being used, trustworthy connections can be established between the local machine and the remote VMs on the clouds. Along with this, Ansible also helps in security enforcement. Some of the qualities like being agentless, capability to support SSH, no unnecessary changes, modular structure, etc [11].

## 6.6. Latency and reliability benchmarking

We used the ping facility for benchmarking the latency [12] of the network. Latency measures the time it takes for a packet to reach the cloud VM (with a specific IP) from the local host. We used the following command to test this:

```
ping 129.114.33.88 -c 10
```

In this command, the '-c 10' option makes 10 requests to the cloud VMs. In the end, it displays a summary of the results. We can thus observe that the minimum round trip time (rtt) was 43.729 seconds, while the maximum was 45.216. During one of the experiments, we noticed that there was 10 percent packet loss, since out of the 10 packets that were sent, only 9 of them could make it back to the local host. However, repeated experiments showed that the system was indeed reliable and that this was a small one-time exception.

```
abhishek@abhishek:~$ ping 129.114.33.88 -c 10
PING 129.114.33.88 (129.114.33.88) 56(84) bytes of data:
64 bytes from 129.114.33.88: icmp_seq=1 ttl=51 time=45.2 ms
64 bytes from 129.114.33.88: icmp_seq=2 ttl=51 time=43.7 ms
64 bytes from 129.114.33.88: icmp_seq=3 ttl=51 time=43.8 ms
64 bytes from 129.114.33.88: icmp_seq=4 ttl=51 time=45.1 ms
64 bytes from 129.114.33.88: icmp_seq=5 ttl=51 time=44.6 ms
64 bytes from 129.114.33.88: icmp_seq=6 ttl=51 time=45.1 ms
64 bytes from 129.114.33.88: icmp_seq=7 ttl=51 time=44.2 ms
64 bytes from 129.114.33.88: icmp_seq=8 ttl=51 time=44.6 ms
64 bytes from 129.114.33.88: icmp_seq=9 ttl=51 time=44.3 ms
64 bytes from 129.114.33.88: icmp_seq=10 ttl=51 time=44.0 ms
```

```
--- 129.114.33.88 ping statistics ---
10 packets transmitted, 10 received, 0% packet loss, time 9012ms
rtt min/avg/max/mdev = 43.729/44.503/45.216/0.575 ms
```

## 7. CONCLUSION

In this project, we used cloudmesh client which is a client that enables us to access and manage various cloud environments.

We used it to gain access to Chameleon cloud VMs by using the SSH protocol. Ansible is an automation platform that helps us in automating the software deployment. We used Ansible scripts to install all our software along with the configuration of the project. Once the software stack was installed, we installed the Vehicle detection application on top of it. The Vehicle detection application running on OpenCV used haar-classifiers to detect the vehicles. It created an image wherein the vehicles were marked with a red rectangle. This image, which was generated on the cloud, was then redirected to the local machine, using ansible fetch. On the local machine, it was saved deep inside the directory named with the IP address. Once this end-to-end process was done, we did benchmarking of the system by using shell scripts. We typically focused on the deployment, elasticity, installation capacity, workload, security, latency and reliability.

## 8. ACKNOWLEDGMENTS

This project was undertaken as a part of the course objective for I524: Big Data and Open Source Software Projects at Indiana University, Bloomington. We would like to thank Prof. Gregor Von Laszewski and all the TAs for their help. Similarly we would also like to thank Andrews Sobral for providing us with the Vehicle Detection application that we ran on the cloud VMs.

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### A. WORK BREAKDOWN

Abhishek Naik modified the Vehicle Detection application code so as to enable it to create a snapshot of the detected vehicles and save it as an image file. This file was later re-routed back to the host machine. He also wrote ansible scripts for the deployment of OpenCV, git and Vehicle Detection. He also wrote the deployment, benchmarking and biography section of the report.

Govind Mishra wrote down ansible scripts for the deployment of python and to carry out remote upgrade. He also wrote down the introduction, requirements, software stack, execution, conclusion, acknowledgments, bibliography, biographies and the work breakdown sections of the report.

# Head Count Detection Using Apache Mesos

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Project P011, September 21, 2017

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Apache Mesos can be used for scaling of applications and providing highly available clusters. It provides the functionality to use resources from multiple agents and execute the application using the offered resources. Deployment of a custom face detection application is done using Ansible on Apache Mesos and analysis of the deployments are benchmarked. The face detection application was created using OpenCV. Ansible playbooks are used to deploy Apache Mesos on virtual machines created on chameleon cloud. For benchmarks, deployment of Mesos on different systems and different sizes of virtual machines were carried out.

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**Keywords:** Cloud, I524, Apache Mesos, OpenCV, Face detection, Mesosphere, Ansible, Big Data, Zookeeper, Marathon, Haar Cascade

Report: <https://github.com/cloudmesh/sp17-i524/tree/master/project/S17-IR-P011/report/report.pdf>

Code: <https://github.com/cloudmesh/cloudmesh.mesos>

---

## 1. INTRODUCTION

There are a number of applications which require the counting of people in an image. The application for detecting headcount in an image can be in the field of attendance management and tagging images on social media. The purpose of this project is to deploy a head count detection framework on Apache Mesos to enable distributed processing of image data over the cloud. Apache Mesos is built using the same principles as the Linux kernel but at a different level of abstraction. It runs on every machine and provides applications with API's for resource management and scheduling across different cloud infrastructures [1]. Ansible is used to automate the deployment of the head count detection application on Apache Mesos which will be deployed on Chameleon cloud. The VGG face detection dataset is used for benchmarking the performance of Mesos on different versions of the Linux Operating System. The head count detection is restricted to detection of the number of frontal faces in an image [2]. This is due to the field of face detection and image processing being vast and thus the head count detection is restricted to detecting faces based on simple criteria. The performance benefits of Apache Mesos in terms of high availability, scalability and fault tolerance are leveraged by deploying the application on a virtual machine which offers its computing resources to Mesos for fast computation.

## 2. WHY MESOS?

Mesos can be used to implement a decentralized scheduling approach. In this approach, each framework decides which offers to accept or reject. There are many incentives that are provided by any decentralized system. The incentives provided

by Apache Mesos system includes short tasks, no minimum allocation, scale down and not accepting unknown resources [3].

## 3. WHAT IS MESOS?

Mesos is built using the same principles as the Linux kernel. However, it is at a different level of abstraction. The Mesos kernel runs on every machine and provides applications such as Hadoop, Spark, Kafka, Elastic Search with API's for resource management and scheduling across entire cloud environments and data center [3].

### 3.1. Design Philosophy

Mesos aims to provide a resilient core to enable various frameworks for efficient cluster sharing. As cluster frameworks are rapidly evolving and highly diverse, this overriding design philosophy focussing on defining a minimal interface enabling efficient resource sharing across frameworks and otherwise push control of task scheduling and execution to the frameworks. Pushing control to the frameworks has two benefits. It allows frameworks to implement diverse approaches to various problems in the cluster and to evolve these solutions independently. This also keeps Mesos simple and minimizes the rate of change required, which makes it easier to keep Mesos scalable and robust. Higher level libraries implementing common functionality are built on top of Mesos even though Mesos provides a low-level interface. Including the functionality in libraries rather than in Mesos allows it to remain small and flexible and lets the libraries evolve independently.

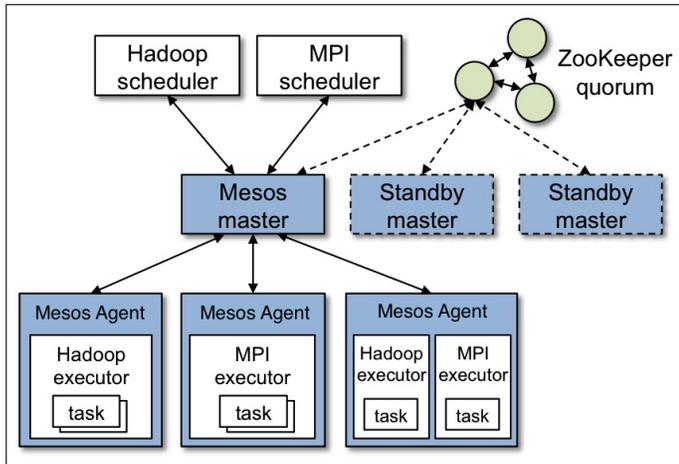


Fig. 1. Mesos architecture [4].

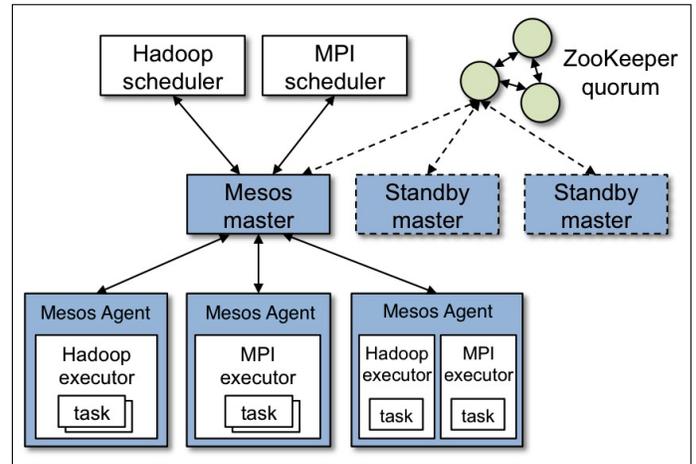


Fig. 2. Example Flow [4].

3.2. Architecture

Mesos consists of a master daemon through which an agent running on each cluster node is managed. It also consists of a Mesos Framework that runs tasks on these agents. The master enables the fine-grained sharing of resources including CPU and RAM across all the frameworks by making resource offers. Each resource offer contains a list of <agent ID, resource1:amount1, resource2: amount2,...> [4]. The master decides how many resources to offer to each framework based on an organizational policy such as strict priority or fair sharing. A diverse set of policies is supported by employing a modular architecture that makes it easy to add new allocation modules via a plug-in mechanism [1].

A framework running on top of Mesos consists of two components: an executor process that can be launched on agent nodes to run framework tasks and a scheduler that registers with the master to the resource offered. While the master determines how many resources are offered to each framework, the framework scheduler selects which of the offered resources to use. When a framework accepts offered resources, the description is passed to Mesos [4].

The sequence of events in the figure are as follows:

1. Agent 1 reports to the master that it has 4 CPU’s and 4GB of memory free. An allocation policy module is invoked by the master which tells it that framework 1 should be offered all available resources [4].
2. The master sends a resource offer to framework 1 which includes details of which resources are available on agent 1.
3. A reply is sent back to the master by the frameworks scheduler with information regarding two tasks to run on the agent, using <2CPU’s, 1 GB RAM> for the first task, <1CPU and 2 GB RAM> for the second task [4].
4. Finally the master sends the task to the agent which allocates appropriate resources to the frameworks executor which in turn launches the two tasks. The allocation module may now offer the unallocated resources to framework 2 [4].

The resource offer process repeats when new resources become free or when tasks are finished.

4. MESOS FRAMEWORK

A Mesos Framework is used to manage tasks. A Mesos framework is highly available only if it continues to manage tasks correctly in the presence of a variety of failure scenarios. There are failure conditions which the framework should consider. The conditions are as follows:

- A framework scheduler which is connected to a Mesos master might fail. It may be due to crashing or losing network connectivity. If the master has been configured to use the high availability mode, this will promote a replica of another Mesos master to become the new leader. In this case, the scheduler re-registers with the new master and ensure the task state is consistent [5].
- A host may fail where a framework scheduler is running. While creating the framework, the framework authors should ensure that multiple copies of the scheduler run on different nodes and a backup copy is promoted to become the new leader where a previous leader fails. This is done to ensure that the framework remains available and can continue to run new tasks [5].
- The host might fail on which a task is running. The node might not have failed but the Mesos agent on the node might be unable to communicate with the Mesos master due to a network partition [5].

4.1. Internal Working of Framework

When the agents are connected to the Mesos master, they offer resources to the Mesos master in terms of CPU’s, RAM and disk space. These resources are available for the master to use till the agents are in the active state. There can be multiple states for the Mesos agents such as Active state, Deactivated state and Unreachable state. When an agent is successfully able to connect to the master, it is in the active state. When an agent is not able to advertise its IP address to the master, the agent state is changed to deactivated. If there are network outages and the agent is unable to reach the master, it goes in the unreachable state. The master is able to use the resources offered by the agent only if the agent is in the active state. When the face detection framework is started on Mesos master, the master searches for any available resource offers from the active agents. It breaks the execution of the framework into multiple tasks and uses the resource offers

to execute the task. The task runs on multiple CPU's if available, and after completion of each task a status update is sent to the Mesos master. Each individual task is assigned a unique task id. If an agent doesn't update the status of the task due to network outage or failure of the agent, the Mesos master persists the task id and it assigns the task id to a new agent which has resources available and the task is resumed. The framework state changes to active when the tasks of the framework are running and changes to completed when the execution of the framework is finished.

#### 4.2. Highly Available Frameworks

Mesos provides unreliable messaging between components by default: Messages are delivered at most once by default. Framework authors should take into consideration that the messages they sent might not be received and should be prepared to take corrective action. Timeouts are used to detect whether a message is lost. There are situations where the framework attempts to launch a task but the message does not reach the Mesos master [5]. To address such issues a framework scheduler should set a timeout after attempting to launch a new task. The scheduler should take corrective action if the scheduler does not receive a status update and thereby launching a new copy of the task [4].

In general, distributed systems cannot distinguish between 'lost' messages and messages that are delayed. There might be a case where the scheduler might see a status update for the attempt of the first task launch immediately after its timeout has fired but it has already begun to take corrective action. Mesos provides ordered message delivery between any pair of processes. If a framework sends a message M1 and M2 to the master, then the master might not receive any messages, or it may receive only M1 or, only M2 or, M1 followed by M2. But it will never receive messages in the order M2 followed by M1 [5]. Mesos also provides reliable delivery of the task status updates. The agent persists task status updates to disk and then forwards them to the master. The master sends status updates to the appropriate framework scheduler. When a scheduler acknowledges a status update, the master forwards the acknowledgment back to the agent, which allows the stored status update to be garbage collected. If the agent does not receive an acknowledgment for a task status update within a specific amount of time, it will repeatedly resend the status update to the master, which will again forward the update to the scheduler. Hence, task status updates will be delivered "at least once", assuming that the agent and the scheduler both remain available [5].

The information about the active tasks and registered frameworks is stored by the Mesos master in memory. Persistent storage is not used and it does not ensure that the information is preserved even after the master is failed. This feature helps the Mesos master to scale to large clusters with many tasks and frameworks [5]. If all the Mesos masters are unavailable or crashed, the cluster should continue to operate. The existing Mesos agents and user tasks should continue running but new tasks cannot be scheduled and frameworks will not receive resource offers or status updates about previously launched tasks. Mesos does not dictate how frameworks should be implemented and does not try to assume responsibility for how frameworks should deal with failures [5].

#### 4.3. Designing Highly Available Frameworks

The patterns followed for designing highly available networks are as follows:

- Frameworks run multiple scheduler instances to tolerate scheduler failures. Only one of the scheduler instances is the leader at any particular given point in time. This instance is connected to the Mesos master, it receives resource offers and task status updates and launches new tasks. The other available scheduler replicas are followers. They are used only when the leader fails and in that case one of the followers is chosen to become the new leader via polling [5].
- The election of a new leader is done via a mechanism and schedulers need that mechanism when the scheduler has failed. This mechanism is typically provided using a coordination service. This coordination service can be Apache ZooKeeper [5].
- After election is conducted and a new leading scheduler is elected, the new leader should reconnect to the Mesos master. When the master is registered, the framework should set the id field in its FrameworkInfo to the ID that was assigned to the failed scheduler instance. This ensures that a new session is not started by the master and the master recognizes the connection. Thus, it will continue the session used by the failed scheduler instance.
- After connecting to the Mesos master, the newly elected leading scheduler should maintain the consistency of its local state with the current state of the cluster. If the previous leading scheduler attempted to launch a new task and then failed immediately, the task might have launched successfully and the newly elected leader will start to receive updates regarding it [5]. Frameworks typically use a consistent distributed data store to record information about active and pending tasks. The coordination service that is used to elect the master can be used for this purpose. Mesos replicated logs can also be used to achieve this. The data store is used to record the actions that the scheduler intends to take, before it takes them. If a scheduler intends to launch a task, it first writes this intent to its data store. It then sends a launch task message to the Mesos master. This helps in cases when the instance of the scheduler fails and a new scheduler is promoted to become the leader, the newly elected leader then consults the data store to find all the possible tasks that might be running on the cluster.

The approach is called as write-ahead logging pattern. The key aspects of this approach can be summarized as one when the scheduler must persist its intent before launching task. If the task is launched and then the scheduler fails before it can write to the data store, the new scheduler instance is unaware of the new task. In this case, the new scheduler instance will begin receiving the task status updates for a task it has no knowledge of. Another aspect is that the scheduler should ensure that its intent has been durably recorded in the data store before it continues to launch the task [5].

### 5. LIFE CYCLE OF A TASK

A Mesos task transitions through a sequence of states. The agent is the actual source from which the state of a task can be determined. The agent on which the task is running provides information regarding the actual state of the task. The framework scheduler learns about the current state of the task by communicating with the Mesos master [4]. It does learn by listening for

task status updates and performing task state reconciliation. The task states are represented by the frameworks using a state machine. It can have one initial state and possibly several terminal states [5].

**TASK\_STAGING** state is the first state of the task. The task begins in the **TASK\_STAGING** state and is in this state when the framework sends the request to the master. The master receives the request to launch the task but the task has not yet started to run [5].

**TASK\_STARTING** state is intended to be used by executor which are custom implemented. This state can be used to describe that a custom executor is aware of the task and might have started fetching its dependencies but it hasn't yet started [5].

**TASK\_RUNNING** is the state when a task transitions to after it has begun running successfully. The framework should perform reconciliation when it attempts to launch a task but does not receive a status update within a particular timeout interval. For unknown tasks, the master will reply with the **TASK\_LOST** status. The framework uses this to distinguish between the tasks that are slow to launch and the tasks that the master is unaware about [5].

**TASK\_KILLING** state is an optional state which is intended to indicate that the request has been received by the executor but the corresponding task has not yet been killed. This might be useful for tasks to be killed smoothly. Executors should not generate this state unless the framework has the **TASK\_KILLING\_STATE** capability [5].

There are several terminal states such as **TASK\_FINISHED** which depicts when a task is completed successfully, **TASK\_FAILED** indicates that the task is aborted with an error, **TASK\_KILLED** indicates that a task was killed by the executor, **TASK\_LOST** depicts that the task was running on an agent that has lost contact with its master and **TASK\_ERROR** indicates that a task is launched but its attempt to launch the task has failed because of an error in the task specification [5].

## 6. COMPARISON OF MESOS, DOCKER AND KUBERNETES

Mesos, Kubernetes and Docker fall into DevOps infrastructure management tools known as Container Orchestration Engines (COEs) [6]. An abstraction layer of protocols are provided by COEs between a pool of resources and the containers of application that run on these resources. COEs also solve the problem of taking multiple discrete resources in the cloud and combine them into a single pool. This pool can be used to deploy a variety of applications. These tools provide a set of features such as Container scheduling, High Availability, Health checks, Service discovery and Load balancing. Container scheduling comprises of performing functions which start and stop containers, distributing containers amongst pooled resources, failure recovery of containers, rebalancing containers from hosts that are failed to hosts that are healthy and scaling of applications [6]. High availability of application and container is provided by these tools. The health checks are used to determine the container and application health while service discovery is used to determine the services which are located on a network [6].

### 6.1. Kubernetes Container Orchestration Capabilities

Kubernetes project originated to resolve the issue of running containers at a massive scale. Kubernetes uses YAML-based deployment model. It is used to manage the scheduling the

containers on host machines. It also includes features such as built-in auto-scaling, secrets management, load balancing and volume management. It requires less third party software than Mesos and Swarm. It consists of a concept of pods which are groups of containers that are scheduled together to form a service. It doesn't support single node master installations with highly available clusters. The learning curve of Kubernetes is steeper than Swarm.

### 6.2. Swarm Container Orchestration Capabilities

Docker Swarm is a native Docker Container Orchestration Engine. Swarm is tightly integrated with the Docker API which makes it extremely suitable for its use with Docker. Swarm uses the same primitives as applicable to single host docker cluster. It simplifies managing container infrastructure as there is no need to configure a different orchestration engine. Swarm also uses a YAML-based deployment model using Docker Compose. Its main features includes auto-healing of clusters, overlay networks with DNS, and usage of multiple masters for high availability. Swarm does not support native auto-scaling as well as external load balancing. Swarm includes the capability of ingress load balancing but it requires a third party load balancer for external load balancing.

### 6.3. Mesos Container Orchestration Capabilities

Apache Mesos takes a more distributed approach to managing datacenter and cloud resources. Mesos uses Zookeeper to manage multiple masters and form a high-availability cluster. Other container management frameworks can be run on top of Mesos including Kubernetes, Apache Aurora, Chronos, and Mesosphere Marathon. The Mesosphere DC/OS, distributed datacenter operating system is based on Apache Mesos. Mesos takes a modular approach to managing containers which allow flexibility in the type of applications that can be run on Mesos and also the scale to which the applications can be run. It can scale upto tens of thousands of nodes and is used by Twitter, Airbnb, Yelp and eBay. The most important features are multiple types of container engines including Docker and its own Containerizer which comes along with a web UI, and its ability to run on multiple Oses including Linux, OS X and even Windows. Due to its complexity and flexibility, Mesos has a steeper learning curve than Docker Swarm.

## 7. ANSIBLE

Ansible is an open source automation engine which can be used to automate cloud provisioning, configuration management, and application deployment [7]. It is designed to be minimal in nature, secure, consistent, and highly reliable [8]. In many respects, it is unique from other management tools and aims to provide large productivity gains. It has an extremely low learning curve and seeks to solve major unsolved IT challenges under a single banner [7].

### 7.1. Architecture

One of the primary differences between Ansible and many other tools in the space is its architecture. Ansible is an agentless tool, it doesn't require any software to be installed on the remote machines to make them manageable. By default it manages remote machines over SSH or WinRM, which are natively present on those platforms [9].

Like many other configuration management softwares, Ansible distinguishes two types of servers: controlling machines

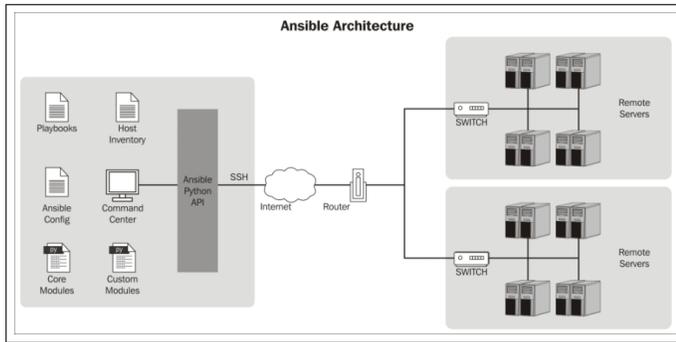


Fig. 3. Ansible Architecture [10].

and nodes. Ansible uses a single controlling machine where the orchestration begins. Nodes are managed by a controlling machine over SSH. The location of the nodes is described by the inventory of the controlling machine [8].

Modules are deployed by Ansible over SSH. These modules are temporarily stored in the nodes and communicate with the controlling machine through a JSON protocol over the standard output [9].

The design goals of Ansible includes consistency, high reliability, low learning curve, security and to be minimalistic in nature. The security comes from the fact that Ansible doesn't require users to deploy agents on nodes and manage remote machines using SSH or WinRM. If needed, Ansible can connect with LDAP, Kerberos, and other centralized authentication management systems [11].

## 7.2. Advanced Features

The Ansible Playbook language includes a variety of features which allow complex automation flow, this includes conditional execution of tasks, the ability to gather variables and information from the remote system, ability to spawn asynchronous long running actions, ability to operate in either a push or pull configuration, it also includes a check mode to test for pending changes without applying change, and the ability to tag certain plays and tasks so that only certain parts of configuration can be applied [8]. The features allow your applications and environments to be modeled simply and easily, in a logical framework that is easily understood. Ansible has low overhead and is much smaller when compared to other tools like Puppet [12].

## 7.3. Playbook and Roles

Playbook is what Ansible uses to perform automation and orchestration. They are Ansible's configuration, deployment, and orchestration language. They can be used to describe policy you need your remote systems to enforce, or a set of steps in a general IT process [13].

At a basic level, playbooks can be used to manage configurations and deployments to remote machines. While at an advanced level, they can be utilized to sequence multi-tier rollouts which involve rolling updates, and can also be used to delegate actions to other hosts, interacting with monitoring servers and load balancers at the same time.

Playbooks consist of series of plays, which are used to define automation across a set of hosts, known as the 'inventory'. These 'play' generally consists of multiple 'tasks', that can select one, many, or all of the hosts in the inventory where each task is a call to an Ansible module - a small piece of code for doing a specific

task. The tasks may be complex, such as spinning up an entire cloud formation infrastructure in Amazon EC2 or Chameleon. Ansible includes hundreds of modules which help it perform a vast range of tasks [9].

Similar to many other languages Ansible supports encapsulating Playbook tasks into reusable units called 'roles'. These roles can be used to easily apply common configurations in different scenarios, such as having a common web server configuration role which can be used in development, test, and production automation. The Ansible Galaxy community site contains thousands of customizable rules that can be reused used to build Playbooks.

Playbook can be used to combine multiple tasks to achieve complex automation [13]. Playbook and Ansible can be easily used in implementing a cluster-wide rolling update that consists of consulting a configuration/settings repository for information about the involved servers, configuring the base OS on all machines and enforcing the desired state. It can also be used in signaling the monitoring system of an outage window prior to bringing the servers offline and signaling load balancers to take the application servers out of a load balanced pool [9].

## 7.4. Integration Of Cloud And Infrastructure

Ansible can easily deploy workloads to a variety of public and on-premise cloud environments. This capability includes cloud providers such as Amazon Web Services, Microsoft Azure, Rackspace, Cloudmesh, and Google Compute Engine, and local infrastructure such as VMware, OpenStack, and CloudStack. This includes not just compute provisioning, but storage and networks as well and the capability doesn't end here. As noted, further integrations are easy, and more are added to each new Ansible release. As Ansible is open source, anyone can make his/her contributions [9].

## 8. OPENCV

OpenCV stands for Open Source Computer Vision Library. It is an extensively used open source machine learning and computer vision software library. OpenCV was built with a motive to provide a common infrastructure for computer vision applications and to accelerate the use of machine perception in the commercial products. Being an open source library licensed under BSD-licensed product, OpenCV makes it easy for anyone to utilize and modify the code [14].

The library has a number of optimized algorithms, which includes a comprehensive set of both classic and advanced computer vision and machine learning algorithms. The algorithms can be used for a variety of purposes ranging from face detection, object identification, classification of human actions to tracking moving objects, extracting 3D models of objects. It has C++, C, Python, Java and MATLAB interfaces and supports Windows, Linux, Android and Mac OS. OpenCV leans mostly towards real-time vision applications and takes advantage of single instruction, multiple data (SIMD) and Streaming SIMD Extensions instructions when available [14].

## 9. FACE DETECTION

Face detection is a specific case of object-class detection. In object-class detection, the task is to find the locations and sizes of all objects in an image that belong to a given class. Face-detection algorithms focus on the detection of frontal human faces. It is analogous to image detection in which the image of

a person is matched bit by bit. Image matches with the image stored in database. Any facial feature changes in the database will invalidate the matching process [15].

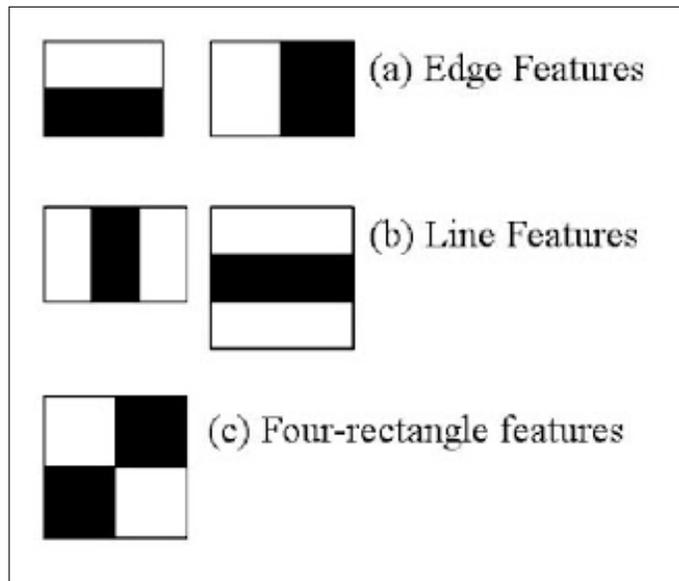


Fig. 4. Features [15].

A number of approaches are used but the most common one which our project utilized is a method where the possible human eye regions are detected by testing all the valley regions in the gray-level image. The basic idea is eyes (white) is separated by darker shades (skin color) above and below it. Then the genetic algorithm is used to generate all the possible face regions which include the eyebrows, the iris, the nostril and the mouth corners [15].

Each possible face candidates is normalized to reduce lighting effect caused due to uneven illumination and the shirring effect due to head movement. The fitness value of each candidate is measured based on its projection on the eigen-faces. After a number of iterations, all the face candidates with a high fitness value are selected for further verification. At this stage, the face symmetry is measured and the existence of the different facial features is verified for each face candidate.

We have utilized face detection Haar cascade provided by OpenCV. The Haar cascade is a classifier achieved using machine learning algorithm known as AdaBoost [16]. Initially, the AdaBoost algorithm required a lot of positive images (images of faces) and negative images (images without faces) to train the face detection classifier. Then the features are extracted from it. Each feature is a single value obtained by subtracting sum of pixels under imaginary white rectangle from sum of pixels under black rectangle [15].

All possible sizes and locations of each kernel are used to calculate plenty of features. For each feature calculation, we need to find sum of pixels under white and black rectangles. Among all the features generated, most of them are irrelevant. To select best features, they are applied to each and every feature on all the training images. For each feature, it finds the best threshold which will classify the faces to positive and negative. There will be errors or misclassifications but when results from all the features are combined the results are excellent. Out of all the features, the features with the minimum error rate, are the features that best classifies the face and non-face images.

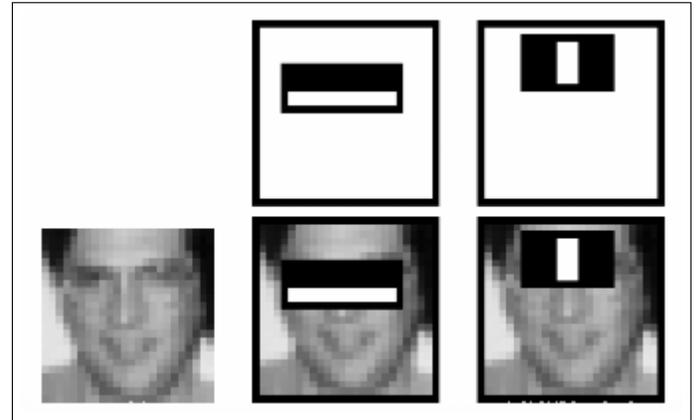


Fig. 5. Basic idea behind features [15].

Final classifier is a weighted sum of these weak classifiers/features. It is considered as weak classifier because it can't classify the image alone, but together with other classifiers, forms a strong classifier. The combined results obtained from all the features help to identify if a face is present in the image, and if it is then the classifier also tells the user about the dimensions of the rectangle and the starting x, y coordinate of that rectangle on the image [16].

## 10. IMPLEMENTATION

In our implementation, we used Ansible version 2.2.1.0, Mesos version 1.2.0, Python version 2.7.12 and OpenCV version 3.2. The deployment was done on chameleon cloud. Firstly, cloudmesh client is set up on the local machine and ansible is installed. A new security is created and the ports 5050 and 5051 are exposed. The default security group was also included which exposed ports 22, 80 and 443. Port 22 is used for accessing the remote machine. The virtual hardware template(flavor) used is m1.medium and the image used was CC-Ubuntu16.04-20161214. A virtual hardware template defines the size of RAM, disk size, and number of cores. The flavor m1.medium specifies 2 VCPU's used, 40 GB root disk, 4096 MB RAM. The cluster was setup to have 3 virtual machines(nodes). Amongst the 3 virtual machines, one was used as Mesos master and the remaining two were used as Mesos agents(slaves). The profile details for cloudmesh client have been set up. The cloudmesh client setup was validated. The system has been deployed using Ansible roles. For the deployment, the system has been divided into multiple roles such as inventory role(r\_inventory), role for create swap file(r\_swap), mesos(r\_mesos) role, master(r\_master) role, agent(r\_agent) role, role for copying framework(r\_copy\_framework) and role for running framework(r\_run\_framework).

## 11. ROLES

The functionality of the Ansible roles are explained as below:

### 11.1. Inventory

The role r\_inventory was used for inventory setup on the local machine. Firstly, the operating cluster was selected and its node details were obtained. These nodes were added to the known hosts file under the ssh directory. The inventory was created selecting two nodes as Mesos agents and one as Mesos master and were tagged accordingly in the inventory file.

### 11.2. Create Swap file

Swap space in Linux is used when the amount of physical memory is full. If the system needs more memory resources and the RAM is full, inactive pages in memory are moved to the swap space. Initially, the built was unsuccessful when attempts were made with RAM size of 2GB, 4GB and 8GB. It was observed, the virtual machines created had no swap space defined. The swap size was increased to 2GB after which Mesos was successfully installed. All these observations led to the conclusion that for successfully installing Mesos on a virtual machine minimum of 2GB swap space is required. The playbook `r_create_swap` successfully creates a swap file of 5GB on all the remote machines.

### 11.3. Mesos

The Mesos package is downloaded from the Mesos website. The latest version of Apache Mesos is 1.2.0 and it is uncompressed on the virtual machines. All the existing softwares on the virtual machines are updated. The dependencies required for Mesos 1.6.0 are `openjdk-8-jdk`, `python-dev`, `build-essential`, `python-virtualenv`, `libcurl4-nss-dev`, `libsasl2-dev`, `libsasl2-modules`, `maven`, `libapr1-dev`, `libsvn-dev`, `zlib1g-dev`, `git`. These packages are specific to different distribution and versions of OSes. Now, the dependencies required for face detection framework are installed. The dependencies include `python-pip`, `numpy` and `opencv-python` to support face detection framework. In Mesos, applications are deployed as frameworks. Mesos is configured using the `configure` command. In order to install Mesos on the virtual machines, the `make` and `make check` commands are executed.

### 11.4. Mesos Master

The Mesos master is run on the host which was selected as the Mesos master in the inventory file. The working directory for Mesos is selected. The IP address of this virtual machine is advertised using the tag `-advertise_ip`. The Mesos master runs on default port 5050. The Mesos master can be validated by entering the IP address followed by the port number of the Mesos master in a Web browser on a local machine.

### 11.5. Mesos Agent

The Mesos agent is run on the hosts which were selected as the Mesos agents in the inventory file. The working directory for Mesos is selected. The IP address of the Mesos agents are advertised and the IP address of the master to which the agents will be connected is specified. In the inventory role, the IP address of the master node was saved in a separate file which is copied to the remote agents in this role and the IP address of the master will be used by the agents to connect to the master node. The agent runs on the default port 5051.

### 11.6. Copy and Run framework

The face detection framework files are copied from the local machine to all the remote virtual machines including both the Mesos master node and Master agent nodes and are placed in their respective directories. The face detection framework is then run on the master node.

## 12. FRAMEWORK IMPLEMENTATION

The test framework provided by mesos have been modified to run face detection application. The framework initializes all the requirements through `face_detection_framework` file after which `face_detection_executor` runs. The executor creates

threads which then run on agents. The executor is designed such that it can be easily modified to support another python application by just changing the call to the main function in `run_task`.

The variable `dataset` and `database_url` are the only variables that need to be modified to change the dataset from which the images need to be extracted and head counts need to be taken. Here, the `dataset` variable tells the dataset name and the `dataset_url` tells the location from where the zip folder can be downloaded. The program downloads and unzips the folder to home directory of the user and this default path can be changed by changing the `global_path` variable. After unzipping the files, the program removes the zip folder as it is no longer required.

Once the dataset is extracted, the file list is given to the face detection program implemented using OpenCV library. The OpenCV library uses cascade files, where the cascade files are simply classifiers which can identify faces in an image or dogs in an image or any other object depending on the cascade file used. For our application, face detection cascade has been used and the link to cascade file is given in `cascade_url`. One can easily change this cascade file and change the way this program functions, i.e. one can just provide the hyperlink in the variable `cascade_url` depending on the cascade file user wants to use and the function will identify dogs, cats, eyes or any other object which the cascade file is trained to identify. The user can find these cascade files online, easily or could train and create one if required.

The program identifies faces, marks them in a rectangle and saves the output in the output folder. The number of images has been restricted to 50 for testing purposes but this can easily be changed by updating the `no_files` and `images_per_file` variable as per the requirement. After the results have been obtained the dataset folder is deleted. The results obtained contains images with faces marked in blue square and the count is maintained in `results.txt` file. These results are saved on the agent machines which is then copied to local machine using `fetch` command automatically.

Whenever new tests are run, the results are appended to `results.txt` file in place of just replacing the results. This has been done as a user might decide to run the application for different dataset or for different images while keeping the head counts for older datasets.

## 13. BENCHMARK

The benchmarks are shown in Table 1 which compare the time to run the `make` command and the `make check` on different VMs. The time required to install, setup a cluster and install prerequisites has been excluded as they are negligible and on average take 5 minutes on each VM and just vary in few seconds on average.

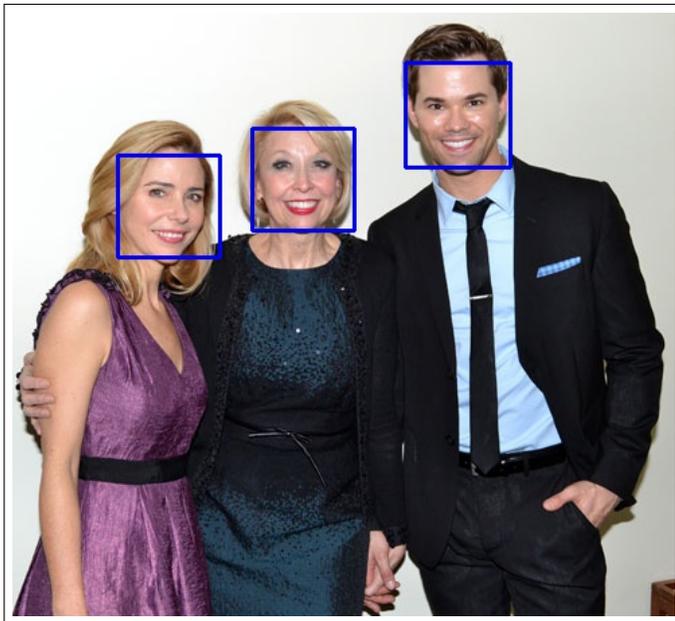
The results shown in table 2 were run on VM's running Ubuntu 16.04 with flavor as medium and swap size of 5 GB. The results were taken for 1 image to see how much time initialization takes. The results show that there is significant improvement when number of agents gets increased.

## 14. CONCLUSION

The head count detection framework is running successfully on Apache Mesos and the output is generated on the local machine which gives the source of the image and the number of head counts detected in the image along with it. Apache Mesos

**Table 1.** Benchmarks

Operating System	Flavor	Virtual Size Allocated	RAM CPU Cores (in GB)	Swap Size (in GB)	HDD Size (in GB)	Time to run make (in hh:mm:ss)	Time to run make install (in hh:mm:ss)
Ubuntu 14.04	small	1	2	2	20	00:43:56	00:48:07
Ubuntu 14.04	medium	2	4	5	40	00:35:23	00:42:32
Ubuntu 14.04	large	2	8	5	80	00:33:27	00:37:21
Ubuntu 16.04	small	1	2	2	20	00:40:32	00:48:32
Ubuntu 16.04	medium	2	4	2	40	00:37:56	00:46:68
Ubuntu 16.04	medium	2	4	5	40	00:19:31	00:32:16
Ubuntu 16.04	medium	2	4	7	40	00:21:47	00:29:43
Ubuntu 16.04	large	2	8	5	80	00:20:31	00:31:23



**Fig. 6.** Sample Output Image.



**Fig. 7.** Sample Result.

**Table 2.** Application Benchmarks

Number Of Images	Run Time with 1 Agent (in hh:mm:ss)	Run Time with 2 Agents (in hh:mm:ss)
1	00:00:28	00:00:45
50	00:01:21	00:01:15
100	00:02:12	00:01:52
500	00:05:08	00:03:25
1000	00:10:21	00:07:32

was successfully deployed on Linux 16.04 and 14.04 systems and the time required to install and deploy Mesos was successfully benchmarked. Implementation of the head count detection framework was successfully tested on Apache Mesos with a cluster of 1 master with 1 agent and 1 master with 2 agents. Ansible was used to successfully deploy Mesos on chameleon cloud and it is seen that Apache Mesos handles the containerization of the framework with ease. The future scope would include deployment of the headcount detection framework over 1,000 virtual machines and test the scalability of Apache Mesos. Along with scalability, the reliability can also be tested by running multiple masters and checking the fault tolerance of Apache Mesos.

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# Optical Character Recognition

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Optical Character Recognition is a technology for converting images of texts, into machine encoded text format. In this project, the input data is in standard image formats and our goal is to recognize the words/letters in the image as accurately as possible and convert the dataset into TXT format. The heart of OCR as a pattern recognition system is a classifier. The images will go through a pre-processing phase which will convert them into a form that is compatible for feeding to the classifier. Then the classifier will determine the class of each glyph in the image. The whole recognition system is installed and operated on the cloud.

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**Keywords:** OCR, Ansible, K-Nearest Neighbor

Report: <https://github.com/cloudmesh/sp17-i524/blob/master/project/S17-IR-P012/report/report.pdf>

Code: <https://github.com/cloudmesh/cloudmesh.ocr/tree/master/code>

## 1. INTRODUCTION

The age of digitalization has made it quintessential to store documents in a digital form for the purpose of allowing valuable information to be stored, edited and searchable in the middle of billions of records. OCR technology is used quite frequently by every industry that has handwritten, scanned or photographic data. This project proposal gives a detailed view on how the OCR technology works, the preprocessing done to remove the noise and the algorithms used to recognize the images. We have delved deep into some of the basic concepts used in the implementation process. We have also discussed some important applications of this technology in the real world and created a benchmark.

## 2. EXECUTION PLAN

This execution plan is to show the distribution of work over the time period of the course. The steps followed to achieve the final results.

1. **6 March - 12 March 2017** To implement the OCR, we first looked for a dataset to train the algorithm and test it. The desired library to use to write the codes and the complexity of the final goal of the project was discussed.
2. **13 March -19 March 2017** Looking for preprocessing steps in order to cleanse noise from the image and convert the image into a standard form which makes it adequate for later processing.
3. **20 March - 26 March 2017** Starting to work with Ansible and Cloudmesh Client for running tasks on virtual nodes.

4. **27 March- 02 April 2017** starting to deploy individual modules for preprocessing, to the virtual machines on Chameleon Cloud service, using Ansible. Cloudmesh Client was used to reserve the virtual machines on the cloud services.
5. **03 April- 09 April 2017** Executing a preliminary form of character recognition using K Nearest Neighbour classification and a large dataset.
6. **10 April - 16 April 2017** Implementing segmentation of image into lines, words and letters.
7. **17 April - 23 April 2017** Executing benchmark and finalizing the project report.

## 3. BACKGROUND

### 3.1. OCR Technology

Optical Character Recognition is a technology which is used to convert different types of documents that can be in the form of scanned documents, including handwritten or machine-written into an editable and searchable form [1]. The images can be in either the basic black & white or colored. The technology analyzes the structure of the document and divides it into small refined segments, so that each segment contains one character. Finally, individual characters are singled out one by one and fed to a classification algorithm which will return the closest letter that the individual character could possibly be identified with.

## 4. SYSTEM CONFIGURATION AND TECHNOLOGIES USED

### 4.1. System Configuration

The python codes and the libraries are run on a Ubuntu 16.04 LTS.

### 4.2. Technologies Used

1. **Python Programming Language** : An object oriented programming language with an open-source license. We chose Python for this project as there are many libraries available in Python that helps in creating a code for OCR easier. Packages such as PIL, Pillow and OpenCV are one of the few libraries that helps in image processing.
2. **OpenCV** : OpenCV is an open source computer vision library. It is used for building computer vision applications. It consists of more than 2500 algorithms including both machine learning and computer vision algorithms [2]. These algorithms are devised for facial and image recognition, track any moving objects etc. We have used OpenCV 2 for creating a KNN classifier and a few of our preprocessing techniques.
3. **Ansible** : Ansible is an IT automation tool. It uses YAML in order to issue the state of the server [1]. Ansible implements the internal command that is required to reach that state which depends on the operating system. The ansible playbook which consists of these internal commands can be applied to any server or service. There is no requirement to instal an additional software on the target system as the commands are run over an SSH session.
4. **Cloudmesh Client** : It is an open source client interface tool that provides us with an easy-to-use interface for accessing cloud services, creating single and multiple VMs, clusters and workstations. We can manage the resources we would like to use and customize them as per our requirement to run the projects. It provides an interface to execute jobs on High Performance Computing clusters [3]. The users can use just one platform to manage all of the cloud resources. Cloudmesh client creates a local copy of the data which results in clouds with similar configurations to be created as well. The default features of the Cloudmesh Client allows easy control of the cloud as well. Cloudmesh includes an API, commandline client and a commandline shell.
5. **Chameleon Cloud** :Chameleon cloud provides OpenStack Cloud (kilo) using the KVM virtualization technology [4]. It is an Infrastructure as a Service(IaaS) platform that allows us to create as well as manage the virtual environment. The virtual machine that we use here is compatible with KVM. Chameleon Cloud also gives access to the bare-metal computing resources, which allows administrative rights to use cloud for computing experiments [5].

## 5. METHOD SURVEY

Optical Character Recognition have already been developed in numerous ways, focusing on different goals. We did a survey on the possible approaches for character recognition.

The main components of every OCR system can be enumerated as feature extraction component, and the classifier.

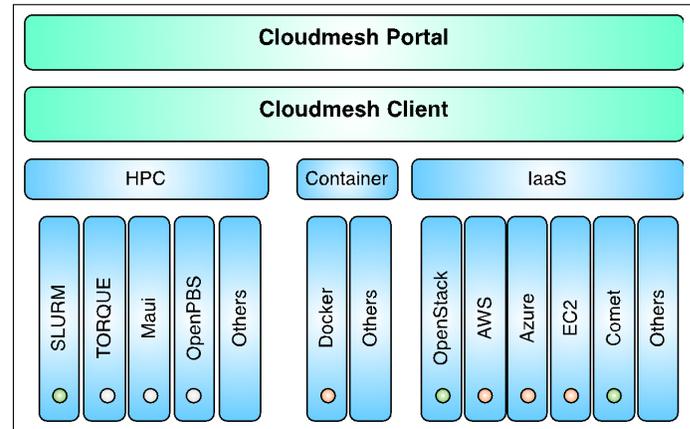


Fig. 1. Architecture of Cloudmesh Client [3]

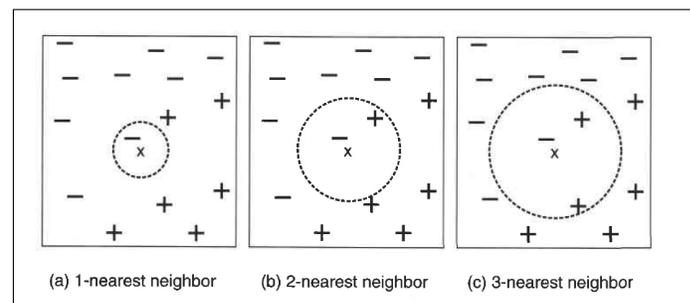


Fig. 2. Example of k-NN classification [7]

Feature extraction methods can be separated into two groups: Template matching, and Structural classification [6]. In **Template matching**, the individual pixels of the image are directly used as features. For each possible character, there is one class and one template feature set, associated with it. In classification, a similarity metric will evaluate the distance of the input character to each of the templates. And thus, the input will be represented with the class of the most similar template.

In **structural classification** structural features of every character, such as loops and curves, are used as features.

There are various types of classification methods. A number of methods that have been used for OCR are Nearest-Neighbor, Artificial Neural Networks, and Support Vector Machines. K-Nearest Neighbor and Artificial Neural Networks are discussed further as the candidates for our job.

### 5.1. K Nearest Neighbour

It is a non parametric algorithm where each of the training data is considered to have a set of vectors and a class label associated with each vectors. The training set will have the labels for the classes , given the test set it calculates the distance between the training set and the test set and calculate the nearest points. A single value of 'K' is given which allows us to decide how many neighbours influence the classification. Figure 2 displays a schema of KNN classification.

### 5.2. Feed Forward Neural Networks

Artificial Neural Network is a paradigm in computing, inspired by the structure of biological nervous systems. It consists of a network of processing units, where the output of each unit is a nonlinear function of its weighted inputs that come from

other units. Such network can be trained to solve different kinds of problems, including classification and clustering. A feed forward neural networks is one in which the neurons are organized in a number of layers and each layer only feeds to the next one, but not to the previous one (no feedback). However, in a back-propagation process, the errors from one iteration of classification will be fed back from the output to the network, in order to modify and improve the network for next iterations.

Due to simplicity and relatively good performance of KNN, we choose it as the classifier for this project. There is an easy to use implementation of it in OpenCV library. Our KNN uses euclidean distance as the distance metric to calculate the nearest neighbours for the 'K' value.

Euclidean Distance

$$d(p, q) = \sqrt{\sigma(p_i - q_i)^2}$$

For the value of K, 5 is chosen so that it is neither too small and sensitive to the noise nor too large which might result in including the points from other classes.

### 6. PREPROCESSING TECHNIQUES

The steps in an OCR full session are as follows: Preprocessing: The input images need to be segmented into units that each of them keep only one glyph (symbol). Also, the colored or grayscale images will be binarized. Feature extraction: The glyphs will be decomposed into features like lines, closed loops, line direction, and line intersections. Character recognition: The image features will be fed to the classifier and they will be compared with stored glyph features and the nearest match will be chosen.

Preprocessing is required on the raw images that we are using to filter out the required subject and distinguish from any other unwanted objects from the image such as watermarks, background subjects etc. We have conducted different preprocessing techniques in order to remove noise and convert the image into a grey scale format as color images requires more complex methods of processing

#### 6.1. Noise Reduction Techniques

Noise reduction is done for extracting out any unwanted bit-pattern, there are linear as well as non-linear techniques for this. Linear : In this method is used to remove any isolated pixel noise from the image. Here the required output filter is taken as a linear combination of the neighborhood pixels Non- Linear : These kind of filters are used to replace the value of a particular pixel in order to remove any kind of impulse noise

#### 6.2. Histogram Based Method

It gives a value to the intensity of the pixel and plot it on a histogram , where darker the image , more the data points would be on the left and center of the histogram . Lighter the image , more the data points would be on the right side of the histogram. Using a histogram equalization method the contrast on the image can be improved in this case. In the histogram equalization method , an image is divided into blocks of pixels and an histogram equalization is done. This allows us to distinguish the images we actually require from the other background images . It allows us to enhance the visibility of the characters' present on the image.

#### 6.3. Median Filter

It is a non-linear noise reduction technique , it is a low pass filter. In this case the pixel values are taken for an area on the image

and an average of the pixel value is taken and assigned to the center pixel in that area. Figure 3 displays a schema of how median filter works. It is an effective means for removing the salt and pepper noise which are random lines occurring on the image due to poor quality of the picture or if the image wasn't scanned well [8]. Figure 4 shows the result of applying a median filter on a scanned image, we can see the reduction in dots and other marks on the image, making it more smooth and usable.

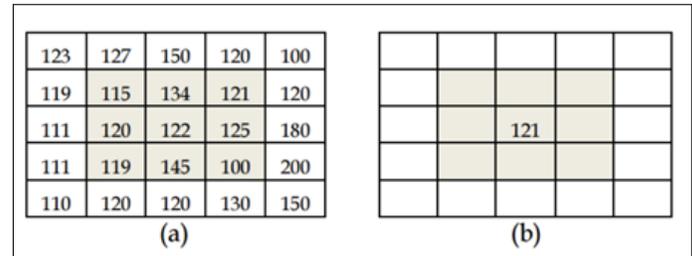


Fig. 3. Averaging of a pixel in median filter [8]

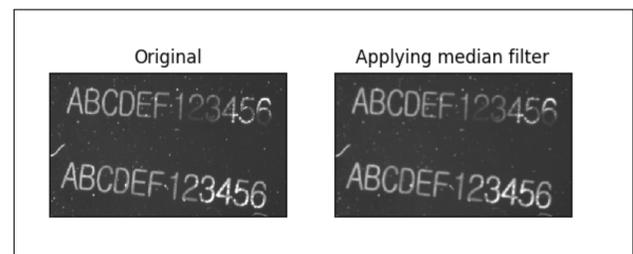


Fig. 4. Result of applying median filter on a scanned image

#### 6.4. Gaussian Blur

Gaussian Blur filter is a low pass filter which is used to eliminate isolated pixel noise. Image smoothing is done here using gaussian filters where the weighted average of the pixel values is computed with the gaussian coefficients as weight. The filter provides a smooth texture to the noisy image.



Fig. 5. After applying gaussian filter on the image preprocessed with median filter

### 6.5. Binarization

Otsu's method [9]: Otsu's method concludes finding the best intensity threshold to separate two classes, often background vs foreground but not always. The algorithm tries to find a separation point that has the minimum weighted within class variance. If the input images are grayscale, the algorithm will simply find a threshold that any intensity below that will be considered as the background and the intensity of the corresponding pixels will be rounded to zero. Similarly, the intensities above the threshold will be rounded to 1. The resulting image (array) will be binary.

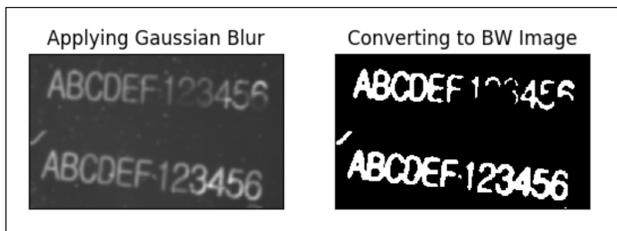


Fig. 6. Applying binarization after applying gaussian filter

### 6.6. Segmentation

Segmentation of the image happens in multiple levels, namely lines, words and letters. Application of all of these three will enable the conversion of whole pages of scanned documents into text format. In this project, segmentation at all levels is implemented using projection profile approach. Projection of the intensities on the vertical axis will differentiate the rows that contain some text, from the ones that only include the background. For word segmentation if the number of background columns are more than a threshold, the two letters will be considered as incorporating different words. The background columns are detected using projection on the horizontal axis, but only for the rows that are included in the current line. Thresholds are defined using expert views in typography [10]. The letter segmentation is simply done after one background column is found. The figure 7 displays the application of our segmentation algorithm on a sample image.

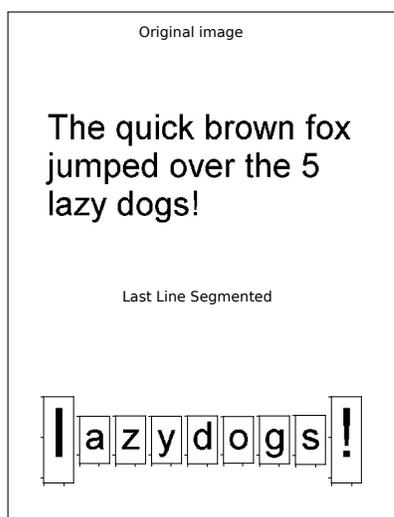


Fig. 7. Applying segmentation

## 7. APPLICATION

OCR converts images to machine-readable text. That will make it the initial tool that needs to be used for processing any documents or simply any written material in a digital image, which has been captured by a camera [11]. Its output can be stored significantly more compact than scanned images. But beyond that, it enables us to process the output information for numerous applications. Examples of these applications include creating a narrator machine to help the visually impaired read nondigital documents and signs, or automatic recognition of automobile number plates.

## 8. LICENSE

The project is developed under the open source Apache License 2.0. The license file is included in the Git repository of the project. The packages and softwares used in developing the project include OpenCV, Python 2.7, Ansible, Cloudmesh. All of these packages are open-source. The license file for OpenCV is included in the project repository (CV\_LICENSE.txt).

## 9. CLOUD DEPLOYMENT

Automatic deployment of program on virtual environment was done using Ansible [12]. The jobs were collected, organized in Playbooks [13] and run on virtual clusters provided by Chameleon Cloud [14]. The tasks include Installing the essential libraries on the remote machine and running the program. The VM reservations were done using Cloudmesh Client. Three Ansible playbooks are used, one for deploying the software stack, one for running the OCR codes on a standard dataset and another one for running it on an arbitrary image. The software stack required for running the program includes the following components:

1. **Git** The Git module is needed for cloning the OCR Python codes. It is installed using apt module.
2. **OpenCV** OpenCV, as discussed in the previous sections, has become the standard library of computer vision. It is used in this project for multiple purposes. As this library is extensive, its installation may take a significant time. Hence, we tried to examine all the possible ways to install it. Building from the source, which is the recommended way for installing it (and any other package) took more than 20 minutes. Even after that, connecting it to the existing Python installation on the VMs was problematic. The alternative ways include using PyPi, Conda (Anaconda package management system), and apt. After trial and error, Apt appeared to be the best solution with installation time of less than 5 minutes and hassle-free python integration. It can be easily installed on VMs using Ansible apt module. So we chose this method.
3. **OCR Code** The codes of the program were checked in the project repository. An Ansible role cloned these codes into each node of the cluster.
4. **Dataset** An Ansible role was used to download and extract the dataset. Unarchive module was used for this purpose.

## 10. DATASET

The dataset used in our project for training the KNN is Chars74k [15]. This dataset provides an extensive collection of English letters and digits, in handwritten form or in various computer fonts

[16]. In this project, a subset of the data, including characters from computer fonts with 4 variations (combinations of italic, bold and normal) was used. The glyphs in this subset include 0-9, A-Z, and a-z. For each glyph, there are 1016 different files, each with one font. However, some of the fonts are similar to each other.

Before this dataset, the MNIST handwritten digits database were used for preliminary purposes [17].

## 11. BENCHMARKING

After wrapping all the necessary material, the code was run in a role and the result was saved in text files, using another role. The accuracy of classification is printed in the console of the local machine. The program was first deployed on single VMs that were reserved manually using Cloudmesh Client. Later on, clusters of 2-4 nodes were used to measure the execution time of deployment. Note that for running the benchmark, there is a trade-off between the runtime and accuracy of classification. The more samples are used for training the dataset, the higher the accuracy will be achieved and of course the longer execution time is needed.

### 11.1. Sample size analysis

Running a dataset of 50 images as the test and train data with  $K=5$ , takes around 20 seconds and yields an accuracy of 65%. The time complexity of the algorithm is  $O(n^2)$ , thus, using 100 samples will multiply the runtime by 4. However, as the dataset used contains 74k images, there is still significant diversity among 100 images. As a result, using 100 images only improves the classification accuracy up to 75%. Changing the number of nodes does not affect the runtime, unless parallelization is exploited.

Each VM on Chameleon Cloud has only 1 core, 2050076 kB (2 GB) of RAM, and 20 GB of storage. Due to small size of RAM, we had to keep the number of training samples under 200.

### 11.2. Cluster size analysis

In this section, the sample size is around 50 different fonts for training the classifier and another 50 for testing it.

For the cluster of **2 nodes**: It took 67 seconds to deploy (allocate) the cluster, 153 seconds to install the software stack and dataset on the nodes, and 169 seconds to run the benchmark on them. The accuracy of classification on one of the nodes was 72.23 and on the other, it was 70.84.

For the cluster of **3 nodes**: It took 98 seconds to deploy (allocate) the cluster, 170 seconds to install the stack and 180 seconds to run the benchmark.

For the cluster of **4 nodes**: It took 131 seconds to deploy (allocate) the cluster, 175 seconds to install the stack and 187 seconds to run the benchmark. As we can see, the higher number of nodes will only add to the time of cluster creation. As the nodes are quite similar, the execution time of the tasks which run in parallel is similar.

### 11.3. OCR on arbitrary images

As the arbitrary images can be significantly different from the standard dataset, the sample size needs to be much higher. However, due to small size of RAM, for running OCR on arbitrary images, we only used a sample size of 200. That causes the accuracy of OCR to be very low, around 20%.

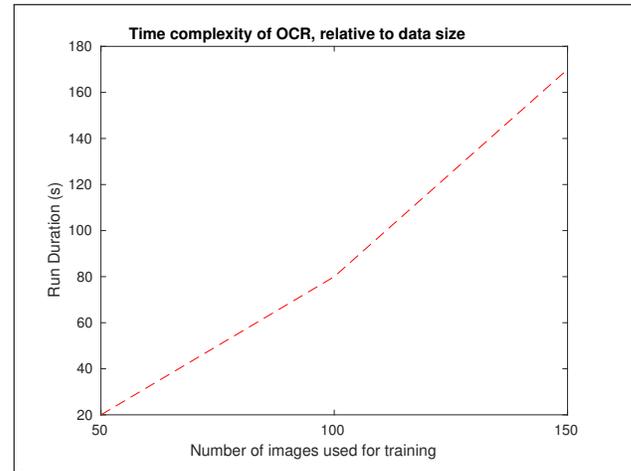


Fig. 8. Time complexity of running OCR on Chameleon Cloud

## 12. REPRODUCIBILITY

Instructions on reproduction of the project are provided in the project repository [18].

## 13. FUTURE WORK

For improving the current OCR system, various kinds of sophisticated structural features can be added to feature extraction. It can also be extended to operate on languages other than English. In order to improve the performance, the power of multiple cores/VMs can be used for parallelization, so that after segmentation, each VM will operate on one line of the text. Thus, multiple lines can be processed at the same time. For improving the recognition accuracy, a lexicon can be used to evaluate the validity of the words that have been formed by OCR, and then possibly correct them to the closest word in the lexicon.

## 14. ACKNOWLEDGEMENT

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## 15. WORK BREAKDOWN

The following was the work distribution followed for the project,

- **Sushmita Sivaprasad** : Researched on the background of implementing the ocr technology, briefed on the system configurations and the technologies that can be used. She implemented the preprocessing steps to remove the noise and inaccuracies in the image file before implementing the K means algorithm. Contributed to the writing of the report.
- **Saber Sheybani** : Implemented the cloud deployment on chameleon cloud and has done the benchmarking of the on the chameleon cloud. Contributed to the writing of the report.

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# Weather Data Analysis

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project-S17-IR-P013, September 21, 2017

**The project aims to analyze climate data with focusing on use of Hadoop Framework for data analysis and Ansible for automating deployment and monitoring.**

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**Keywords:** Cloud, I524

Report: <https://github.com/cloudmesh/sp17-i524/tree/master/project/S17-IR-P013/report/report.pdf>

Code: <https://github.com/cloudmesh/sp17-i524/tree/master/project/S17-IR-P013/code>

## 1. INTRODUCTION

The study of environmental science and climatic changes around has been done for decades, the study has always been predictive based on the past experiences and forecasting of the weather conditions around us. With use of modern days technologies it determining the climatic changes and with analysis done around it has helped human being to prepare and face the natural calamities. Though with current equipment weather department has strengthen their arms but has not been able to be full proof and many time its not been able to predict/ forecast the climatic changes effectively. The study of the whether data and geo graphical changes is ongoing evolving process. Thus more and more researcher needs modern days tools and technologies to leverage it and forecast more accurately.

### 1.1. Objective

The goal of this is to study the weather data and analyze the relationship between the geo graphical changes such change in geo magnetic field and/or natural disaster. With use of Hadoop for distributed data analysis aims to find any pattern that might exist between these parameters. The course of the analysis will also provide visualization of these parameters in order to identify any pattern in a more intuitive way. By leveraging the power of Ansible for application deployment over cluster and monitoring the application performance to determine scalability and throughput. The conclusion will be determined by establishing any existing pattern, analysis done over it and by visualizing it.

## 2. DATA SOURCES

Weather data has been recorded since 19th century. This data can be used to estimate climate changes and forecasting. The same data can be used to find any existing pattern with natural disasters. Following sources have been compiled for weather, natural disaster and geo magnetic fields.

- Weather-Data[1]
- Natural Disaster[2]
- Geo Magnetic Field[3]

## 3. HIGH LEVEL DESIGN

The design of the application is thought of leveraging power of Hadoop as main processing unit of analysis with deployment on the cluster environment where application requires multiple processing units for execution, database for persistence and visualization tools for graphical outputs. The project is divided into following steps:

- Data cleaning and persistence - The raw data cannot be used directly for analysis. First data has to be parsed and required parameters will be extracted. Then this extracted data will be dumped into a NoSql database.
- Core Analysis Program - Core analysis program will be responsible for figuring out any hidden patterns between aforesaid parameters. Program will compare natural disasters occurred, geo-magnetic orientation and climate data set on a given location and duration and compute relationship between them. The program will be an MapReduce implementation and is the heart of the application. The program will be executed through Hadoop framework. Hadoop will execute the program in a distributed manner.
- Deployment and Monitoring - The application needs multiple processing units and monitoring system. Ansible will be used for deployment and manage nodes for program execution. Ansible will be responsible for following tasks i) Deployment and configuration of Hadoop on the multiple nodes. ii) Starting Hadoop servers, inserting/reading data. iii) Execution of the commands to run the analysis using

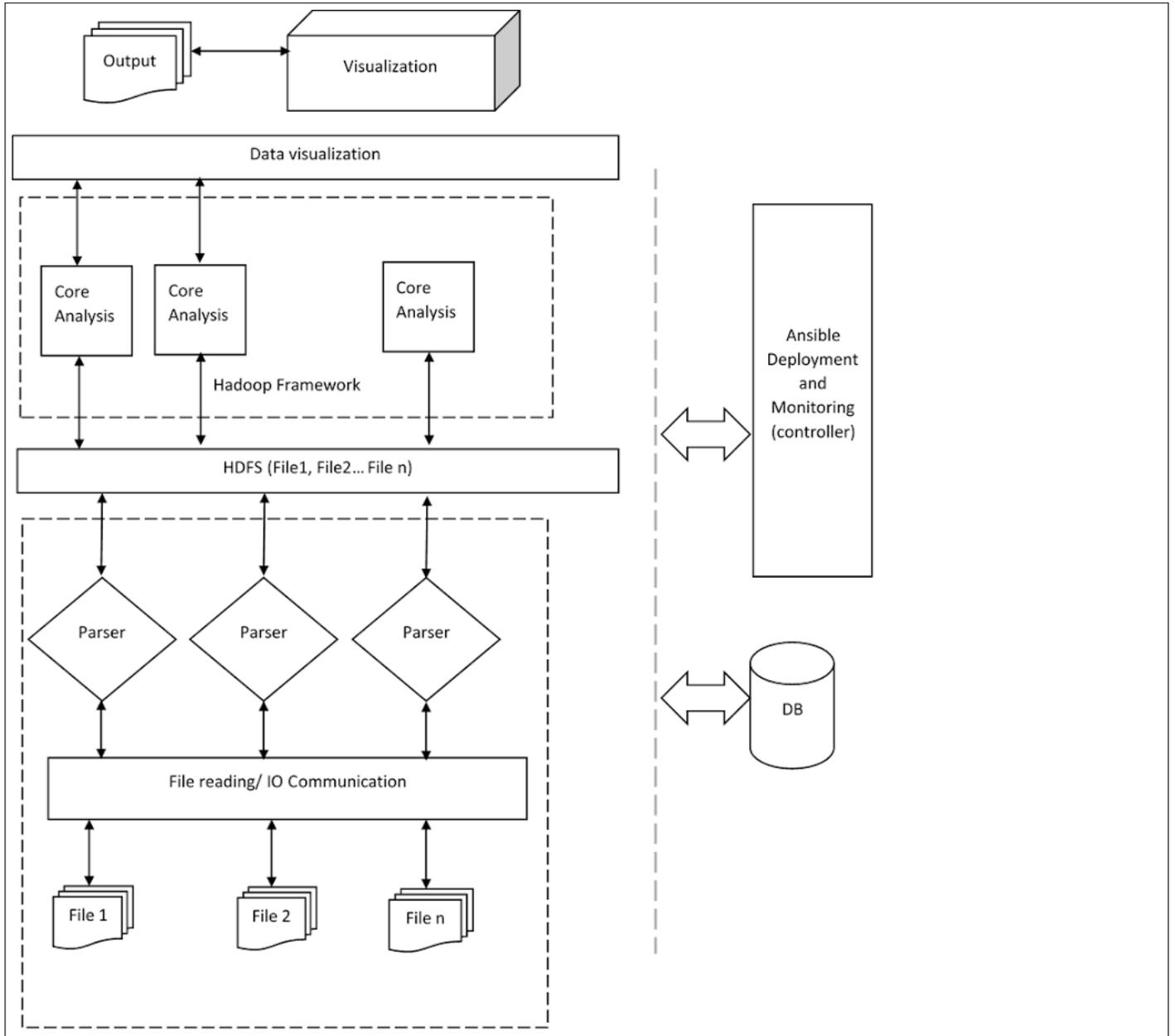


Fig. 1. Architecture

Hadoop to filter the input data and write response to HDFS or some output file. iv) This output can be then passes to the visualization step as the input data.

- Visualization - Finally once the programs completes execution, using the scikit-tool or other visualization tool kit and the output file, graphs and patterns depicting the relationship can be plotted more intuitive representation.
- BenchMarking - The application can be benchmarked for the scalability by addition more nodes and checking the performance for strong scaling. The report will be represented in tabular format.

#### 4. DATA CURATION

Getting data ready is the very first and basic step for analysis. We have chose NCDC [4] as our source of data. NCDC [4] exposes few rest apis for accessing weather data. Following will give you a brief understanding on the apis used for getting the required data.

1. Datasets : This groups data into monthly daily , yearly pattern. There are eleven different datasets. We will be choosing GSOM (Global Summary Of Monthly) as our primary datasets. (URL : <https://www.ncdc.noaa.gov/cdo-web/api/v2/datasets> ,Attributes : GSOM). For this project we will use GSOM only.
2. Data Categories: This groups data into data category like Temperature, Pressure etc. We will consider only few. ( URL : <https://www.ncdc.noaa.gov/cdo-web/api/v2/datacategories>, Attributes : "TEMP" (Air Temperature) , "PRES" (Pressure) , "EVAP" (Evaporation) and "VELOCITY" (Velocity) ). For our project we will be using PRCP, SNOW, TMAX, TMIN and TAVG.
3. Data Types: This group Data Categories into further smaller sub types. (URL : <https://www.ncdc.noaa.gov/cdo-web/api/v2/datatypes?datasetid=GSOM&datacategoryid=TEMP> , Attributes : "TAVG" (Average Temperature), "TMAX" (Maximum Temperature) and "TMIN" (Minimum Temperature) ) Other Data Categories does not have sub type.
4. Location Categories: This groups data in terms of location. (URL : <https://www.ncdc.noaa.gov/cdo-web/api/v2/locationcategories> , Attributes : "CITY" , "CLIM\_DIV" (Climate Division), "CLIM\_REG" (Climate Region) , "CNTRY" (Country) ,"ST" (State)). For this project we will be downloading data for India only.
5. Location: Groups data in terms of country, state etc. (URL : <https://www.ncdc.noaa.gov/cdo-web/api/v2/locations?locationcategoryid=CNTRY>, Attributes : "FIPS:IN" (INDIA) , "FIPS:IO" (Indian Ocean))
6. Station : This collects stations details based on the location id. (URL : <https://www.ncdc.noaa.gov/cdo-web/api/v2/stations?locationid=FIPS:IN> , Attributes: ids , mindate and maxdate). All of the stations details will be collected.
7. Data : This collects actual weather data for the given stationId, startdate and enddate. (URL : <https://www.ncdc.noaa.gov/cdo-web/api/v2/data?datasetid=GSOM&stationId=GHCND:IN1NCBC0005&startdate=1970-10-10&enddate=1971-10-10>). Since the project only requires only 5 attributes, further filter is applied while invoking the API. The data received will be saved into database.

##### 4.1. Collecting Data

NCDC uses token based authentication for security and with each token , no more than 10,000 hits are allowed per day. Well 10,000 seems huge but truly its not. We have targeted one country (India) and 5 attributes chiefly precipitation, snow, maximum temperature, minimum temperature and average temperature for each month. Total number of weather data stations in the country is around 3500 and each station has a data range of 30 to 50 years. This leads to a total of 100,000 hits or more. To handle this, we need to load data incrementally, i.e. the curation program should have the ability to resume the download from the last save point. Before we dive more into logical section , lets first see the technology stack for data collection.

##### 4.2. Technology Stack

We have considered python , Apache thrift and Apache Hbase for data curation step. We will be covering a short introduction of the steps to configure the system, before diving into the core logic of curation. Since we are going to use Apache Hadoop for our analysis purpose, Hbase comes as a natural choice of NoSql database. Java is the default language for both Hadoop and Hbase. So now the question is how to connect to Hbase using python and the solution is Apache Thrift or thrift. Thrift is a library from apache which generates hbase client. Thrift supports many third party languages including python. The following steps will be required to install thrift first.

###### 4.2.1. Install Apache Thrift [5]

1. Download Thrift from "<http://redrockdigimark.com/apachemirror/thrift-0.10.0.tar.gz>".
2. Extract the file and run ./configure.
3. Execute sudo make install or simply make to generate the binaries. If using make, the thrift binaries has to put into path manually (can be found under compiler/cpp/).
4. After thrift is available in path , it can be tested by running "thrift -version".
5. Then the python module has to be created to be used within python. To do this download "<https://github.com/apache/hbase/blob/master/hbase-thrift/src/main/resources/org/apache/hadoop/hbase/thrift/Hbase.thrift>" file.
6. Then execute "thrift -gen py <path/to/Hbase.thrift>". This will generate "gen-py" folder.
7. Add this folder to python path by export PYTHONPATH=<path/to>/gen-py/:\$PYTHONPATH.

For details you can check Installation steps. Installation of Hbase will be discussed later along with Hadoop. Now thrift is ready to use. Execute "/hbase thrift start" to start the thrift server. Hbase has to be started separately.

#### 4.2.2. Install Happybase [6]

Happybase is a wrapper program written on thrift to facilitate data access layer in python in a more readable and swift way. Rather than using thrift client directly we will be using happybase python module. To install happybase run "pip install happybase". Once done test the python library by running the following test code

##### Listing 1. Connect-Hbase

```
import happybase as hbase

connection = hbase.Connection('localhost')
print connection.tables()
```

## 5. HBASE AND TABLE STRUCTURE

Hbase [7] is a column based key-value database. We have considered two tables for weather data 'wda\_stations' and 'wda\_weather'. The structure of the tables are as follows

##### Listing 2. WDA\_STATIONS Table

```
{[station-id-key : {
  station : {name : {}, id : {}},
  date_range : {
    min_date : {},
    max_date : {}
  },
  location : {
    latitude : {},
    longitude : {}
  }
}]}
```

##### Listing 3. WDA\_WEATHER Table

```
{[yyyy-mm-key : {
  weather : {station-id : {
    data-type : {value}
  }}
}]}
```

### 5.1. Table Definition

Stations table will consist of all the weather stations with its location and the date range within which it is was active. Location will have the latitude and longitude. The station id will be the key for the table. NCDC uses a uniquely identifiable key for the stations across the globe. This makes the best attribute for the primary key irrespective of country and region. Weather table is a more completed table and has dynamic column family. The key for the table is the year and month in (YYYY-MM) format. Each key contains all the stations with their weather parameter. For example say a key 1967-01 (meaning January 1967) is having 10 stations with station id sid-1 to sid-10. Each station id will having 4 parameters or data types (TAVG,TMAX,TMIN and PRCP). And finally each parameter have their values.

## 6. DATA PERSISTENCE LAYER

The project is structured with python packages. We have a specific package for persistence as 'iu.i524.S17IRP013.dao'. The dao has the scripts to connect hbase and performs db operations. The base script is 'hbase\_connect.py' which does the connection. The connection is made through Apache Thrift Rest Api. It has the connection object, which is used by the other two dao classes.

### 6.1. Station Dao

This script does all CRUD operations on stations table. On startup it will create the table if not available. It has 2 main functions insert and retrieve. The insert function takes key value pair as argument and put it into hbase table. Another function and the important one is 'get\_station\_data' which takes the start row as argument and returns next ten records. This is done via scan command of hbase which supports record limitation.

##### Listing 4. Stations Dao

```
def get_station_data(start_row=''):
    st_list = dict()
    count = 0
    if(start_row == ''):
        for key, data in table.scan(limit=10):
            st_list[key] = {'min_date':data['date_range:
                min_date'], 'max_date':data['date_range:
                max_date'], \
                'station_id': data['station:
                id'], \
                'latitude':data['location:
                latitude'], \
                'longitude':data['location:
                longitude']}
    else:
        for key, data in table.scan(limit=11, row_start=
            start_row):
            count = count + 1
            if(count > 1):
                st_list[key] = {'min_date':data['
                    date_range:min_date'], 'max_date':
                    data['date_range:max_date'], \
                    'station_id': data['station:
                    id'], \
                    'latitude':data['location:
                    latitude'], \
                    'longitude':data['location:
                    longitude']}

    return st_list
```

### 6.2. Weather Dao

Weather dao is similar to station in dao in all respect except it deals with weather table. Apart from the getting records from the weather table, there is another method to get all keys from the table. We will see in later sections why we need the entire key list from the table.

## 7. WEATHER DATA PERSISTENCE

Once happybase, thrift and hbase is functional, we are ready to download our weather data. Weather data download is divided into two steps 1) Getting weather stations details for a given country and 2) Getting Weather data for a given station. Lets see them individually :

- Download Weather Stations - To consume rest services we have used python's inbuilt request response module. Let us walk you through the code. We have two main python script one for data access and another for rest consumption. "stations\_dao.py" is for accessing table "wda\_stations" in hbase. The functions are self explaining and hence will not be repeated here. "weather\_services.py" is for consuming NCDC rest services. To load all stations, we will be using the code 'FIPS:IN' i.e the region code for India.

##### Listing 5. Get Weather Stations

```
def get_stations(country='FIPS:IN', offset=0):
    url = NCDC_API + NCDC_SERVICES.STATIONS + \
        '?locationid=' + country + '&offset=' + str(
            offset)
```

```

response = requests.get(url, headers=HEADERS)
return response.json()

def load_stations():
    limit = 25
    offset = 0
    nbr_of_records = 0
    result = Services.get_stations(offset=offset)
    while(result != {}):
        nbr_of_records = nbr_of_records \
            + insert_station(result['results'])
        offset = offset + limit
        result = Services.get_stations(offset=
            offset)
    print str(nbr_of_records) \
        + 'stations loaded successfully!!'

```

The function 'load\_stations' calls 'get\_stations' till all the available stations are downloaded. 'insert\_station' is the DAO (*Data Access Object*) call and inserts the dataset into hbase table.

- Download Weather Data - With all stations in the table, we invoke the data api of NCDC for downloading weather data. The argument for getting weather data is station id and date range. The two main methods for loading weather data are as follows

#### Listing 6. Get Weather Stations

```

def load_weather_data():
    start_row = ''
    st_list = stations.get_station_data(start_row=
        start_row)
    while st_list != {}:
        for key, value in st_list.items():
            get_weather_data(startDate=value['
                min_date'], \
                endDate=value['max_date'], stationId=
                    key, station_details=value)
            start_row = key
        print 'Weather Data loaded till station id
            = ' + key
    st_list = stations.get_station_data(
        start_row=start_row)

def get_weather_data(station_details, startDate='
    1968-01-01', endDate='1970-01-01', stationId='
    GHCND:IN001011001'):
    date_range_list = AppUtil.get_year_list(
        start_date=startDate, end_date=endDate)
    for date_range in date_range_list:
        limit = 25
        offset = 0
        result = Services.get_weather_data(
            startDate=date_range['min_date'], \
            endDate=date_range['max_date'],
            stationId=stationId, offset=offset)
        while(result != {}):
            # print result['results']
            insert_result(result['results'],
                station_details)
            offset = offset + limit
            result = Services.get_weather_data(
                startDate=date_range['min_date'], \
                endDate=date_range['max_date'],
                stationId=stationId, offset=offset)

```

The 'load\_weather\_data' function retrieves station data from the station table in a batch of ten. For each station id, it is then passed to 'get\_weather\_data' function to get weather data for the given station id. This data is again persisted into wda\_weather table for future analysis and usage. These are the main functions to download weather data. All other functions are helper functions to enable the download.

## 8. INSTALL PYTHON PROGRAM

Our python programs are structure and packaged. So to use it, we need to install the packages, in order to make them available in the classpath or pythonpath. There is a setup.py script provided with the main source folder. This script installs the entire package into python core folder. To execute this *pip* must be pre-installed. Once *pip* is available run the following command

#### Listing 7. Install python packages

```
sudo pip install <path_to_src_folder>/src
```

Use sudo or super user to install as other may have permissions issues. Once they are installed, we are ready to run our map reduce program.

## 9. EXECUTION

The application expects all the data in hbase are prefetched and ready. For downloading the datasets into hbase follow the steps

- Install the python packages. Check all installations hbase, hadoop, thrift and happybase.
- Start Hadoop and Hbase and Apache Thrift.
- Open up python cli and run the command 'iu.i524.S17IRP013.hadoop.init.DataSetup.py'.
- The above command will take time and will dump data into hbase table.
- It also created hdfs input folder as '/wda/input' and write 'wda\_row\_keys.txt' file into it. This file will have all the keys (year-month format) from weather table.

### 9.1. Run MapReduce

We need hadoop streaming api to execute our map reduce program. Hadoop streaming api reads from hdfs and write it onto the standard io. This data is then read by our map program *wda\_mapper.py* and further sent to reducer program *wda\_reducer.py*.

#### Listing 8. Run MapReduce

```

bin/hadoop jar <path_to_streaming_jar>{share/hadoop/
    tools/lib}/hadoop-streaming-2.7.3.jar \
    -file <path_to_mapper>/run/wda_mapper.py -mapper
        wda_mapper.py \
    -file <path_to_reducer>/run/wda_reducer.py -reducer
        wda_reducer.py \
    -input /wda/input -output /wda/output

```

The above will execute the map reduce analysis program and write the output into hdfs '/wda/output' folder. Once the program is finished check the output with following command :

#### Listing 9. Run MapReduce

```

hdfs dfs -ls /wda/output
hdfs dfs -cat /wda/output/<name_of_the_file>{part-r
    -00000}
Output >>
{'TAVG': ('GHCND:IN001020700', '35.02'),
'TMAX': ('GHCND:IN001020700', '43.08'),
'PRCP': ('GHCND:IN001011000', '863.7'),
'TMIN': ('GHCND:IN001020700', '14.08')}

```

## 10. DEPLOYMENT USING ANSIBLE

Ansible is open source automation tool. It can be used for deployment of software, configuration management and automation in the execution of application. It also serves for monitoring of the state of the application. As per current state of our project we have used ansible for deployment of software in our project. The script deploys Java, Hadoop, Hbase on the independent clusters. It also configures the properties in the key files. This script can further be extended to build the analysis , deploy and run the analysis module. Monitor the progress of the execution and display the reports, however currently it is work to be done.

In the project a separate directory structure is created for deployment. This folder consists of some key files and folders. We can dig into the details for each of them in below section.

1. Inventory.
2. Playbook.yml.
3. Roles —> Roles is a directory and we can going to explore the roles used in the project as we proceed.

### 10.1. Inventory Configuration

Inventory file contains the list of hostname or nodes that can be accessible by ansible. These nodes are then used in the script for deployment and configuration. In the current project chameleon server nodes were created and configured. These IP address can be changed dynamically. This file can also contain the group inside Which multiple ip can be configured. The deployment of hadoop was in clustered mode where we have on master and multiple slaves. In the inventory.configuration file there are multiple section with header which mentioned the list of nodes/IP address those needs to be included in the group. For example in the below file we have two groups.

#### Listing 10. Inventory

```
[weatherClusterMaster]
  <ipaddress1> ansible_ssh_user=cc
[weatherClusterSlave]
  <ipaddress2> ansible_ssh_user=cc
  <ipaddress3> ansible_ssh_user=cc
```

1. WeatherClusterMaster : Node/Instance with ipaddress1 falls under the master cluster.
2. WeatherClusterSlave: Node/Instance with ipaddress2, ipaddress3 falls under the slave cluster.

The mapping of IP address to the group from the inventory file is used in the playbook.yml to represent them as a group. There are some script which needs to be part of the master cluster deployment however it don't need to be executed on the slave cluster. This problem is address using the playbook.yml roles

### 10.2. Playbook

Playbook works on mentioned host of group. It mentions the roles those will be operated on each of the host. The main.yml inside the task folder within each roles will be applied to The cluster.

#### Listing 11. Playbook Modules

```
---
- hosts: weatherClusterMaster
  remote\_user: root roles:
    - java
```

```
- hadoop
- hbase
- master
- hosts: weatherClusterSlave remote\_user: root
roles:
  - java
  - hadoop
  - hbase
```

As mentioned above the hosts mentions the instance on which the scripts are going to be executed. So all the ipaddress those are mentioned under the weatherClusterMaster will undergo the execution of scripts those are mentioned in each of the roles for that task. These script will be executed using the remote\_user mentioned in the script. In above example from project, both the cluster will execute the script mentioned inside java, hadoop and hbase role however master cluster additionally will execute the script from the master role folder as well. These could be the addition scripts like configuration of slave addresses in the slaves file and many such task which needs to be executed only for master instance.

### 10.3. Roles

Roles folder contains the list of the roles mentioned in the playbook.xml. There could be multiple roles which can be executed on node or group of nodes. In current project there are four roles i.e. java, hadoop, base and master. The name are very much self explanatory. Java : — Java role installs java on the remote machine . Roles contains multiple directory. The task directory is the main directory which mentions the list of task / script those needs to be executed on the nodes.

Current project mentions 4 different task in java. All these task takes care of installing java on the remote node.

Hadoop — Hadoop along with Hbase is the major role. The task file mentioned the below list of task

1. Download hadoop.
2. Extract hadoop.
3. Set java home/ Hadoop home configuration in bashrc.
4. Set Java home/Hadoop home path to env.rc
5. Create and Configure logging file.
6. Update core-site.xml
7. Configure slaves
8. Update other configuration files like core-site.xml, hdfs-site.xml, yarn-site, mapper- site.xml.
9. Replace hosts.

#### Sources file

The sources folder consists of other key folders like

1. Vars This is yml file which maintains the mapping for placeholder names used in the configuration files.
2. Meta : This file can contain it dependency roles and other details.
3. Templates : This contains the template configuration file.

After Hadoop, HBase, Thrift is installed and configured using similar way. You can refer to the main.yml inside the task folder in for the script details.

## 11. BENCHMARKING

The aforesaid program has been executed on futuresystems. The execution time has been collected by increasing nodes from 1 (single) to 3 (multiple) with 2cpus each. The graph indicates the

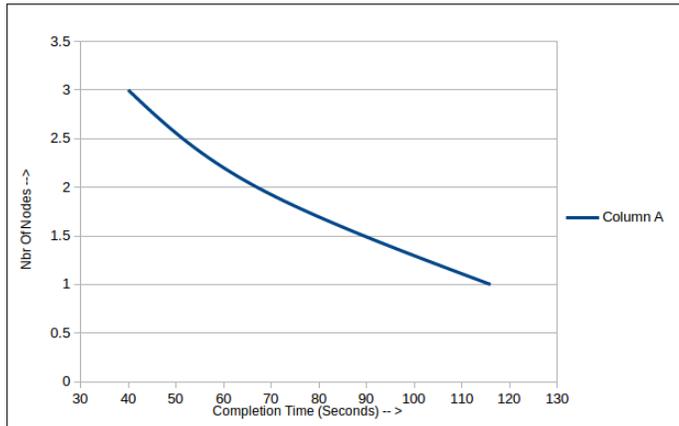


Fig. 2. Benchmarking

reduction in time with increase in nodes. Since the data used for the sample is not big enough, the time taken for starting the framework is considerably high as compared to total time taken by the analysis program itself. So only the map reduce time or

```

17/05/01 12:12:19 INFO mapreduce.Job: map 0% reduce 0%
17/05/01 12:13:29 INFO mapreduce.Job: map 33% reduce 0%
17/05/01 12:13:30 INFO mapreduce.Job: map 67% reduce 0%
17/05/01 12:13:41 INFO mapreduce.Job: map 83% reduce 0%
17/05/01 12:13:42 INFO mapreduce.Job: map 100% reduce 0%
17/05/01 12:14:00 INFO mapreduce.Job: map 100% reduce 67%
17/05/01 12:14:10 INFO mapreduce.Job: map 100% reduce 100%
17/05/01 12:14:15 INFO mapreduce.Job: Job job_1493620614560_0001 completed successfully
17/05/01 12:14:17 INFO mapreduce.Job: Counters: 51
    
```

Fig. 3. Map Reduce Snapshot

the program time has been considered and not the ancillary time which includes time to start the hadoop framework.

## 12. SCOPE OF EXTENSIONS

The application is only distribute the data load from the hbase table. But fetching data from NCDC is sequential. Though its only a one time job, it takes considerable amount of time to download. The same application can be extended to use Hadoop MapReduce for downloading and persisting the raw data from Rest APIs. The same fundamentals can be used for this purpose. Initial weather stations can be downloaded sequentially and then the keys are to be distributed in HDFS for further weather data download.

### 12.1. Limitation

There is a limitation in download imposed by NCDC. NCDC uses token bases authentication which allows only 10000 invocation per day. To distribute the download among multiple nodes requires multiple tokens.

## 13. PROBLEM AND WORKAROUND

Usually Hadoop is run with java and connects directly with the Hbase to retrieve the data from database. However in the current implementation we have python script which is used for the analysis. The challenge was to fetch the data from Hbase by

running the Hadoop program in python. There were some of the library available which connects Hadoop to Hbase however those were not reliable and supported by Apache.

### Workaround for Connecting Hadoop to Hbase

In order to execute the python script on Hadoop in cluster, there was a work around considered. In this work around, all the keys were stored in the hadoop file system. These key were then divider as per the nodes and passed to the mapper method. For each key, mapper method called the hbase to fetch the data. This call to Hbase was via apache thrift and happybase

### Let drill down more on what is Apache thrift.

Apache thrift is mechanism or framework which can be talk between two services which may or may not been written in same language. Apache thrift has its own Interface definition language, its compiler can generate client code and server code in same or different language and hence can be used as a bridge to talk between the two different language.

Apache thrift is very similar to SOAP. The way SOAP uses UDDI for publishing and discovering the service, thrift uses zoo keeper for finding services. Apache thrift was connecting to the Base with the help of Apache

HappyBase is a developer-friendly Python library to interact with Apache HBase. Below the surface, HappyBase uses the Python Thrift library to connect to HBase.

## 13.1. Security

This project has been deployed and tested on FutureSystems. To create instances on futuresystems follow the link. It uses nova client for managing instances. Now to run the Ansible playbook the key file has to be provided with `-private-key` or the default `id_rsa` will be used. There are two ways to handle this

1. The key used for creating the instances needs to be downloaded into your local file and pass the same key for running the ansible playbook. This can be done through scp command within india.futuresystems.org.
2. Copy your local keys ( `/.ssh/id_rsa` & `/.ssh/id_rsa.pub`) into india.futuresystems.org. Use the same key to create the instances. In this process you don't have to provide the key file explicitly as it would be using `/.ssh/id_rsa` by default.

The aforesaid process is manual. We have used the first option to carry out the project.

## 14. CONCLUSION

MapReduce (MR) with Hadoop is an efficient framework for distributed computing. It can be run on any commodity hardwares and virtual machines. It has also some useful plugins available for shared computing which can share dataset without doing any IO operations, ex - Twister and Spark. Python with Hadoop on other hand is not so great combination as the communication requires additional layer i,e Standard IO. We have seen earlier that there is no support for Hbase communication within the hadoop as well. FutureSystems and Jetstream works well with the framework. Chameleon VMs did not have all ports opened (except 22 for ssh) which is a must for Hadoop to work in cluster as Hadoop uses IPC protocol for inter node communication.

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# Analysis of Airline delays data using Spark and HDFS

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Airline delays data is analyzed by developing an automated process for deploying Hadoop and Spark on Chameleon and Jetstream cloud computing environments. The data set used is publicly available and analyzed for obtaining various results like average delay of an airline and an airport. The automation process is carried out using Ansible scripts and a cloud manager called Cloudmesh Client is used to interact with the clouds. Spark is used as the cluster computing framework and Hadoop Distributed File System is used as the distributed storage system for the data sets. Benchmarking is done after the analysis to determine the efficiency and performance of the system.

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**Keywords:** Ansible, Spark, Cloudmesh Client, Hadoop, YARN

Report: <https://github.com/cloudmesh/sp17-i524/blob/master/project/S17-IR-P014/report/report.pdf>

Code: <https://github.com/cloudmesh/sp17-i524/tree/master/project/S17-IR-P014/code>

Ansible: <https://github.com/cloudmesh/sp17-i524/tree/master/project/S17-IR-P014/ansible>

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## 1. INTRODUCTION

Analysis of airline delays data by deployment of Hadoop and Spark on Chameleon and Jetstream clouds is the main focus of the project. A data set having the airlines information such as flight arrival time, departure time and average delays is considered. This data set is available to everyone. Cloudmesh Client is used as the cloud manager which provides command line to access multiple clouds. It is used to create a Hadoop cluster with Spark as an add-on. The cluster is then deployed on Chameleon and Jetstream clouds by using the Cloudmesh Client. Ansible scripts are written and the Cloudmesh Client interacts with these scripts to automate the deployment.

Ansible scripts are written for extracting data sets from the published zip file and deploying them on the clouds. Hadoop Distributed File System is used to store the extracted data sets. A program is written in Spark to perform the data analysis. Spark runs on the Hadoop cluster and accesses the HDFS for retrieving the data sets. There are several results that are obtained from this analysis. Top ten airports that have delays are identified, average delay per an airline and per an airport is determined and top ten airlines with comparatively more delays are identified.

The program is deployed by using an Ansible script. Bar graphs are drawn for the analysis performed. Along with the deployment and analysis, benchmarking is done to evaluate the performance of the program on each node of a cluster and on different clouds. The efficiency of the program is determined by varying the sizes of the data set and comparing the results.

## 2. INFRASTRUCTURE

Infrastructure for the project includes Cloudmesh Client, Chameleon and Jetstream clouds. Cloudmesh Client is used to access multiple clouds from a single command line. Chameleon and Jetstream provide cloud computing environments for the system.

Cloudmesh Client is a toolkit that provides a standardized interface for accessing various workstations, clusters and heterogeneous clouds. It acts as a manager that allows users to manage the available set of resources. Cloudmesh Client plays an essential role in the deployment process by handling the interactions between users and virtual machines being used in the clouds [1].

Cloudmesh Client provides several services which make it easy for the users to manage the virtual machines in the clouds. The “vm boot” command in Cloudmesh Client is a single instruction for creating virtual machines. Security rules can be uploaded to the clouds by using “secgroup” command from Cloudmesh. Key management in the clouds is simplified Cloudmesh’s key add and upload commands. Deletion of the virtual machines created can be easily carried out by specific commands defined in Cloudmesh.

Cloudmesh Client makes it easy for the users to switch virtual machines from one cloud to other by specifying the name of the cloud. Cloudmesh provides a command shell that allows users to develop and run scripts and each command can be called by the user from the command line. Cloudmesh Client essentially provides virtual machine management through a convenient

programmable interface.

### 2.1. Chameleon Cloud

Chameleo is a project aimed at providing large-scale open research platform for cloud design and services. The project receives funding from the National Science Foundation (NSF). Chameleo provides a wide range of services like developing platforms-as-a-service, optimizing virtualization technologies and infrastructure-as-a-service components [2]. Chameleo allows full user configurability of the software stack, ranging from provisioning of bare metal to the delivery of high functioning cloud environments, by supporting a graduated configuration system.

The Chameleon testbed is hosted at the University of Chicago and the Texas Advanced Computing Center. It consists of 5PB of total disk space with 650 multi-core cloud nodes. A portion of the testbed is dedicated for supporting experiments with large disk, high memory and co-processor units. Chameleo facilitates integration of clouds and networks enhancing their capabilities.

### 2.2. Jetstream

Jetstream is a cloud computing environment that can be used by researchers as a configurable infrastructure. They are provided with interactive computing and data analysis resources [3]. Jetstream allows researchers to create their own private computing system with customizable virtual machines. Jetstream’s operational software environment is based on OpenStack and has a web-based user interface. It provides a library of virtual machines for performing specific analysis tasks. It can be used for tailoring workflows for both small scale and larger scale environments. It can also be used as the backend to science gateways to supply research jobs to HTC or other HPC resources.

Table 1 shows the specifications used from both Jetstream and Chameleon cloud environments.

**Table 1. Hardware Specifications of Chameleon and Jetstream**

	Chameleon	Jetstream
CPU	Xeon X5550	Haswell E-2680
cores	1008	7680
speed	2.3GHz	2.5GHz
RAM	5376GB	40TBr
storage	1.5PB	2 TB

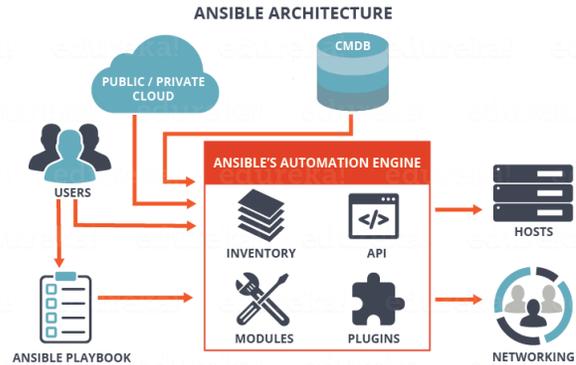
## 3. SOFTWARE STACK

Following are the deployment and analysis tools used in the project.

### 3.1. Ansible

Ansible is an open-source software that facilitates automation of configuration management and application deployment. Ansible consists of controlling machines and nodes. Controlling machine starts the orchestration and manages the nodes over SSH [4]. Resources are not consumed by Ansible when the nodes are not being managed. This is due to the fact that there are no

daemons that run for Ansible in the background. This makes Ansible a software with an agent-less architecture. This architecture prevents the nodes from polling the controlling machine thereby reducing the overhead on the network as shown in figure 1.



**Fig. 1. Ansible Architecture** [5]

Modules, Inventory, Playbooks and Ansible Tower are the components of the Ansible architecture. In Ansible, a module is work unit written in a scripting language. It is idempotent and standalone. Inventory is a configuration file that lists the nodes that are accessible by Ansible. It allows the users to add a set of nodes to a group. Nodes are generally represented by IP addresses or hostnames.

Playbooks are YAML format files which consist of configurations and express deployment in Ansible. A group of hosts are mapped to a set of roles through Playbook. Ansible Tower is a web-based console which makes Ansible a center for automating tasks. Ansible is consistent and minimal in nature. Ansible does not deploy agents to nodes which makes it very secure.

### 3.2. Apache Spark

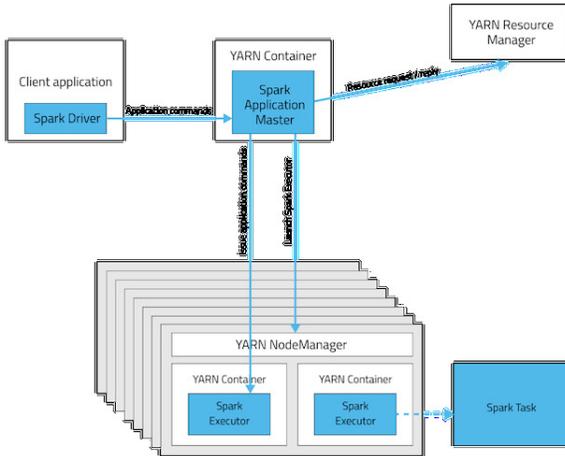
Apache Spark is an open source framework that provides cluster-computing capabilities. Spark allows its users to program different clusters by providing an interface [6]. It facilitates fault-tolerance and data parallelism. Spark makes use of a data structure called as resilient distributed dataset (RDD) which is distributed over different virtual machines in a cluster.

RDDs are immutable which means that they cannot be changed once they have been created. They provide mechanisms for exploratory data analysis and iterative algorithms for processing dataset iteratively. Spark interfaces with systems like Cassandra, Hadoop Distributed File System (HDFS) and Amazon S3 for distributed storage and interacts with Hadoop YARN for cluster management.

Task scheduling, dispatching and some fundamental I/O functionalities are achieved in Spark through the Spark Core. It is an application programming interface which reflects functional programming. Functions similar to map and reduce are provided by the interface which produces new RDDs as output by taking in the required RDDs. RDDs make use of different types of Java, Scala or Python objects. The operations of RDDs are fault-tolerant and lazy. Structured and semi-structured data is supported in Spark through Spark SQL that processes a new data model called DataFrames. Spark SQL provides ODBC/JDBC server and command-line interfaces.

RDD transformations are performed on the data by the Spark Streaming component. It takes in data and performs stream-

ing analytics. Spark MLlib is a machine learning framework that simplifies machine learning pipelines in Spark [6]. MLlib is provided with several statistical and machine learning algorithms. This reduces the overhead of performing classification and regression, correlations, linear regression, support vector machines and k-means clustering method. A simple spark architecture can be observed in figure 2. Apache Spark consists of a graph processing component known as GraphX. It depends on RDDs and generally used for graphs that are immutable.



**Fig. 2.** Spark with Yarn Architecture [7]

Generally, map and reduce functions use variables which are defined outside the functions in Spark driver. New copies of each variable are provided to the tasks running on the cluster but the driver is not provided with the updates of these copies [8]. To solve the problem, Spark makes use of shared variables called accumulators. An accumulator can be considered as a container used for aggregating data across different tasks running on multiple executors.

Accumulators are designed for distributed sums and counters and can be effectively used for distributed computations [9]. They act as read-only variables for the executors and can only be read by the driver programs. Accumulators are not thread-safe but they are serializable. They can be safely sent over the wire for execution after being referenced in the code in executors. Accumulators even help in the debugging process by counting the events.

**3.3. Hadoop Distributed File System**

The Hadoop Distributed File System (HDFS) is a distributed file storage system that provides reliable and scalable data storage. It is a fault-tolerant storage system. It spans large clusters of commodity servers [10]. It supports thousands of servers and a billion files. HDFS distributes storage and computation across many servers making the combined storage resource grow with demand and remain economical at every amount of storage.

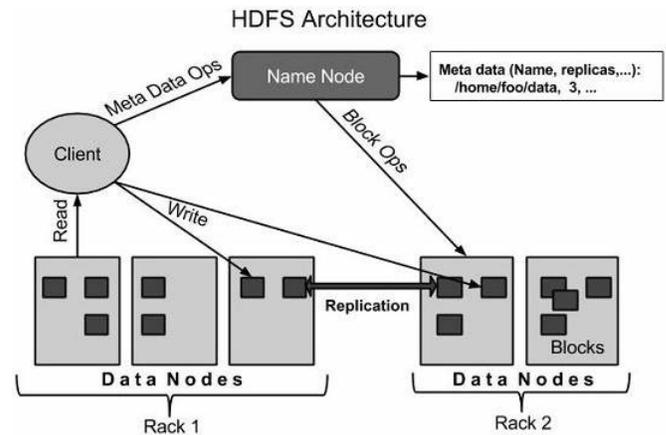
HDFS allows the users to connect the nodes across several clusters in which the data is distributed. It provides high throughput access to large datasets [11]. The data files can be accessed by the users in a streaming manner as the data files are stored as a continuous file system. MapReduce programming model is employed when applications are executed. HDFS has a write-once-read-many model which simplifies data coherency and lightens the requirements of concurrency control. It allows

only one writer to write data at a given point of time. It appends bytes to the end of a stream and stores the streams in the order they were written.

HDFS provides portability across heterogeneous operating systems and ensures efficiency by processing the distributed data in parallel. It automatically redeploys processing logic in the failure situations by maintaining multiple copies of data. Rather than processing data close to logic, HDFS processes logic closer to data. It is accessible in different ways.

A web browser can be used to browse files in HDFS. It consists of a single node called name node and several data nodes that store data as blocks within the files. The name node is responsible for regulating client access to files and managing the namespace of the file system. This includes opening, closing and renaming files and directories. Name node monitors the data nodes in creating, deleting and replicating data blocks by mapping them to the data nodes. Each data node contains an open server socket through which remaining data nodes read or write data.

To be fault-tolerant, HDFS replicates file blocks according to the number that an application specifies. It optimizes replica placement by using an intelligent replica placement model which in turn, ensures reliability and efficiency. HDFS supports large files by placing each file block on a different data node. To overcome failures, it makes use of heartbeat messages for detecting connectivity between data nodes and the name node. Data nodes are required to send heartbeat messages to the name node periodically and the failure is detected when name node stops receiving the messages. In this situation, the data node is marked as dead and removed from the system. When the data node count reaches a limit value, replication is done by the name node. Figure 3 shows the architecture of HDFS.



**Fig. 3.** HDFS Architecture [12]

HDFS supports data block rebalancing to avoid the used space for data nodes from being underutilized. If the free space on a data node is too low, it automatically moves blocks from one data node to other. Rebalancing is also done when new nodes are added to the cluster. It ensures integrity of data stored in HDFS. The file system performs checksum validation on the files by storing computed checksums in separate files in the namespace of actual data [11]. All other HDFS functionalities are similar to that of other distributed file systems.

### 3.4. YARN

Yet Another Resource Negotiator (YARN) is a technology used for cluster management. Hadoop supports a broad range of applications through YARN as it decouples MapReduce's scheduling mechanism and resource management from the data processing component [13]. YARN consists of a node manager and a central resource manager. Node manager monitors the operations of cluster nodes while the resource manager manages the Hadoop system resources which are used by the applications. YARN separates HDFS from MapReduce which improves the efficiency of the Hadoop environment in processing different operations.

The resource manager is responsible for governing a cluster by assigning applications to the underlying resources. Resources like bandwidth and memory are orchestrated by the resource manager to the underlying node managers [14]. Applications that run within YARN are managed by the ApplicationMaster. YARN allocates resources through ApplicationMasters and monitors the underlying applications through node managers. ApplicationMasters are responsible for execution of containers and negotiation of resources from the resource manager. They are assumed as buggy as they are user code and a security issue.

The node manager manages the nodes within a cluster by providing per-node services within that cluster. YARN uses the data nodes and name nodes from HDFS layer. Data node is used for replicated storage services across a cluster while the name node is used for metadata services. Execution of YARN is initiated by a client application that sends a request. ApplicationMaster is then triggered by resource manager to represent the application.

In the cluster, the ApplicationMaster negotiates containers for the application at each node by making use of a resource-request protocol. After the completion of the application, it unregisters the containers from the resource manager. YARN improves the ability to scale Hadoop clusters to large configurations by reducing the overhead on resource manager and making the ApplicationMaster responsible for the management of job execution. Moreover, it allows a parallel execution of different programming models like machine learning and graph processing.

YARN allows users to create distributed applications which are more complex than the ones developed by the traditional MapReduce paradigm. It provides a scope for customized development by exposing the underlying framework [14]. This makes it more robust and it does not need to be segregated from other distributed frameworks that reside on the cluster. YARN frees up resource overhead that has been dedicated to the distributed frameworks which simplifies the complexity of the overall system.

As YARN provides customized development, it becomes more difficult to build YARN applications. This is due to the development of ApplicationMaster which is required after launching resource manager on a client request. YARN initially allocates a certain number of resources within a cluster. It processes the application and provides touchpoints to monitor the progress of the application. After this process, it releases resources and performs a cleanup when it finds the status of the application as complete. YARN provides many services which are beyond the scope of traditional MapReduce.

### 4. DATASET

Airlines delay data set is used as the data for analysis. It is analyzed using Pyspark. It is published by the United States department of transportation as the flight related information. This data is free for anyone to use and analyze. Here, we get flight arrival and departure times and delays for all flights taking off in a certain period.

Data is obtained by mentioning a year or a period of time within which the flight information is required. Three files containing this information namely airlines.csv, airports.csv and flights.csv are available in the form of a zip file. The flights.csv file contains the following fields: Flight ID, airline, airport, departure, arrival and delay. Airlines.csv has airline ID and airline name. The airports.csv file consists of airport ID and airport name. These files are placed in the local file system or in HDFS. The spark program reads the files from either location. If the files are placed in HDFS, "hdfs://" is to be given as a prefix to the file path.

### 5. DEPLOYMENT

The deployment process is driven by Ansible playbooks and Cloudmesh Client commands and scripts. The process is initiated on user's local Ubuntu instance. The commands are executed in local machine as well as virtual machines on the cloud.

- Cloudmesh Client is used to access multiple clouds from the command line. This makes it easier to switch to another cloud in case of a failure.
- After the Cloudmesh Client installation, ssh key is to be added to the Cloudmesh database and uploaded to all the active clouds.
- The configuration file of the Cloudmesh Client is to be modified by making Chameleon and Jetstream as active clouds.
- Security rules are then added to the user's security profile after which security group is uploaded to communicate with the virtual machines.
- A virtual cluster is to be created on the cloud by specifying the number of nodes.

Cloudmesh provides one line command for doing so. In order to make use of the nodes, floating IPs need to be assigned to the created nodes. Cluster creation fails when the cloud runs out of floating IPs. Floating IP is required for the communication between the servers and ssh from the client to the cloud. A Hadoop cluster is defined on top of the cluster we defined. Table 2 shows the resources on the cloud that have been used.

**Table 2. Resources on clouds**

	Chameleon	Jetstream
Flavor	m1.medium	m1.medium
OS	Ubuntu 14.04	Ubuntu 14.04
secgroup	default	default
Nodes	3	3

- Similar to the cluster previously defined, multiple specifications can be defined for the Hadoop cluster and one specification has to be activated.
- After this, Hadoop cluster can be deployed by synchronizing the Big Data stack.
- To use Spark as an add-on in the Hadoop cluster, Spark is to be passed as an argument while defining the Hadoop cluster.
- The details of the specification of the Hadoop cluster can be viewed by using the “cm hadoop avail” command.
- The Spark cluster can then be deployed by using “cm hadoop sync” and “cm hadoop deploy” commands.
- The process of uploading the data set to HDFS and running the Spark program on the uploaded data set is automated through an Ansible script.
- Installing the analysis code into the repository is also automated.

## 6. ANALYSIS

Airlines dataset publicly available from US Government website is used for performing analysis and finding out various insights. The dataset is downloaded by identifying the goals to be accomplished. The dataset consists of three files, they are flights.csv, airlines.csv, airports.csv. The flights.csv has key information like the departure, delay of various airlines and airports. The airlines.csv and airports.csv files contains the code for an airline and airport respectively and their corresponding names. The airline and airport files can be used as lookup files. The flight data is the key for the analysis.

Initially, the flight data is parsed to create a flight tuple with all the fields in the flight class to be members of the named tuple, just like class and its objects. The following functions are implemented they are parse, split and notHeader. Parse is used to parse each individual row in the flights.csv and convert it into a named tuple. The split function is used to split each column value in a row based on comma since the dataset is comma separated values. After loading the SparkContext, the airlines data is parsed to eliminate the header and split it accordingly.

Similarly, the airports data is parsed. The flights data is parsed such that each individual row is converted into a named tuple. By using this parsed data, output is obtained by performing various transformations and actions.

The process is to transform the flights RDD by applying filters and map functions for getting the delay based on two instances i.e, airports and airlines. Then ReduceByKey and CombineByKey actions are performed by aggregating and computing the average delay in case of each airport and sorting functions are applied to sort the output in descending order and based on that, the top ten airports to avoid are obtained given the average delay per airport. Since the codes of various airlines and airports are the only ones available, lookup operations are performed by using countAsMap() operation with airports and airlines dataset and by using broadcast, the lookup information is passed on to all workers and executors within them.

The top ten airlines to avoid are found by computing the total minutes of delay per airline over a period of time. Figure 4 shows the top ten airlines obtained by the analysis. The analysis can be further improvised by using various Machine Learning

techniques which helps in predicting the delays over a period of time ahead and provides various insights which are helpful in making better decisions in choosing airlines and airports to commute.

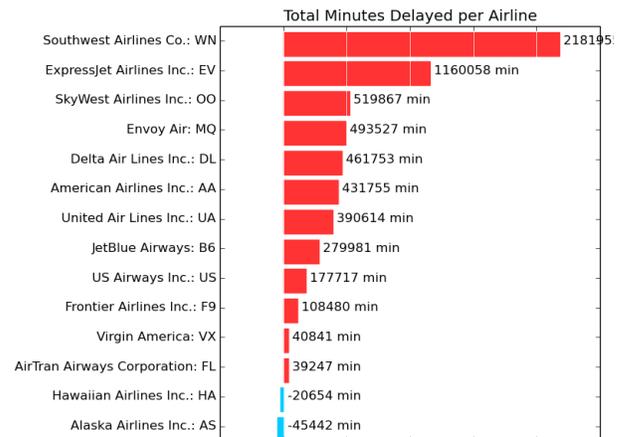


Fig. 4. Top ten airlines to avoid

## 7. BENCHMARKING

Benchmarking is carried out after the deployment and data analysis. It is done to evaluate the efficiency and performance of the system. As a part of benchmarking, the flight and airline data analysis performed is evaluated by running the code on Jetstream and Chameleon cloud computing environments.

The data is transferred to Hadoop Distributed file system and analysis is done by using Spark with YARN. To evaluate the efficiency of the analysis, the dataset has been used in varying sizes. Datasets with increasing size in rows have been considered for this purpose. As it is known that the transformations in Spark are lazy, the results are not evaluated right away. This makes it even more efficient.

Python’s time module is used for obtaining the current time. Time for running the analysis is found out by determining timestamps both before and after running the code, named beforeTime and afterTime respectively. The required time is determined by subtracting beforeTime from afterTime. Due to Spark’s lazy evaluation, the time module used is wrapped around the Spark actions. Figure 5 shows the time, in seconds, taken by the analysis in Jetstream cloud computing environment with different dataset sizes.

Figure 6 shows the performance of the analysis on Chameleon cloud environment.

As the analysis code, data and packages are installed on the clusters through Ansible playbook, the time taken for the automation on Chameleon and Jetstream clouds is determined and the values obtained on each cloud are compared. The comparison is shown in figure 7.

## 8. TIMELINE

Week by week timeline for project completion is specified in this section.

1. March 6 - March 12, 2017: Created virtual machines on Chameleon cloud using Cloudmesh.

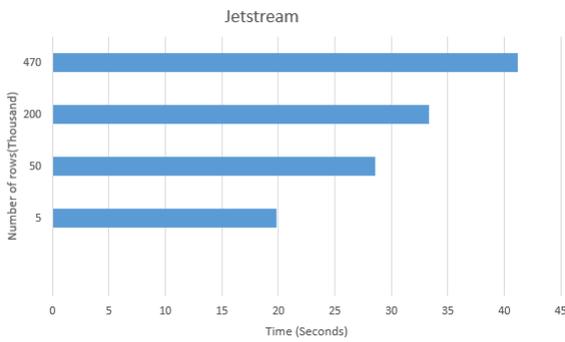


Fig. 5. Performance on Jetstream

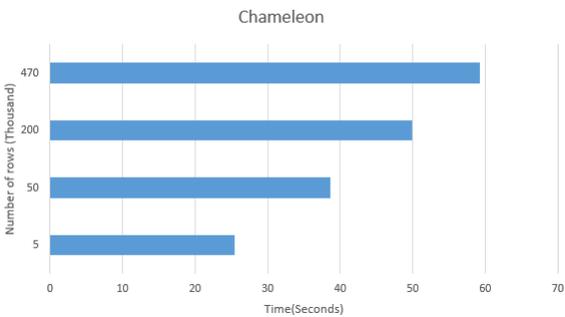


Fig. 6. Performance on Chameleon

2. March 13 - March 19, 2017: Deployed Hadoop cluster to Chameleon cloud using Cloudmesh.
3. March 20 - March 26, 2017: Acquired data for performing analysis and submitted the project proposal.
4. March 27 - April 02, 2017: Created virtual machines on Jetstream cloud using Cloudmesh and deployed Hadoop cluster to the cloud using Cloudmesh.
5. April 03 - April 09, 2017: Performed analysis on the data using Apache Spark on top of Hadoop stack.
6. April 10 - April 16, 2017: Developed Ansible playbook to deploy Hadoop and Spark to the cloud machines.
7. April 17 - April 23, 2017: Completed project report and developed benchmarks for the project.

**9. WORK BREAKDOWN**

Below is the work distribution for the implementation, testing and documentation of the project.

- Bhavesh Reddy Merugureddy
  - Creating and deploying clusters on Jetstream.
  - Acquiring the data and performing analysis on flight data.
  - Writing transformations and actions required for the analysis using Spark.
  - Setting up and testing the end to end flow on Jetstream cloud.

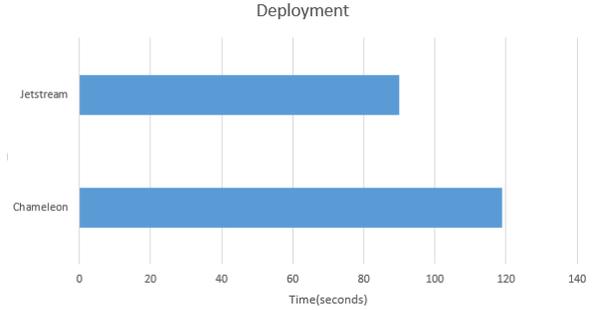


Fig. 7. Deployment in Chameleon and Jetstream

- Performing benchmarking for the analysis on Jetstream by varying the data set size.
- Writing related sections in this report.
- Niteesh Kumar Akurati
  - Creating and deploying clusters on Chameleon.
  - Collecting airport data and performing analysis.
  - Implementation of Ansible scripts for deployment of code, data and the required packages.
  - Setting up and testing the end to end flow on Chameleon cloud.
  - Performing benchmarking for the analysis on Chameleon by varying the data set size.
  - Writing related sections in this report.

**10. CONCLUSION**

Airline delays data has been analyzed by the deployment of Hadoop and Spark on Chameleon and Jetstream cloud computing environments. A publicly available data set containing flight and airline related data is taken for analysis. Cloudmesh Client is used as the cloud manager to access multiple clouds and deploy a Hadoop cluster on Chameleon and Jetstream clouds. Ansible scripts are written for extracting data sets from the published zip file and deploying them on the clouds. Hadoop Distributed File System is used to store the extracted data sets. A program is written in Spark to perform the data analysis which is deployed by using an Ansible script. Bar graphs are drawn for the analysis performed. Apart from the deployment and analysis, benchmarking is done to evaluate the performance of the program on each node of a cluster and on different clouds. The efficiency of the program is determined by varying the sizes of the data set and comparing the results.

**11. ACKNOWLEDGEMENTS**

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# Deployment and performance analysis of a Storm cluster on various cloud environments

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Project-P015, September 21, 2017

Apache Storm is a free and open source distributed realtime computation system. Storm makes it easy to reliably process unbounded streams of data, doing for realtime processing what Hadoop did for batch processing. Storm is simple, can be used with any programming language. Storm has many use cases: realtime analytics, online machine learning, continuous computation, distributed RPC etc. Storm is really fast at data processing: a sample benchmark clocked it at over a million tuples processed per second per node. It is scalable, fault-tolerant, guarantees that data will be processed, and is easy to set up and operate. Storm integrates with the queueing and database technologies we already use. Storm is currently being used to run various critical computations in Twitter at scale, and in real-time, this led us to explore and deploy it on various cloud. In this paper we try to deploy storm on various clouds and benchmark the performance on various data, doing real time processing on sample datasets. First, we describe the architecture of Storm, its deployment and its methods for distributed scaleout and fault-tolerance. We intend to perform a deployment and performance benchmarking to realise the storm on various clouds. We wish to identify and examine the best clouds for storm in terms of deployment and performance. ©

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**Keywords:** Storm, Ansible, Java, Python

**Report:** <https://github.com/cloudmesh/classes/blob/master/project/S17-IR-P015/report/report.pdf>

**Code:** <https://github.com/cloudmesh/cloudmesh.storm>

## 1. INTRODUCTION

Currently modern data processing environments require processing complex computation on streaming data in real-time. Places like Twitter where each interaction with a user requires making a number of complex decisions, often based on data that has just been created, this mandates for a real time data processing system, Storm currently delivers on this account and provides many other services which we will see in the coming sections. Storm is designed to be, some of these things we observed while running our sample projects for deployment:

**Scalable :** Nodes may be easily added or removed from the Storm cluster without disrupting existing data flows through Storm topologies see Fig 3.

**Resilient :** Fault -tolerance is crucial to Storm as it is often deployed on large clusters, and hardware components can fail. The Storm cluster must continue processing existing topologies with a minimal performance impact.

**Extensible :** Storm topologies may call arbitrary external functions (e.g. looking up a MySQL service for the social graph),

[1] and thus needs a framework that allows extensibility.

**Efficient :** Since Storm is used in real-time applications, it must have good performance characteristics. Storm uses a number of techniques, including keeping all its storage and computational data structures in memory.

**Easy to Administer :** A critical part of storm features or development is that it should be easy to administer. Given that there a lot of computations going on at every stage, tools should be developed which warn the user and development team of any major conflicts arising.

## 2. DATA MODEL AND ARCHITECTURE

Storm data processing architecture consists of streams of tuples flowing through topologies [2]. A topology is a directed graph where the vertices represent computation and the edges represent the data flow between the computation components. Vertices are further divided into two disjoint sets, spouts and bolts. Spouts are tuple sources for the topology. Typical spouts pull data from queues, such as Kafka [3] or Kestrel. On the other

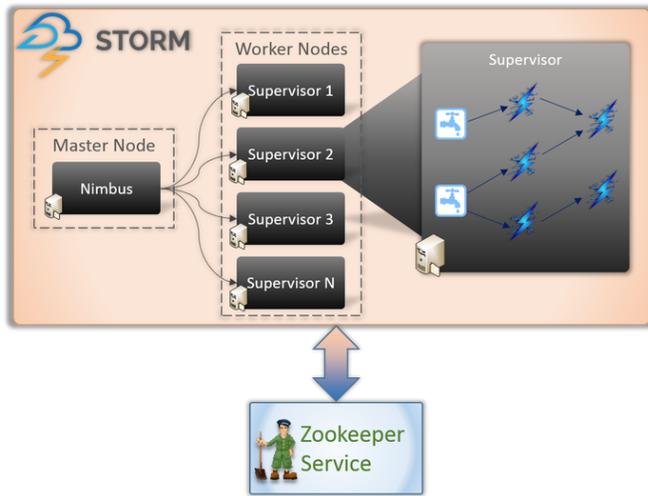


Fig. 1. Storm Architecture

hand, bolts process the incoming tuples and pass them to the next set of bolts downstream. Note that a Storm topology can have cycles. From the database systems perspective, one can think of a topology as a directed graph of operators.

## 2.1. Storm Overview

Storm runs on a distributed cluster. Clients submit topologies to a master node, called the Nimbus. The Nimbus is responsible for distributing and coordinating the execution of the topology. The actual work is done on worker nodes. Each worker node runs one or more worker processes. At any point in time, a single machine may have more than one worker processes, but each worker process is mapped to a single topology see Fig 1. Note more than one worker process on the same machine may be executing different part of the same topology. Each worker process runs a JVM, in which it runs one or more executors. Executors are made of one or more tasks. The actual work for a bolt or a spout is done in the task. Thus, tasks provide intrabolt or intraspout parallelism, and the executors provide intratopology parallelism. Worker processes serve as containers on the host machines to run Storm topologies. Note that associated with each spout or bolt is a set of tasks running in a set of executors across machines in a cluster. Data is shuffled from a producer spout or bolt to a consumer bolt (both producer and consumer may have multiple tasks). This shuffling is like the exchange operator in parallel databases.

Storm supports the following types of partitioning strategies [2]:

- Shuffle grouping, which randomly partitions the tuples.
- Fields grouping, which hashes on a subset of the tuple attributes or fields.
- All grouping, which replicates the entire stream to all the consumer tasks.
- Global grouping, which sends the entire stream to a single bolt.
- Local grouping, which sends tuples to the consumer bolts in the same executor.

The partitioning strategy is extensible and a topology can define and use its own partitioning strategy. Each worker node

runs a Supervisor that communicates with Nimbus. The cluster state is maintained in Zookeeper [4], and Nimbus is responsible for scheduling the topologies on the worker nodes and monitoring the progress of the tuples flowing through the topology. Loosely, a topology can be considered as a logical query plan from a database systems perspective. As a part of the topology, the programmer specifies how many instances of each spout and bolt must be spawned. Storm creates these instances and also creates the interconnections for the data flow. We note that currently, the programmer has to specify the number of instances for each spout and bolt. Part of future work is to automatically pick and dynamically changes this number based on some higher-level objective, such as a target performance objective.

### 2.1.1. Storm Internal Architecture

In this section, we describe the key components of Storm), and how these components interact with each other.

### 2.1.2. Nimbus and Zookeeper

Nimbus plays a similar role as the "JobTracker" in Hadoop, and is the touchpoint between the user and the Storm system. Nimbus is an Apache Thrift service and Storm topology definitions are Thrift objects. To submit a job to the Storm cluster (i.e. to Nimbus), the user describes the topology as a Thrift object and sends that object to Nimbus. With this design, any programming language can be used to create a Storm topology.

As part of submitting the topology, the user also uploads the user code as a JAR file to Nimbus. Nimbus uses a combination of the local disk(s) and Zookeeper to store state about the topology. Currently the user code is stored on the local disk(s) of the Nimbus machine, and the topology Thrift objects are stored in Zookeeper.

The Supervisors contact Nimbus with a periodic heartbeat protocol, this comes in very handy so we can periodically verify if the nodes are working, advertising the topologies that they are currently running, and any vacancies that are available to run more topologies. Nimbus keeps track of the topologies that need assignment, and does the match-making between the pending topologies and the Supervisors.

All coordination between Nimbus and the Supervisors is done using Zookeeper. Furthermore, Nimbus and the Supervisor daemons are fail-fast and stateless, and all their state is kept in Zookeeper or on the local disk(s). This design is the key to Storm's resilience. If the Nimbus service fails, then the workers still continue to make forward progress. In addition, the Supervisors restart the workers if they fail.

However, if Nimbus is down, then users cannot submit new topologies. Also, if running topologies experience machine failures, then they cannot be reassigned to different machines until Nimbus is revived. An interesting direction for future work is to address these limitations to make Storm even more resilient and reactive to failures. All the above workings, whether Nimbus and Zookeeper are working properly are viewed in the UI of the storm deployment, and can be viewed from the localhost of that particular node.

### 2.1.3. Supervisor

The supervisor runs on each Storm node. It receives assignments from Nimbus and spawns workers based on the assignment. It also monitors the health of the workers and respawns them if necessary. The main thread reads the Storm configuration, initializes the Supervisor's global map, creates a persistent local state in the file system, and schedules recurring timer events. There are three types of events, which are:

The heart beat event, which is scheduled to run every 15 seconds, and is runs in the context of the main thread. It reports to Nimbus that the supervisor is alive.

The synchronize supervisor event, which is executed every 10 seconds in the event manager thread. This thread is responsible for managing the changes in the existing assignments. If the changes include addition of new topologies, it downloads the necessary JAR files and libraries, and immediately schedules a synchronize process event .

The synchronize process event, which runs every 3 seconds under the context of the process event manager thread. This thread is responsible for managing worker processes that run a fragment of the topology on the same node as the supervisor. It reads worker heartbeats from the local state and classifies those workers as either valid, timed out, not started, or disallowed. Timed out worker implies that the worker did not provide a heart beat in the specified time frame. Not started worker indicates that it is yet to be started because it belongs to a newly submitted topology. A disallowed worker means that the worker should not be running either because its topology has been killed, or the worker of the topology has been moved to another node.

### 3. TECHNOLOGIES

Following are the technologies used as a part of development of the entire project see Table 1.

**Table 1.** Technologies

Usage	Technologies Used
Distributed Computation and Storage:	Storm
Development:	Python and Java
Deployment:	Ansible, Bash Shell script
Project Repository:	GitHub
Document Preparation:	LaTex

### 4. CLOUDMESH

Cloudmesh client is a simple client to enable access to multiple cloud environments form a command shell and commandline. The entire application is built on python which essentially needs no prerequisite knowledge and is as a ready-to-use tool. For our project, as we need access to clouds for deployment, this comes as a welcome as it helps us with the entire deployment process. Many thanks to our professor, Gregor von Laszewski and others collaborators for supporting our project directly and indirectly in the form of this tool which enabled us to deploy the project easier without any hassles.

### 5. CLOUD DEPLOYMENT

We selected three clouds for deployment of our project: Chameleon Cloud, Jetstream, and Kilo. In our automated deployment and benchmarking process, first we create a cluster of a particular size, update the ansible hosts file and run the ansible script to deploy the entire project on the cloud. The entire process of deploying the project on various clouds have been tried

and tested, and the results have been collected for benchmarking. The results of benchmarking have been presented after a brief comparison and deployment strategy.

### 6. CLOUD FLAVOR AND IMAGE COMPARISON

The following table shows a comparison of key computing resources on Chameleon, FutureSystems, and Jetstream cloud environments. See Table 2 for the comparison.

**Table 2.** Cloud Hardware Specification Comparison

Cloud	Kilo	Chameleon	Jetstream
Image	Ubuntu-14.04	Ubuntu-14.04	ubuntu-14.04
Flavor	m1.small	m1.small	m1.small
CPU	Xeon E5-2670	Xeon X5550	Haswell E-2680
cores	1024	1008	7680
speed	2.66GHz	2.3GHz	2.5GHz
RAM	3072GB	5376GB	40TBr
storage	335TB	1.5PB	2 TB

### 7. DEPLOYMENT AUTOMATION

#### 7.1. Automation with Ansible

Ansible Playbook is the primary tool used for deployment. Ansible will help push configurations to the environment automatically based on playbooks written. For this project, we have used Ansible Roles to automate the deployment of storm and zookeeper clusters. The Ansible script installs the zookeeper and storm on all nodes and starts the cluster dynamically using handlers. These tasks are handled by the respective roles. CMD5 provided by the cloudmesh client is used to create a secgroup, a cluster and deploying the software automatically.

The following commands are provided with the CMD5 storm extension:

cloud: Set the cloud on which to deploy the cluster

name: Set the name of the cluster

size: Set the size of the cluster

flavor: Set the flavor to use

image: Set the image to use

cluster info: Displays the information to be used to create the cluster

cluster deploy: Does a multitude of tasks, creates a secgroup and uploads it, leverages cloudmesh client to create vms on the cloud and create a hosts file, runs the ansible script to install software and manage handlers to ensure that processes have been started.

cluster status: Checks the ports to ensure that zookeeper and storm nimbus have been started and are running.

cluster delete: deletes the cluster vms and deletes the secgroup from the cloud

submit: Submits the jar file to nimbus. The jar file has to be included in the same folder as the script to run it.

The important command in the above is the "storm cluster deploy" command. It utilizes four roles created using ansible, namely, setup, zookeeper, nimbus and supervisors. The roles are explained as follows:

**Setup:** Installs software packages, java jdk, java jre, supervisor on all nodes in the cluster. Creates the folders for zookeeper and storm for installation, and supervisor logs. Updates the hosts file so the nodes can communicate with each other.

**Zookeeper:** Downloads and unpacks zookeeper files into the folder created above. Creates a "myid" file updates the config file on each node. Creates a supervisor config file to run the process in the background. Finally, starts the zookeeper cluster.

**Nimbus:** Installs maven on nimbus nodes. Downloads and unpacks storm files into the folder created above. Updates the storm config files and creates supervisor config file to run nimbus and ui in the background. Starts the storm nimbus and ui on the master node.

**Supervisors:** Downloads and unpacks storm files into the folder created above. Updates the storm config files and creates supervisor config file to run storm workers (supervisors) in the background. Starts the storm workers on the slave nodes.

### 8. DEPLOYMENT BENCHMARKING

Following zookeeper recommendations, deployment testing was done starting with a cluster size of 5. Zookeeper recommends a minimum cluster size of 5 and scale the clusters in odd numbers. This way, the server cluster can ensure reliability.

#### 8.1. Chameleon Cloud

Chameleon cloud was used for development and most of the scripts were run and tested on this cloud. The ansible scripts developed on this cloud were then tested on the remaining clouds to ensure they are platform independent. The results of deployment are presented in the table 3 and illustrated in the form of a bar plot (Fig 2).

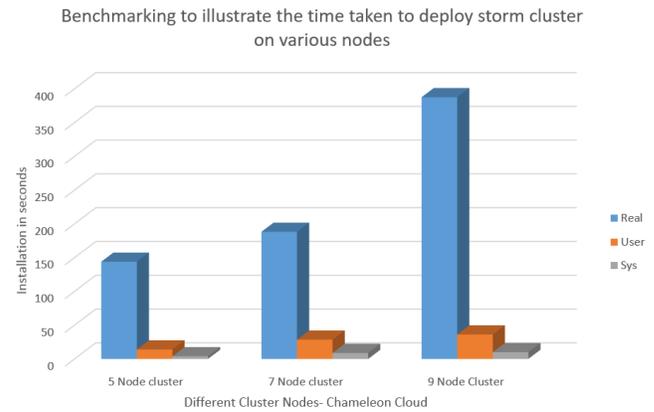
**Table 3.** Table illustrating the various times it took to deploy on Chameleon cloud

Install Time	5 node cluster	7 node cluster	9 node cluster
Real:	143.91	188.19	387.536
User:	13.928	28.432	36.192
Sys:	3.964	8.872	9.988

#### 8.2. JetStream Cloud

Automated deployment on Jetstream cloud of various cluster node sizes of 5, 7 and 9 and results are presented as follows, in the form of a table 4 and illustrated as a figure 3.

A bar description of the time taken for deployment on different size clusters see Fig 3.

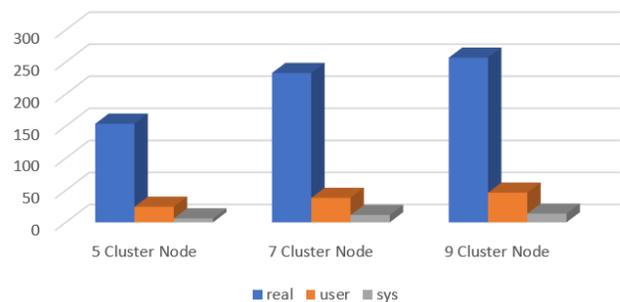


**Fig. 2.** Bar diagram to compare the time taken to deploy on Chameleon

**Table 4.** Illustrating the various times it took to deploy on Jetstream

Install Time	5 node cluster	7 node cluster	9 node cluster
Real:	153.73	232.923	256.675
User:	24.232	38.14	46.208
Sys:	5.988	11.54	13.568

Time taken to deploy various cluster sizes on Jetstream Cloud



**Fig. 3.** Bar diagram to compare the time taken to deploy on Jetstream

#### 8.3. Kilo Cloud - FutureSystems

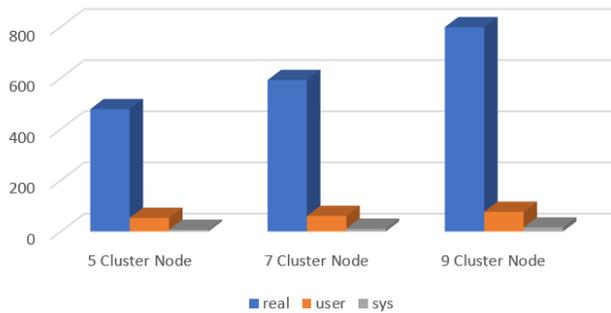
Automated deployment on Kilo cloud of various cluster node sizes of 5, 7 and 9 and results are presented, in the form of a table 5 and illustrated as a figure 4

A bar description of the time taken for deployment on different size clusters see Fig 4.

**Table 5.** Illustrating the various times it took to deploy on Kilo

Install Time	5 node cluster	7 node cluster	9 node cluster
Real:	478.426	592.267	798.894
User:	53.728	61.104	77.388
Sys:	7.048	11.224	16.116

Comparison of deployment times taken to deploy on various cluster sizes on Kilo Cloud



**Fig. 4.** Bar diagram to compare the time taken to deploy on Kilo

**9. DEPLOYMENT SUMMARY ON VARIOUS CLOUDS**

Comparison between installation time on the three clouds with differing cluster sizes is done in the figure 5. The following inferences were made:

- Kilo cloud - Not conducive to development or production as the creation of vms on the cloud and the installation of software took a relatively long time.
- Chameleon and Jetstream clouds have similar rates of deployment. As observed, jetstream is more suitable for production.
- All the clusters took similar amount of time for starting the zookeeper and storm processes.

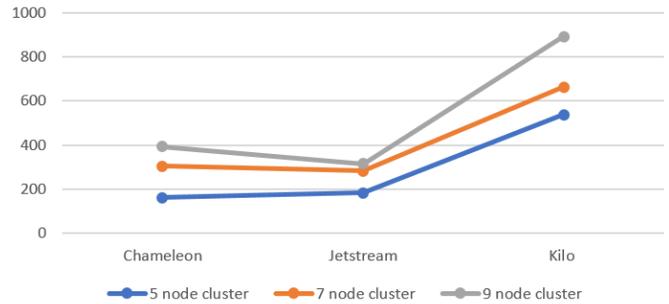
The table showcases the times plotted. see Table 6

**Table 6.** Time to deploy various cluster sizes on various clouds

Install Time	Chameleon	Jetstream	Kilo
5 node:	161.802	183.95	539.202
7 node:	305.494	282.603	664.595
9 node:	393.716	316.451	892.398

A plot has been illustrated to distinguish the installation time on the different clouds see Fig 5.

Comparison between various clouds based on the deployment times



**Fig. 5.** Graph plot to compare the time taken to deploy on various clouds

**10. ANALYSIS OF PERFORMANCE BENCHMARKING ON VARIOUS CLOUDS:**

As a part of this Project we would like to examine the difference in terms of performance between clouds and analyze the results to discern the advantages of one cloud over the other. To test the performance, a topology from the storm-starter project was used. The topology is based on the basic word count topology with a few changes. The first difference is the rate of production of sentences. The rate may be set using arguments. This enable us to perform stress testing on clusters of different sizes and clouds. The second difference is the number of worker nodes to be used. This property allows us to accurately define the number of storm supervisor nodes to run the topology on and gather the results effectively. The final difference is the time for which the topology runs. This is an important feature as the metrics are printed with a period of 30 secs. This implies that every 30s, the number of sentences that have been executed successfully is printed and a new set of sentences are generated for the next 30 secs. We have chosen a value of 5 minutes as this gives us an accurate idea of the effectiveness of the cluster. The definitions of throughput and latency are mentioned as follows: **Latency** is the time required to perform some action or produce a result. **Throughput** is the number of such actions performed per unit of time.

A result is produced/completed on a storm cluster when an "ack" is received. The number of such acks defines the throughput of the cluster. For example, if we have received 12,600 acks during a 30s time period, then the throughput rate is 420/sec. Higher throughput rates are desired for better computing capability with lower latency.

Analysis for the entire cloud based on the mentioned parameters and tests were performed, the strategy has been done by writing a shell script, performance.sh which runs for different input sizes for a given cluster and collects the output in a file. This test has been performed on all clusters in a given cloud, repeated on different clouds. All the results are tabulated in the next sections, a detailed analysis based on the results obtained is also elucidated clearly.

**10.1. Hardware:**

All the nodes on each of the clouds deployed had the following features in common:

Image: Ubuntu-14.04-64

Flavor: m1.small

Nodes: Depending on the cluster size various node sizes are deployed

**10.2. Experimental Results and Analysis:**

Following were the inferences and conclusions derived from the performance benchmarking, with respect to the ThroughputVs-Latency topology.

- 5 node cluster: The throughput graph starts small and rises equally upto a rate of 150000, at which point, the throughput on chameleon cloud falls rapidly. The results on kilo cloud indicate that a 5 node cluster is sub-optimal for this cloud. Jetstream cloud scaled very well with increase in throughput. The results are tabulated here see Table 7 and illustrated here see Fig 6.
- 7 node cluster: Chameleon cloud performed better on a 7 node cluster but the throughput falls rapidly after 300000. Kilo cloud performed sub-optimally at all throughput levels. Jetstream cloud scaled exceptionally well with an increase in throughput. The results are tabulated here see Table 8 and illustrated here see Fig 7.
- 9 node cluster: The difference in performance between chameleon cloud and jetstream cloud is negligible. Kilo cloud performs well upto a throughput value of 150000 and falls afterwards. Jetstream cloud is consistent at all throughput levels and chameleon cloud performed equally well. The results are tabulated here see Table 9 and illustrated here see Fig 8
- While significant improvements were observed on clusters of larger sizes, the results are not consistent at all times for chameleon cloud. Jetstream cloud provided consistent results and can be used for production clusters as shown by its performance results. Kilo cloud is not suitable for deployment or for production. The results are consolidated in the form of a graph see Fig 9.

**Table 7.** Throughput vs Latency on all 5 node clusters on 3 clouds:

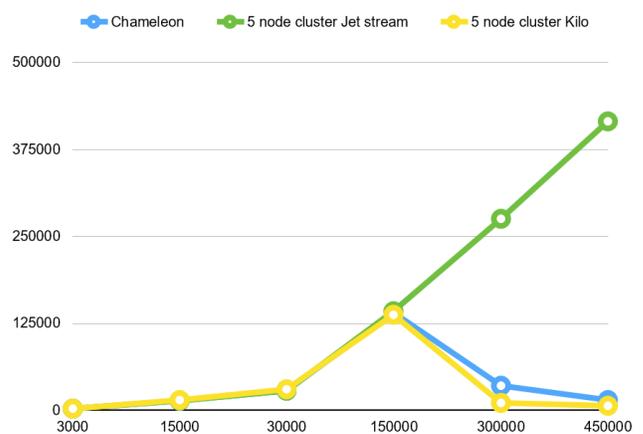
	5 node cluster		
Throughput:	Chameleon	Jetstream	Kilo
3000:	2940	2760	2906
15000:	13958	13654	15093
30000:	27946	28178	30095
150000:	140454	142084	137352
300000:	35417.5	275074	10506
450000:	14946.667	414982	6268

**Table 8.** Throughput vs Latency on all 7 node clusters on 3 clouds:

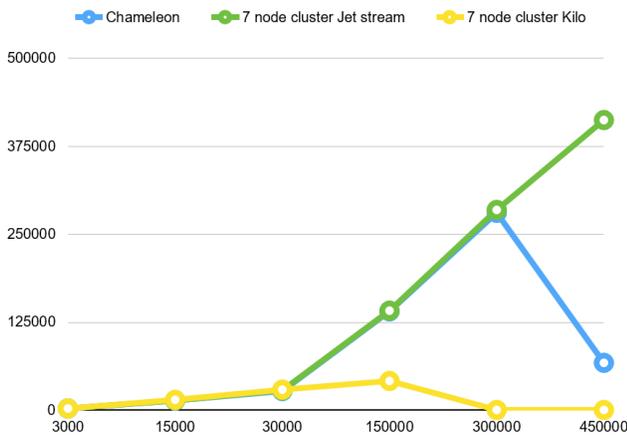
	7 node cluster		
Throughput:	Chameleon	Jetstream	Kilo
3000:	2702	2734	2875
15000:	13502	13766	14348
30000:	27364	28110	29160
150000:	140124	141894	41275
300000:	280170	284356	431.25
450000:	67857.5	412488	435

**Table 9.** Throughput vs Latency on all 9 node clusters on 3 clouds:

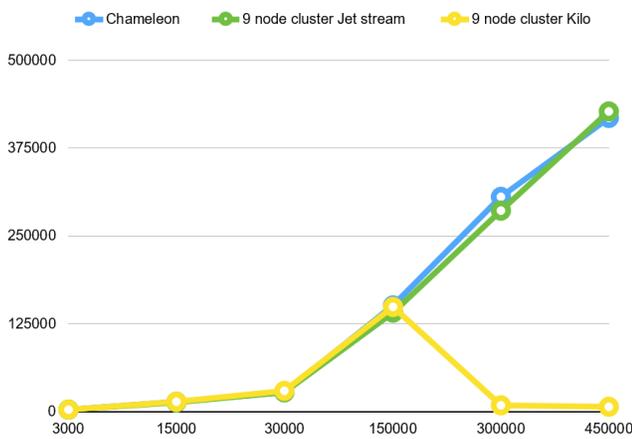
	9 node cluster		
Throughput:	Chameleon	Jetstream	Kilo
3000:	2700	2754	2848
15000:	14722.22	13784	14337
30000:	27724	27282	29455
150000:	151562.22	141580	149440
300000:	305566.667	286708	8832
450000:	418002	427174	7312



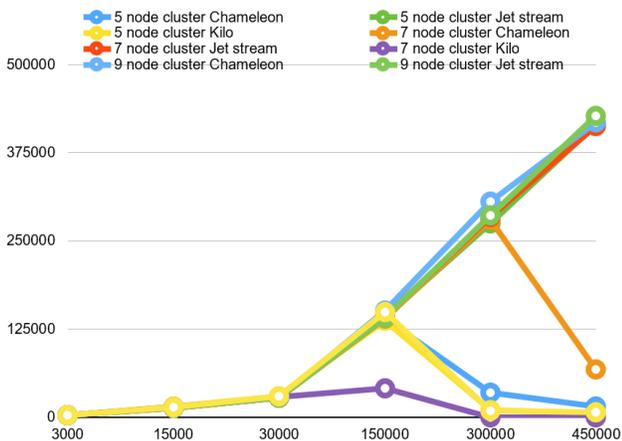
**Fig. 6.** Graph plot to compare the performance on 5 nodes across various clouds



**Fig. 7.** Graph plot to compare the performance on 7 nodes across various clouds



**Fig. 8.** Graph plot to compare the performance on 9 nodes across various clouds



**Fig. 9.** Graph plot to compare the performance on all the nodes across various clouds

**11. SUMMARY**

We have created, tested and demonstrated a fully automated method to configure and deploy a Storm cluster which can be

deployed on any cloud environment using cloudmesh. We have deployed it on Chameleon, Jetstream and Kilo cloud. Benchmarking strategy is envisioned by viewing the time it takes to deploy a particular cluster on various cloud environments. We did a benchmark test on Chameleon, Jetstream and Kilo cloud to measure the time taken to deploy 5, 7 and 9 node clusters, so far it has shown satisfactory results and we are striving to take it beyond to other cloud environments as well, outside the cloudmesh usage. A performance benchmarking has also been done to better analyze the various cloud performances on deployment of a storm cluster. We have measured the Throughput and Latency for different lengths of input to check the performance on various clouds. All the results have been illustrated and various conclusions drawn based on the data obtained from the complete deployment of the storm cluster.

**12. ACKNOWLEDGMENTS**

This project was a part of the Big Data Software and Projects (INFO-I524) course. We would like to thank Professor Gregor von Laszewski and the associate instructors for their help and support during the course. Special mention to cloudmesh client which made most of the gruelling taks straightforward.

**13. CODE REFERENCES**

Following were the code resources used in deploying the cluster at various stages.

- While coding configurations related to Storm we used the following resources, we have looked at the sample use cases of the storm application at Twitter and Spotify. Code resources for Storm-[5][6][7][8][9][10][11][12][13][14]
- While configuring the Zookeeper cluster, we came across many solutions, the important question we came across is whether to use a stand-alone mode or a server mode configuration also while researching for various cluster sizes, we have come to the conclusion that storm is better deployed on cluster sizes more than 5. However, the server mode configuration is quite relevant to our project, so used many resources for coding the required configurations. Zookeeper-[15][16][17][18][19][20][21][22]
- The following code resources were used in analyzing the topologies which were created part of development of the storm cluster. We went through many use-cases such as like in the case of Spotify while researching this topic. Running Topologies on a cluster-[23][24][25][26][27][28]
- While encountering various issues with Zookeeper, following code resources were used, of these we examined whether dynamic topologies where possible to create, problems with running a 3 node cluster, and other config files configuration. Zookeeper Troubleshooting-[29][30][31][32][33][34]
- While checking the log files to check if storm is working or not, had to explore many resources to make sure it was up and running. Storm Troubleshooting-[35][36][37][38]
- Storm yaml defaults file details were obtained from the many code resources.-[39]

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**A. WORK BREAKDOWN**

- Ajit Balaga: Responsible for deployment of storm cluster on various clouds and clusters of different sizes, played an instrumental role in understanding the storm and its architecture. Developed the cmd5 storm commands extension and ansible scripts for deployment, responsible for performance benchmarking on chameleon cloud, jetstream and 9 node cluster on kilo cloud.
- Vasanth Methkupalli: Responsible for deployment of the storm cluster on various clouds of different cluster sizes using ansible, almost automated the entire deployment of storm cluster on cloud. Performed deployment benchmarking on various clouds and analysis. Also, responsible for performance benchmarking on Kilo cloud and analysis of the entire Performance benchmarking.

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# Predicting Customer Churn Using Apache Spark Machine Learning

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This report presents a reference implementation to the Customer Churn Prediction Project that is built using Apache Spark Machine Learning. In this report, we discuss the models used for predicting customer churn along with their accuracies. We will also discuss the software deployment on Chameleon and Jetstream cloud computing environments using Ansible and Cloudmesh Client scripts.

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**Keywords:** Prediction, Bigdata, Apache Spark, ML, Hadoop, Ansible, Cloudmesh, Analytics

Report: <https://github.com/cloudmesh/sp17-i524/tree/master/project/S17-IR-P016/report/report.pdf>

Code: <https://github.com/cloudmesh/sp17-i524/tree/master/project/S17-IR-P016/code>

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## 11 WORK BREAKDOWN

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### 1. INTRODUCTION

One of the most important business metrics is churn rate- describing the rate at which your customers stop doing business with you. Our aim is to build a predictive model which uses data science to predict in advance which customers are at risk of leaving. Such model will allow the company to be proactive and focus on such customers. We used Apache Spark[1] Machine Learning library(ML)[2] for fitting a predictive model on our dataset. Detailed analysis and modeling was carried out in Python Programming language and different machine learning algorithms were tested on the same dataset. Application deployment was initially done on localhost, followed by deployment on two different clouds. Finally Performance metrics on each of the infrastructure was compared and has been included the report.

### 2. ARCHITECTURE

Our application was prototyped on smaller dataset locally and was then modified to run on cluster. Fig 1 below describes the runtime architecture of a distributed spark application.

In distributed mode, Spark uses a master/slave architecture with one central coordinator and many distributed workers(2 in our case). The central coordinator is called the driver. The driver communicates with the distributed worker called executors. The driver runs in its own Java Process and each executor is a separate Java process. A driver and its executors are together termed a Spark Application. A Spark application is launched on a set of machines using an external service called cluster man-

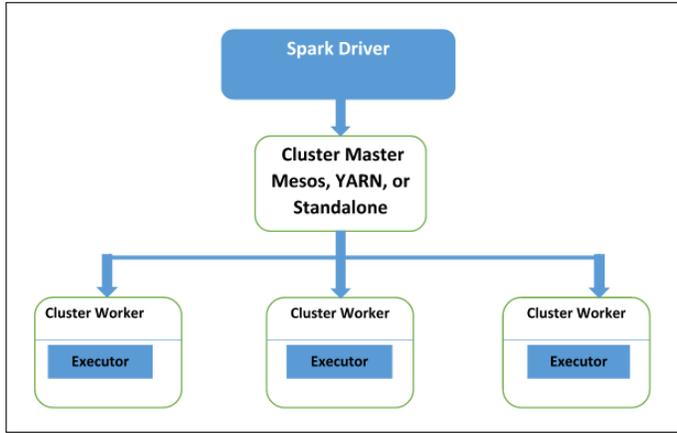


Fig. 1. Runtime architecture of spark in distributed mode[3]

ager. We used Hadoop YARN[4] as our cluster manager in cloud deployments.

### 2.1. The Driver

The driver is the process where main() method of our program runs. It is the process running the user code that creates a Spark-Context, creates RDDs(Resilient Distributed Dataset), and performs transformations and actions.

### 2.2. Executors

Spark executors are worker processes responsible for running individual tasks in a given spark job.Executors have two roles. First, they run the tasks that make up the application and return the result to the driver. Second, they provide in-memory storage for the RDDs.

### 2.3. Hadoop YARN

YARN is cluster manager that provides a data processing framework to run on a shared resource pool, typically on the same node as the Hadoop filesystem( HDFS)[5]. In our project, an HDFS Spark cluster was set up on cloud using Cloudmesh Client.[6] The dataset was stored on the same HDFS system which was then accessed by our spark application for quick data processing. Using YARN in spark is also straightforward with the help of spark-submit as follows:

```
$ ./bin/spark-submit --master yarn yourapp
```

### 2.4. Launching a program

Spark provides a single script to submit our program to it called spark-submit. Through various options, spark-submit can connect to different cluster managers and control how many resources the application gets. For example following command can be used to launch a spark application.

```
$ ./bin/spark-submit --class path.to.your.Class
--master yarn --deploy-mode cluster [options]
<app jar> [app options]
```

## 3. TECHNOLOGIES

Table 1 lists the set of technologies that were used in building this project.

Technology	Usage
Python[7]	Development
Hadoop[8]	Big Data Technology
Spark[9]	Big Data Technology
Apache Spark ML[2]	Machine Learning Library
Cloudmesh Client[6]	Cloud Resource Manager
GitHub[10]	Project Repository
Ansible[11]	Application Deployment & Configuration Management
Chameleon[12], JetStream[13]	Cloud deployment & Benchmarking

Table 1. Technologies used

- **Python:** Python is a high level programming language having various popular libraries for data analysis and machine learning algorithms, making it our preferred choice for the project.
- **Hadoop:** Apache Hadoop is a framework that allows processing and storing huge amounts of data across a distributed resource pool. Therefore, in order to improve overall performance and scalability Hadoop was installed at the foundation of each virtual machine in the cloud.
- **Spark:** Apache Spark is a cluster computing platform designed to be fast and general purpose. It extends the popular MapReduce model to efficiently support more types of computations including interactive queries and stream processing. We will primarily use Spark’s machine learning library to build a predictive model on our dataset.
- **ML:** ML is Spark’s primary machine learning library. It is DataFrame[14] based API that makes practical machine learning scalable. The main concepts in Spark ML are:
  1. DataFrame A DataFrame is a Dataset organized into named columns.[14]
  2. Transformer A Transformer is an abstraction that includes feature transformers and learned models. It converts one dataframe into another.[15]
  3. Estimator An Estimator is an algorithm which can be fit on a DataFrame to produce a Transformer. For example, training/tuning on a DataFrame and producing a model.
  4. Pipeline A Pipeline is specified as a sequence of stages, and each stage is either a Transformer or an Estimator. It represents a workflow, which is run in a specific order.[16]
- **Cloudmesh Client:** Cloudmesh Client provides an application programming interface(API), which allows us to manage a set of cloud resources. It standardize access to various clouds and clusters. In our project, Cloudmesh Client is used to set up Hadoop virtual cluster with Spark on two cloud environment. Following tasks are performed using Cloudmesh Client:

1. Uploading Public Key- using Cloudmesh’s key add and upload commands.
2. Uploading Security Rules- using Cloudmesh’s sec-group commands.
3. Creating Hadoop/Spark Cluster- using Cloudmesh’s deploy command.

- **GitHub:** GitHub is ‘a web-based Git or version control repository and Internet hosting service’ [10]. We used Github repositories to store our files related to documentation, ansible scripts and python code.
- **Ansible:** Ansible is an open source automation platform that automates Application Deployment, and many other IT needs. In our project, Ansible is used to manage the configuration and automate deployment of software stacks on to the clouds. Ansible scripts are run via localhost by providing it with the IP addresses of the cloud VM’s set up using Cloudmesh Client.

#### 4. CLOUD INFRASTRUCTURE

Two clouds were selected for deployment: Chameleon Cloud and Jetstream. For successful deployment, following applications/utilities were used.

##### 4.1. Chameleon Cloud

Chameleon is a collaborative cloud service funded by National Science Foundation primarily meant for research community. In our project three virtual machines were created on this cloud. One acting as master node and the other two as executor nodes for our spark application.

##### 4.2. Jetstream Cloud

Jetstream is a cloud service led by Indiana University’s Pervasive Technology Institute (PTI) in collaboration with other universities [13] across the United States. In our project three virtual machines were created on this cloud. One acting as master node and the other two as executor nodes for our spark application.

##### 4.3. Cloud Hardware Comparison

Table 2. below shows a comparison of key computing resources on Chameleon and Jetstream Cloud environment.

Clouds	Chameleon	Jetstream
CPU	Intel Xeon X5550	Dual Intel E-2680v3 "Haswell"
Cores	1008	7680
RAM	5376 GB	40 Tbr
Speed	2.3 GHz	2.5 GHz
Storage	1.5 PB	2TB

**Table 2.** Cloud Hardware Specifications.

#### 5. GETTING STARTED

The following section describes the process involved in building the spark application to predict the customer churn.

##### 5.1. Loading the data

The ‘Customer Data’ used in the project contained 21 columns and 7000 rows. The data was stored in Hadoop distributed file system (HDFS) configured on the cloud cluster. Each row in the dataset represents an observed customer and each column represents attribute of that customer. Dataset was loaded into Spark DataFrame [14] along with the specified schema. After the dataframe was instantiated, it was queried using SQL queries with the help Pyspark DataFrame API.

##### 5.2. Feature Engineering

Every single information we use to represent a customer is called a “feature” and the activity of finding useful features is called “feature engineering.” In the Customer data set the data is labeled with two classes – Yes (Churned) and 0 (Not Churned). The features for each customer consist of:

**Labels**→ Churn: Yes or No

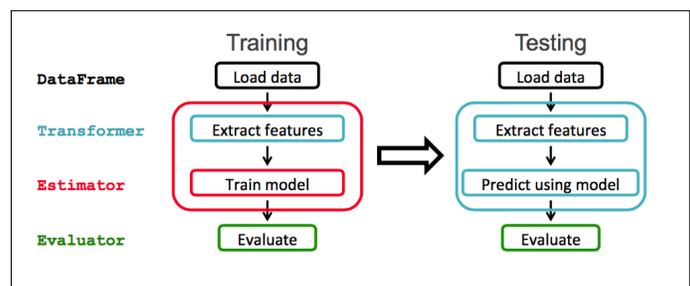
**Features**→ customerID,gender,SeniorCitizen,Partner, Dependents, PhoneService,MultipleLines,InternetService, OnlineSecurity, OnlineBackup,DeviceProtection,TechSupport, StreamingTV, StreamingMovies,Contract,PaperlessBilling, PaymentMethod, MonthlyCharges,TotalCharges

##### 5.3. Define Feature Array

In order for the features to be used by a machine learning algorithm (Spark ML), It is useful for combining raw features and features into a single feature vector, which are vectors of numbers representing the value for each feature. Next, VectorAssembler[17] is used to transform and return a new dataframe with all of the feature columns in a vector column. Finally we use this dataframe to train our model.

##### 5.4. Model Training

Fig 2 below shows the workflow used in training our machine learning algorithm.



**Fig. 2.** Spark ML Workflow [18]

We used the following Machine Learning Algorithm and compared them using metrics like accuracy, AUROC and confusion matrix.

1. Random Forest
2. Decision Tree
3. Support Vector Machine

For each of the algorithms, the data was split into training and testing subsets with a ratio of 70 percent for training and 30 percent for testing. The predictive performance of each of the algorithm was evaluated by comparing predictions on the

testing data set with true values (known as ground truth) using a variety of metrics such as Accuracy, AUROC and Confusion Matrix.

## 6. MODEL EVALUATION

We used Spark ML's inbuilt classification evaluators to evaluate the predictions of our algorithms. Table 3 below shows the accuracy for each of the algorithm used.

Classification Algorithm	Accuracy (%)
Decision Tree	83.75
Support Vector Machine	86.82
Random Forest	84.02

**Table 3.** Predictive Accuracy

## 7. DEPLOYMENT

The project deployment scripts were designed to be simple and reproducible. The deployment consists of Ansible playbooks and Cloudmesh Client scripts. It is run on user's local machine(Ubuntu 16.04). Deployment scripts will install all the necessary software along with project codes onto the cluster nodes, run spark job on the cloud and finally fetch result on the users local machine. The following section describes how to use the deployment scripts to install and run the project in the cloud.

### 7.1. Requirements

In order to run the project deployment scripts, one must have Ansible and Cloudmesh Client configured and installed on their local machine.

1. Cloudmesh Client: In our project Cloudmesh Client is used to set up Hadoop virtual cluster with Spark on two cloud environment. In order to run a virtual machine in the cloud, /.cloudmesh/cloudmesh.yaml configuration file should be configured to fill in detail about our cloud accounts such as username, password, project name, etc. Following tasks are performed in our project using Cloudmesh Client:

- (a) Uploading Public Key- using Cloudmesh's key add and upload commands.

```
$ cm key add --ssh
$ cm key upload
```

- (b) Uploading Security Rules- using Cloudmesh's secgroup commands.

```
$ cm secgroup upload
```

- (c) Creating Hadoop/Spark Cluster- using Cloudmesh's deploy command.

```
$ cm cluster define --count 3
--image CC-Ubuntu14.04
$ cm hadoop define spark
$ cm hadoop sync
$ cm hadoop deploy
```

2. Ansible Scripts: In our project, the entire cloud interaction including spark application installation, uploading data, setting up environment, running the spark application, and fetching the result is performed via Ansible playbooks. Ansible script was used in the following way:

- (a) Local Configuration : In the host file the IP address of remote namenode of the cluster is specified as follows:

```
[predict]
129.114.33.144 ansible_ssh_user=cc
```

- (b) predict\_setup.yaml : sets up environment, copies files/code and installs dependencies on the namenode of the cluster.

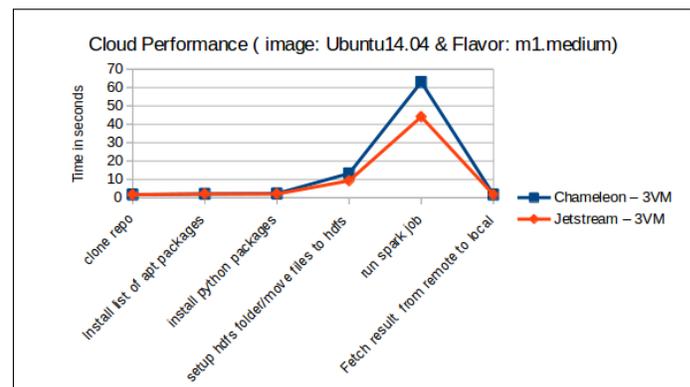
- (c) predict\_execute.yaml : This moves the downloaded data to HDFS through the following command:

```
$ hdfs dfs -put <source> <hdfs-folderpath>
```

This HDFS file will serve as an input to our spark application. Finally the spark application is submitted to the namenode, which runs it on distributed framework and fetches result from remote to local after job completion.

## 8. BENCHMARKING

After the Hadoop Spark cluster is set up on the cloud, a benchmarking process is run to assess the performance of our deployment and Spark job on the two clouds. Figure 3 below compares the time set up environment, install dependencies, run application and fetch result from both the clouds. For measuring the time we used shell script to calculate the time elapsed between begin and completion of Ansible playbooks.



**Fig. 3.** Time Comparison in seconds

First time installation for the dependencies and apt-packages takes considerable amount of time(10-15 minutes) and hence are not included in the above comparison graphs. Specifically, Spark application performs 23 percent faster on 3 node Jetstream cluster when compared to similar cluster on chameleon.

## 9. CONCLUSION

We have built and tested a fully automated program to configure, deploy and run Apache Spark's Machine Learning algorithm for customer churn prediction on two cloud environments(Chameleon and Jetstream). The use of Ansible Galaxy to

automate deployment and Cloudmesh Client to setup Virtual Cluster on cloud helped in reproducibility and scalability.

## 10. ACKNOWLEDGMENT

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## 11. WORK BREAKDOWN

The work in this project was equally distributed between the following authors.

**Diksha Yadav:** Data analysis and building Spark pipeline for machine learning algorithm in stand alone mode, benchmarking and troubleshooting.

**Yatin Sharma:** Code deployment, building ansible scripts, benchmarking and troubleshooting.

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