censys

2025 State of the Internet Report

Understanding Adversary Infrastructure Through Real Investigations and Data

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Chapter One

Introduction

Adversary infrastructure is the hidden scaffolding of modern cybercrime and espionage. From **command-and-control (C2) services** and **malware loaders** to **proxy networks** that route through trusted IP space, this infrastructure lets attackers scale campaigns, mask origins, and persist long after initial exploitation. For defenders, understanding this layer is critical: it's often the best place to detect and disrupt attacks before they reach intended targets.

This report centers on **adversary infrastructure**—C2 and the surrounding tools threat actors use to establish control, move laterally, and exfiltrate data—and examines how that ecosystem behaves through real data. We examine the structural patterns of adversary infrastructure at Internet scale—where it resides, how long it persists, and how different signals reveal continuity even as individual services change. This view spans both traditional C2 ecosystems and emerging edge-based infrastructure like residential proxies and IoT botnets, highlighting the ways attackers build, sustain, and evolve the scaffolding behind modern threat operations.

Data Accuracy and Historical Context

Censys enables organizations to see the Internet as it truly is and to secure it more effectively. Governments, enterprises, and insurers rely on Censys for attack surface management, supply-chain risk assessments, cyber-insurance underwriting, and monitoring of critical infrastructure.

Tracking adversary infrastructure requires **breadth**, **freshness**, and **accuracy of Internet data** to deliver insights that are both actionable and trustworthy. Censys provides the most complete map of global Internet infrastructure, tracking ~794 million IPv4 services[1]—almost triple the 275 million observed a decade ago when we first started scanning the Internet.

While Censys emphasizes accuracy above all else, Censys also excels in speed. In controlled experiments, it discovered new services in a median of just 5.7 hours (12.3 hours on average), faster than all other platforms. This rapid detection empowers researchers to identify and monitor fast flux infrastructure designed to evade detection.

	Self-Report	Est % Accurate	Est % Unique	Est. # Accurate
Censys	794M	92%	100%	730M
Shodan	810M	68%	100%	550M
Fofa	3.1B	20%	65%	403M
ZoomEye	3.5B	10%	99%	346M
Netlas	877M	49%	63%	270M

Over 92% of the services listed in Censys reflect live services, not stale or duplicate results, ensuring the best insights to track malicious infrastructure. Censys also provides historical context of every identified IP, Port, and services, providing insights to how infrastructure has changed over time.

	Top 10	Top 100	All 65K
Censys	96%	92%	82%
Shodan	80%	40%	10%
Fofa	63%	62%	43%
ZoomEye	82%	54%	26%
Netlas	63%	27%	3%

With unmatched coverage, Censys identifies 96% of services on the top ten ports and 92% across the top hundred, while still capturing 82% of services across the entire 65k port space allowing security teams and researchers to track malicious services, open directories, and other adversary infrastructure running on non-standard or high ports that are often poorly unmonitored.

Censys is more than a dataset; it is a platform widely adopted across research and industry. Over 500 academic papers have used its data to study Internet security, public key infrastructure, IoT devices, industrial control systems, and more. Most relevantly, Censys has also been used to study malware infrastructure, the subject of this year's *State of the Internet Report*.

Chapter Two

Malware Detection Trends

Let's begin with a broad look at the malicious infrastructure landscape. We examined 80 of our malware detections over a period of 6 months, from December 2024 to May 2025.

During this study time frame, we observed **an average of 2,906 malware detections** for each snapshot date. Mid-December marked the greatest number we observed online during the period. Following the peak in December, we observed a 14% drop in detections in early January. This appears to be primarily driven by a drop in Cobalt Strike instances in China. Cobalt Strike was the most commonly observed malware family, and they are largely concentrated in China.

Total Malware Detections Over Time

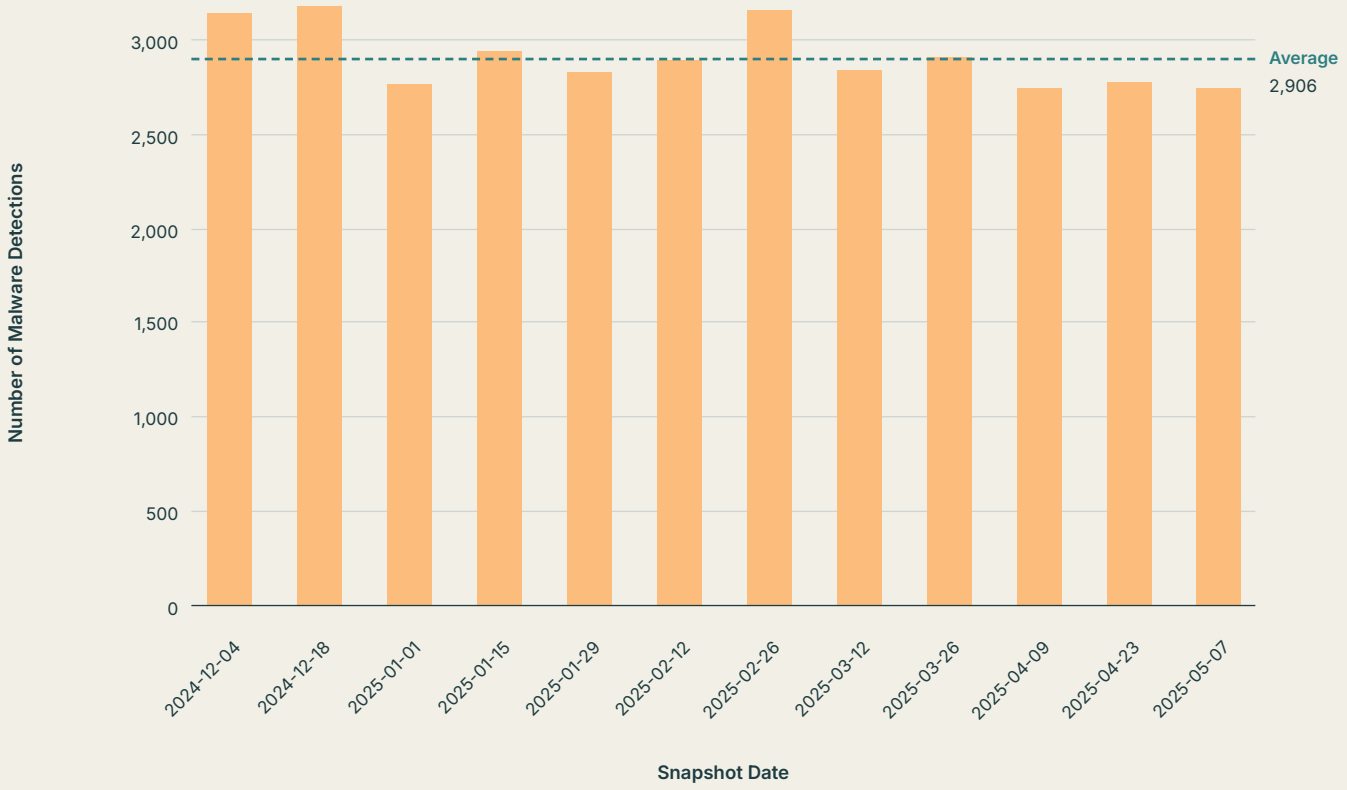


Figure 1. Malware detections from December 2024 through May 2025

Note: The data shows detections as of May 2025, but Censys continuously updates and adds detections over time.

Malware Families

Cobalt Strike originated as a pentesting and red teaming tool; however, it has been widely adopted by threat actors since its initial release over 10 years ago. In addition to C2 functionality, it offers extensible post-exploitation tooling attractive to security professionals and threat actors alike.

Despite the decline into January and takedown efforts spanning two years[2], Cobalt Strike consistently had the greatest observed Internet presence of the detections we examined during the study period—**it represents 34% of the C2s we observed as of May 2025**.

The next largest families during this time frame were **Viper** (15% of total) and **Sliver** (13% of total). While Cobalt Strike is a commercial tool, Viper[3] and Sliver[4] are open source alternatives for adversary emulation. Viper and Sliver are slightly younger projects than Cobalt Strike, but their availability has likely contributed to their popularity.

Operation Morpheus & Other Notable Incidents

Read the story of a global disruption campaign against pirated versions of Cobalt Strike and other notable CVE investigations in our blog.

Read the Blog

Top 10 Malware Detections Over Time

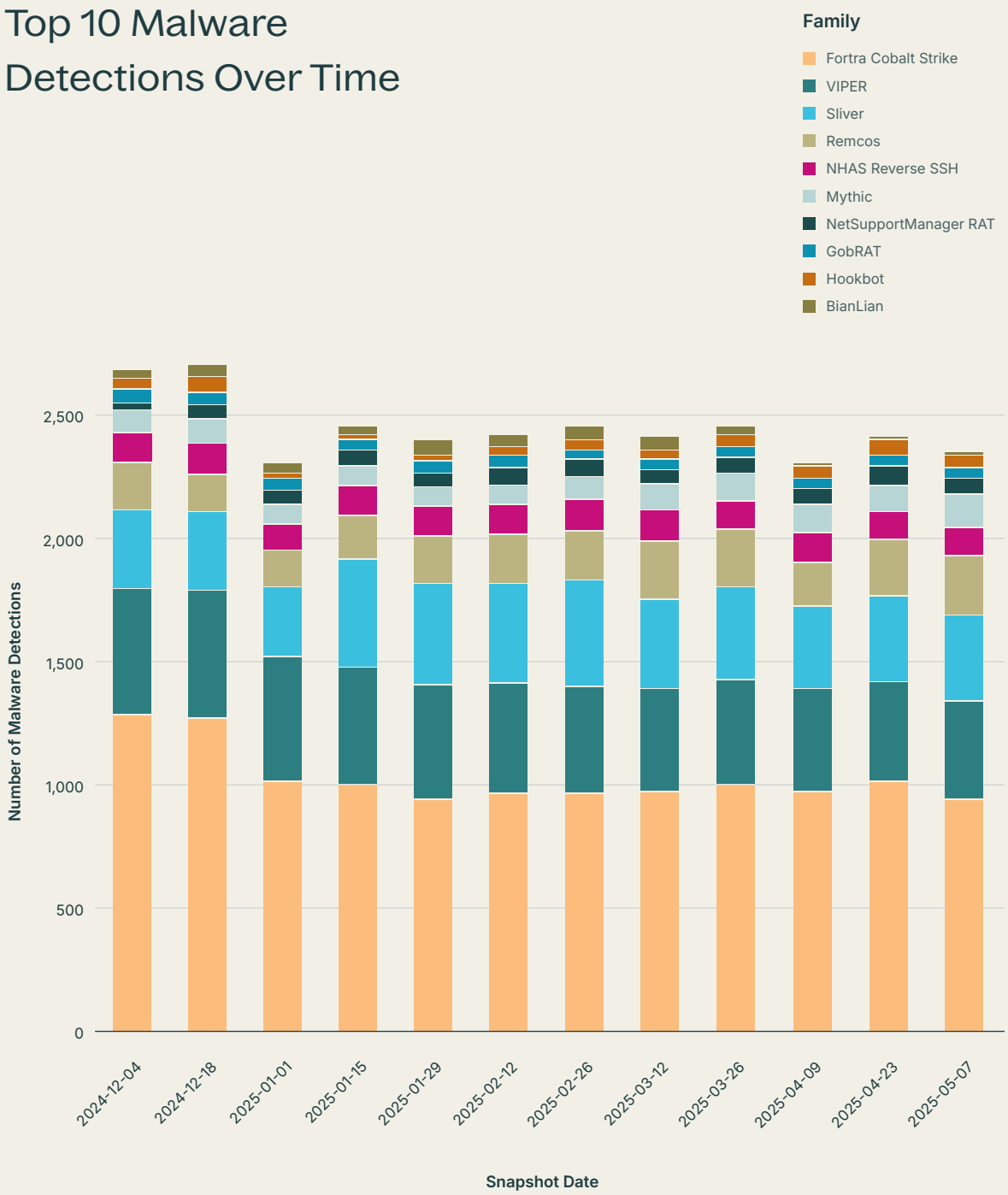


Figure 2. Top malware families from December 2024 through May 2025

Geography Trends

As of May, we observed detections in a total of **62 countries globally**, with China and the U.S. topping the list and hosting 55% of malware collectively. Beyond the U.S. and China, we observe concentrations of malware in Asia, Europe, and North America.

It can be tempting to look for deeper meaning in geographic regions with high concentrations of malicious infrastructure, but rather than having geopolitical significance, concentrations of malware are more likely driven by hosting provider availability, pricing, and permissiveness.

Global Malware Detection Concentrations

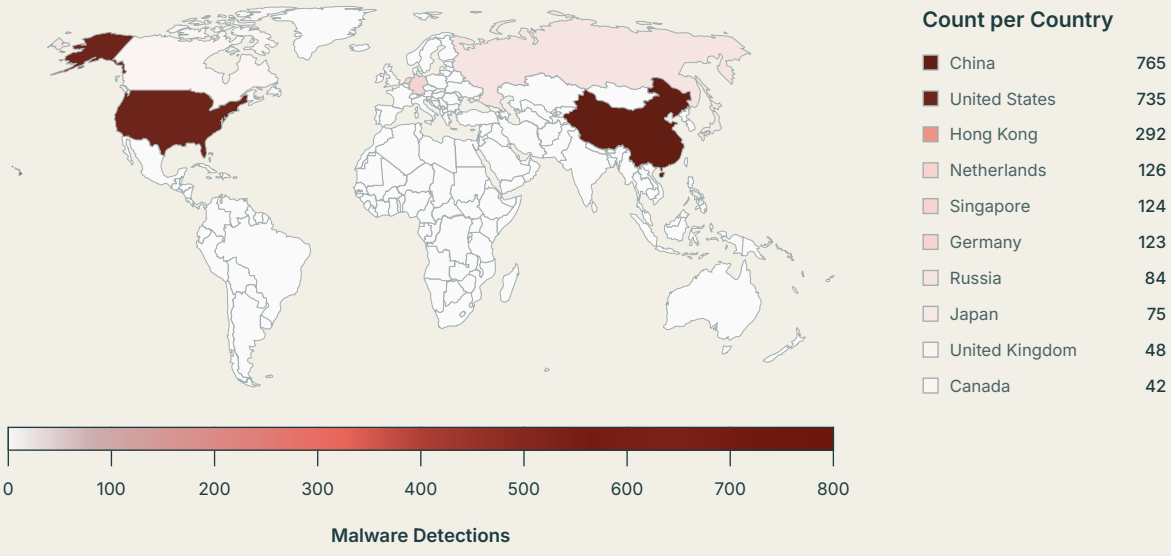


Figure 3. Geographic spread of malware detections, May 2025

Note: The legend depicts only the top 10 countries where we observe detections

Network Trends

China-based providers Alibaba and Tencent top the list of where we observe the greatest volume of malware detections across the snapshot dates studied, and Huawei's Cloud Service also makes the top 10. Rounding out the list are several U.S.-based providers, including Cologix, Digital Ocean, Colocrossing, Vultr, Amazon, and Microsoft.

Top 10 ASNs Hosting Malware Over Time

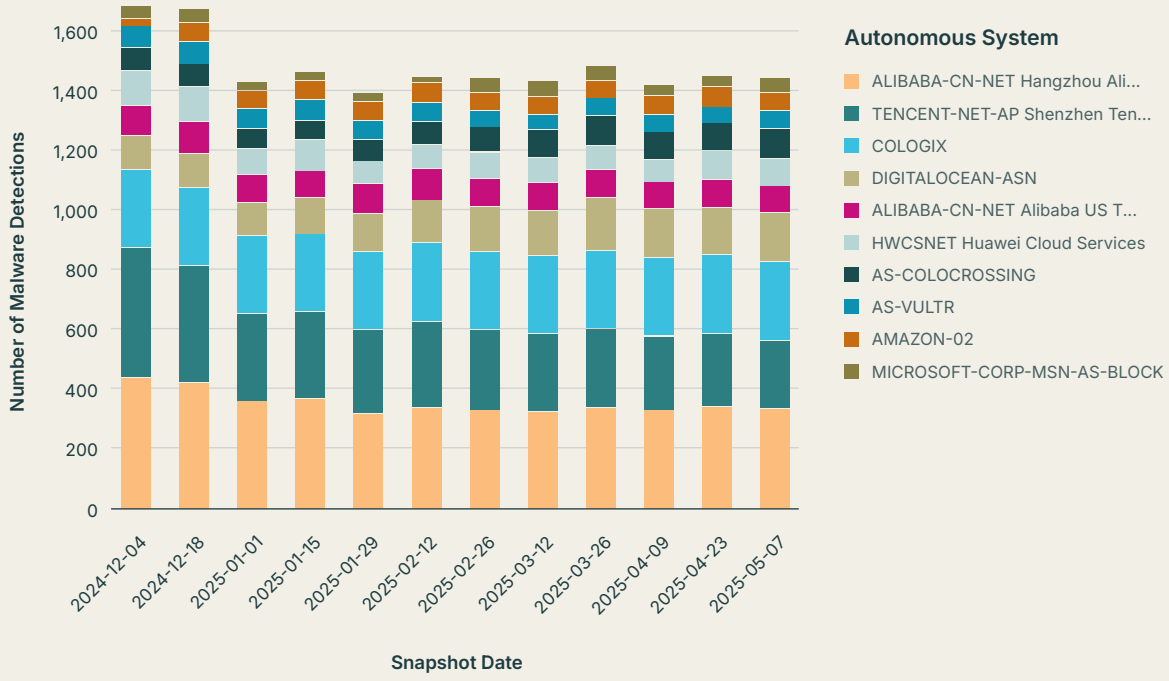


Figure 4. Top networks where we observe malicious infrastructure, December 2024 through May 2025

SPOTLIGHT

PlugX

We can also find interesting exposure patterns when we look beyond the most common families shown above. Consider **PlugX** as an example.

PlugX[5] is a remote access trojan (RAT) known since 2008[6] and used by China-linked threat actors such as APT41 and Mustang Panda.

We generally observed a decline in PlugX instances over the study timeframe, apart from a slight and short-lived uptick in early April 2025. This decline follows news of a takedown[7] from the U.S. Department of Justice in January 2025.

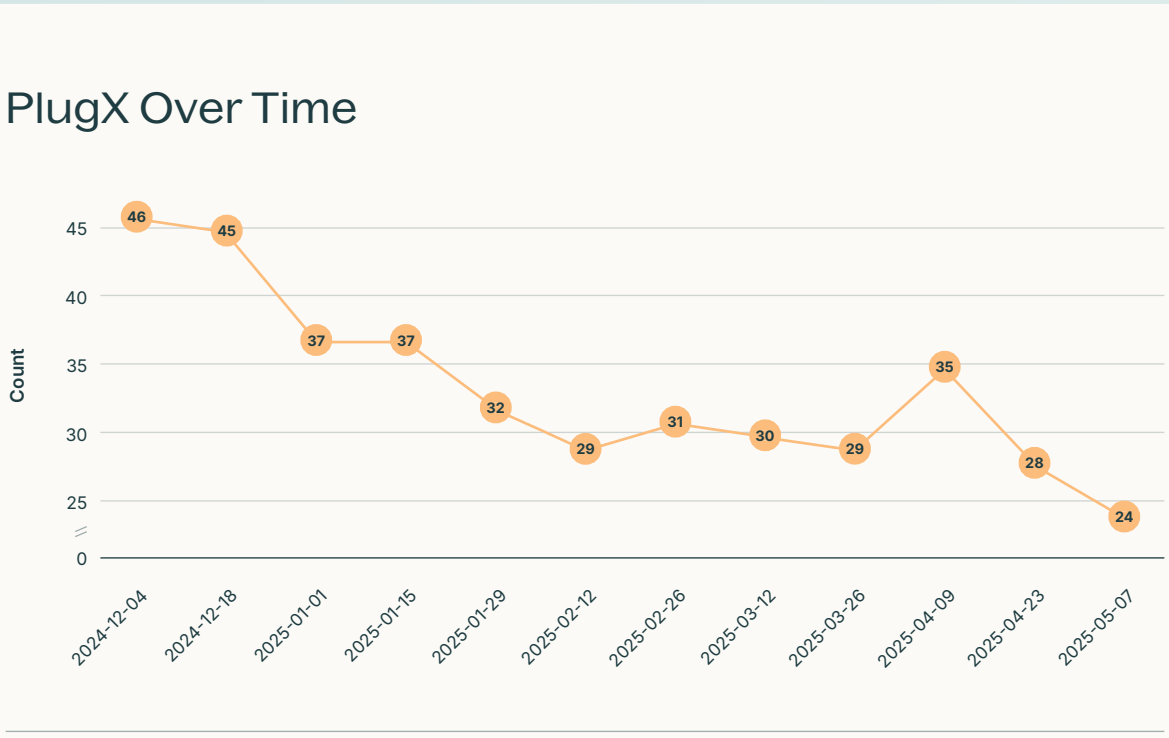


Figure 5. PlugX instances, December 2024 through May 2025

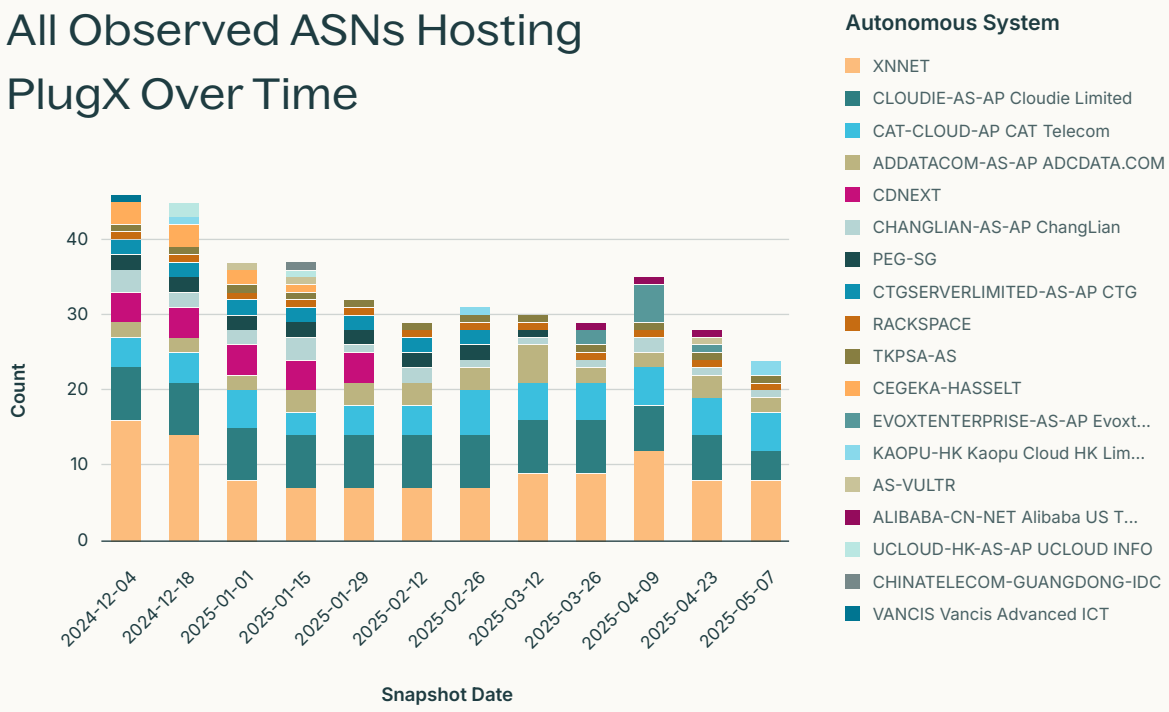


Figure 6. All networks where we observed PlugX instances, December 2024 through May 2025

In examining all autonomous systems (AS) where we observe PlugX, we note minimal overlap with the global top autonomous systems where we observe C2 infrastructure. The only shared ASes are Vultr and Alibaba, which could point to more specific or discerning operations by PlugX operators.

XNNET, a U.S.-based provider, tops the list of networks where we observe PlugX, followed by Hong Kong-based Cloudie and CAT Telecom, based in Thailand.

Chapter Three

C2 Time to Live

A previously unexplored concept of threat infrastructure is their **time to live**, or **TTL**. Understanding how quickly threat infrastructure remains online, disappears, or moves is incredibly useful for defenders and researchers. Given the unique perspective of Censys, which is continuously scanning entities on the Internet, we are able with high confidence to examine TTLs, or the lifespans, of services and understand the repercussions of varying TTLs for defenders and researchers.

In this section, we will examine a C2 server's TTL using two perspectives, network liveliness and content liveliness.

Lifespans by Network Availability

TTL can traditionally be viewed from the network sense: how long is a specific service online before it disappears? We focus our analysis on the most common malware families we observed, Cobalt Strike and Viper.

Cobalt Strike and Viper services act quite differently.

First, Cobalt Strike's TeamServer, the part controlled by a threat actor, services are much shorter lived, with TTLs on average/median of 11.2/5.0 days, whereas Viper services exhibit TTLs of 17.4/18.5 days. We hypothesize that this is because Cobalt Strike is more well known and prevalent, thus showing a much wider range of behaviors than Viper services.

Most Common Malware Families Observed

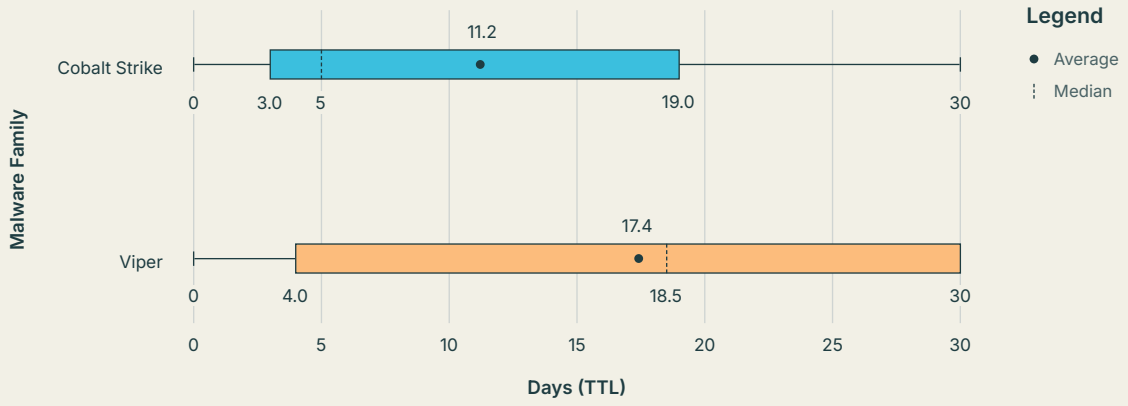


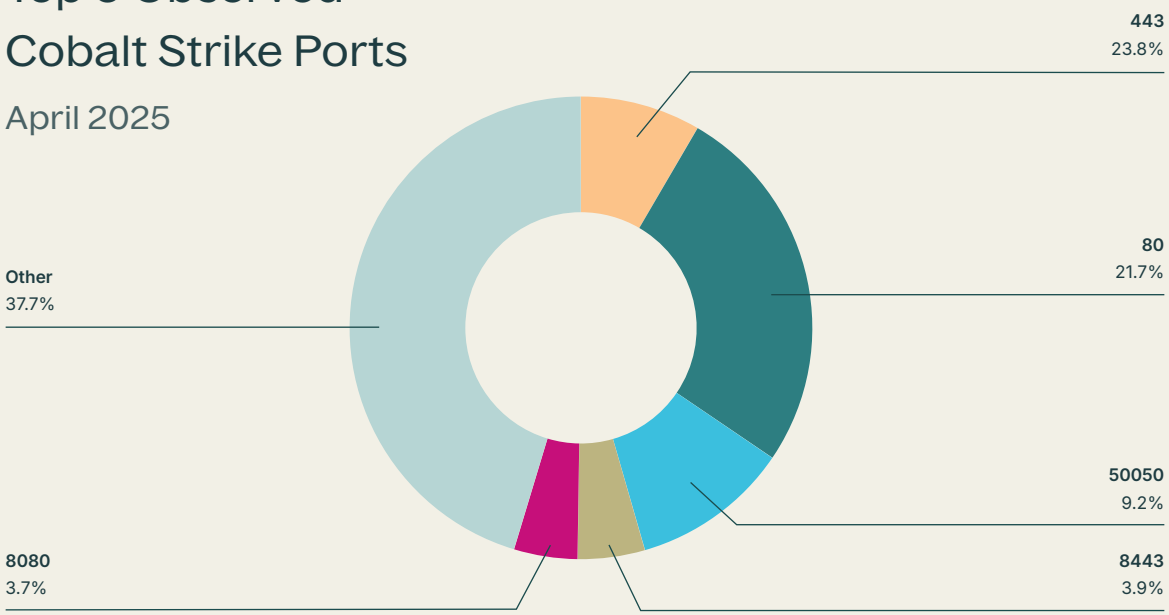
Figure 7. Cobalt Strike and Viper TTLs in days according to service/network availability

This overarching view of the two C2 families exemplifies the huge variability in even these basic metrics. We next dive deeper and examine the most popular ports for Cobalt Strike and Viper services. Since there is a much longer tail for Cobalt Strike than Viper services, we simply show the five most prevalent ports and their mean/median TTL in days, found in **Figures 8 and 9**.

Even within a family, there can be a variance of difference. With popular Cobalt Strike ports, this variance is far smaller, ranging from an average of 6.3 days to 11.8 days. However, for Viper we see a much larger range, from an average of 6.8 days to 30 days (the duration of our data analysis period). This points to the need to not only investigate specific families and their behaviors, but also specific sub-areas within those families.

Top 5 Observed Cobalt Strike Ports

April 2025



Top 5 Cobalt Strike TTL by Port

April 2025

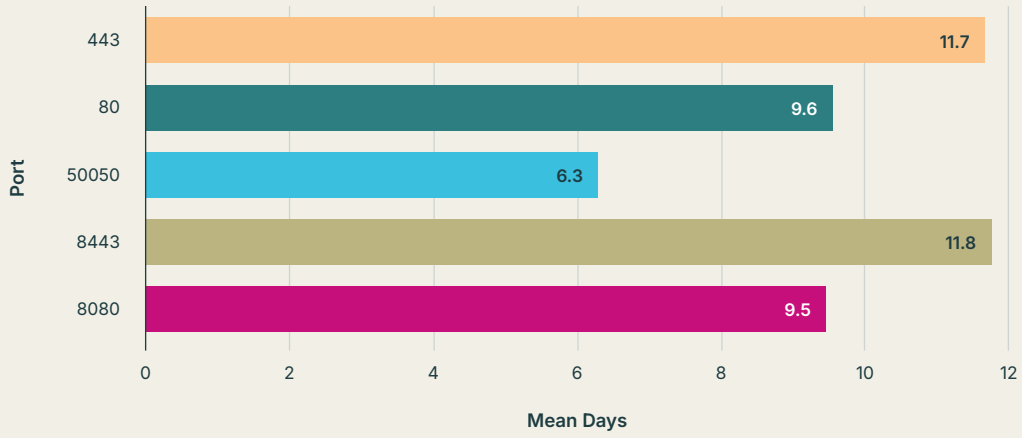
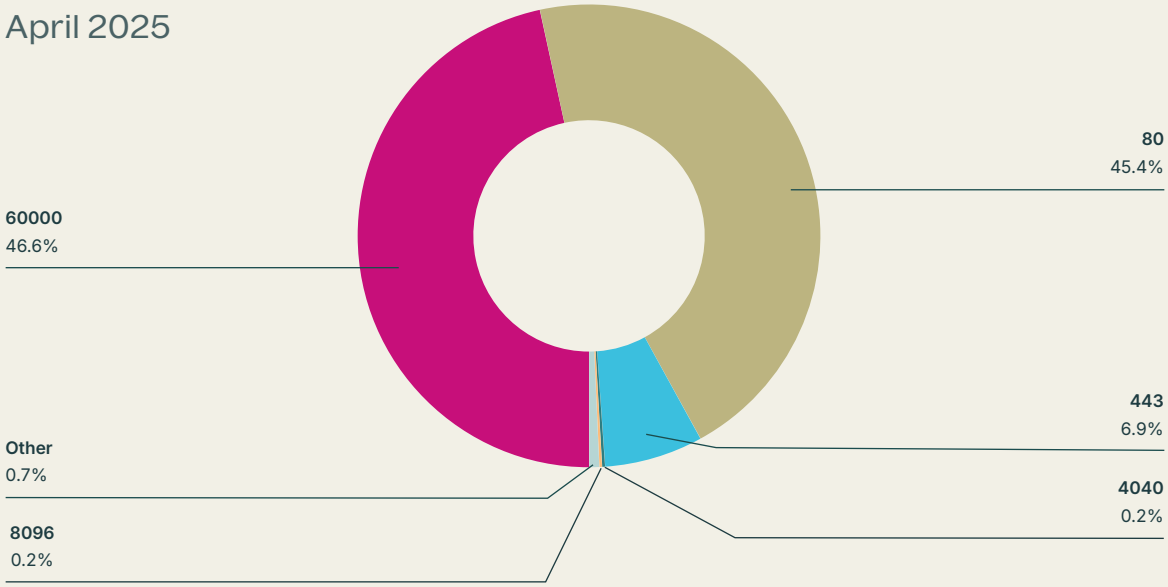


Figure 8. Cobalt Strike most populous port TTLs in days according to service/network availability

Top 5 Observed Viper Ports

April 2025



Top 5 Viper TTL by Port

April 2025

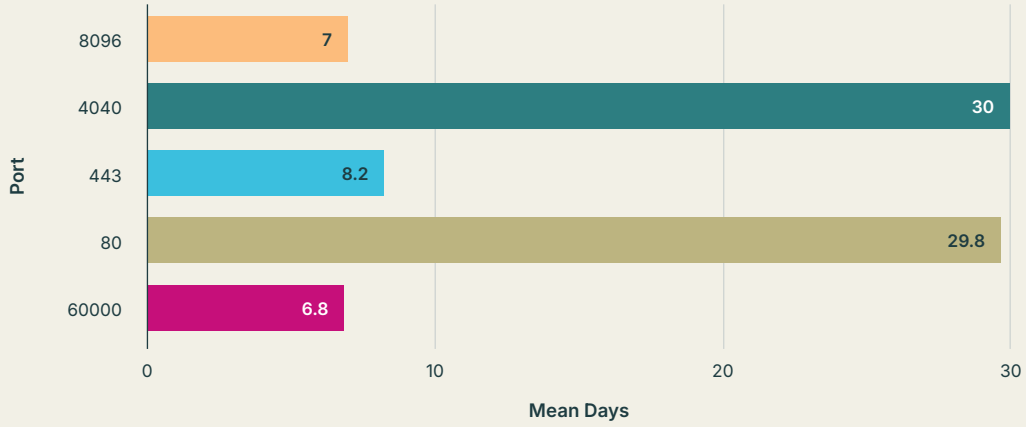


Figure 9. Viper most populous port TTLs in days according to service/network availability

Lifespans by Content

Thus far we have examined TTLs in the context of network availability: when was the service online, and when did it go down? However, there is more to a service than just its network availability, as a service often has rich forms of content associated with it. We examine Cobalt Strike servers through observed watermarks for 32-bit copies of Beacon, and analyze their lifespans through a content-level perspective.

Watermarks in Cobalt Strike beacons are an embedded value that are believed to correlate to a purchaser's software license. We begin by examining x86_ watermarks in aggregate during the month of April. We find a large variation in the number of unique IPs per watermark, which indicates that it is feasible to track liveliness based on this content-based watermark.

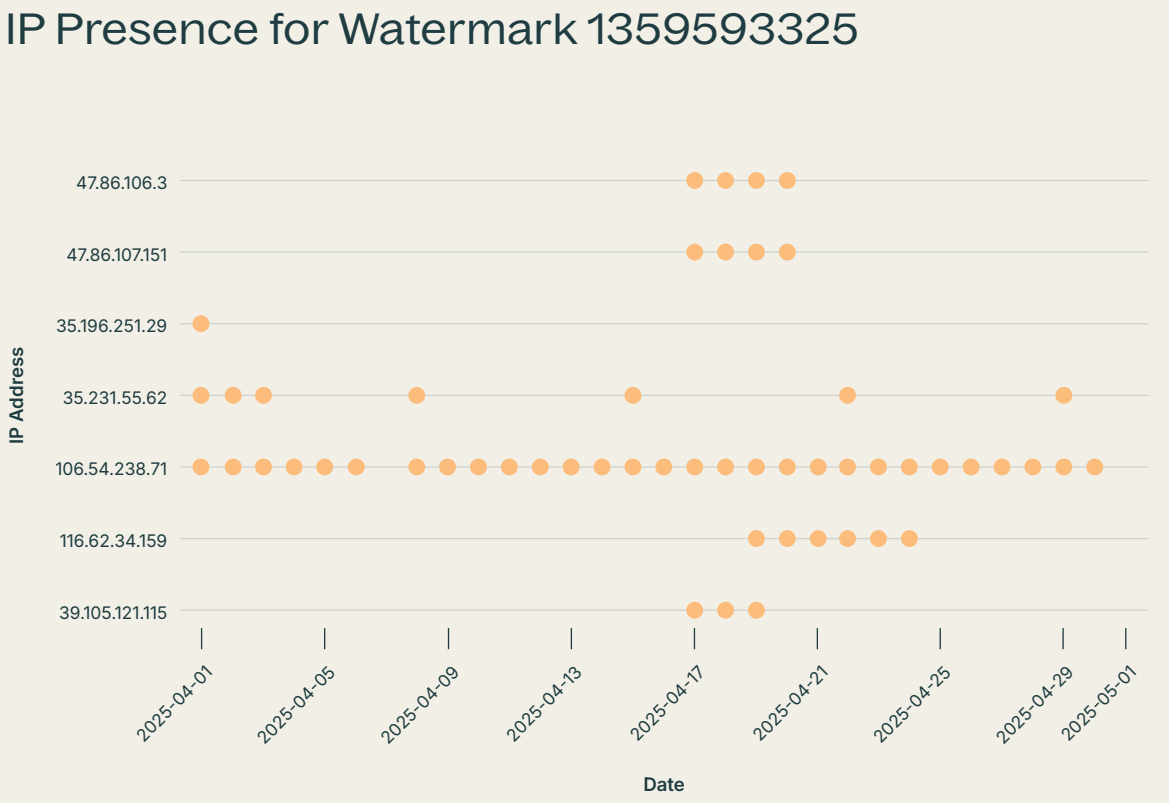


Figure 10. An example of service-level appearance for IPs with watermark 1359593325

Figure 10 shows the difference that comes with examining hosts at the watermark, or content, level. If you look at specific IPs, you can see that while the service may disappear, the watermark actually remains the same.

When we use the watermark as an indicator of liveliness, for these IPs that have an x86_watermark, we find that the average/median TTL for services is 9.5/4.0 days, while the average/median TTL for services based on their watermarks is actually 11.1/6.0 days. The increase is slight, but belays the potential importance of tracking services based on their uptime or content.

Watermark Changes by IP Over Time

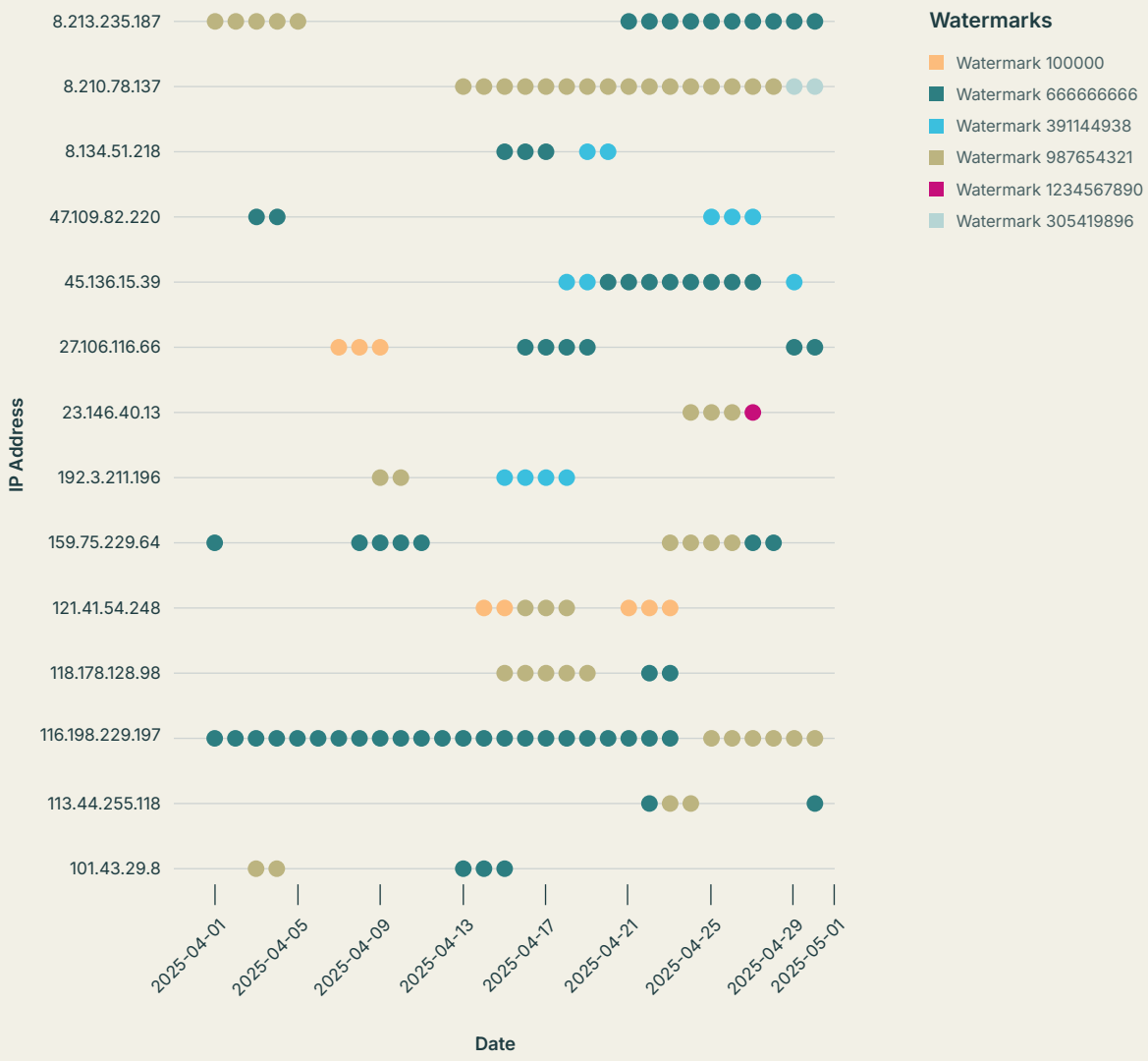


Figure 11. IPs that change a watermark at least once

To add to this nuance, we also check how many IPs have more than one watermark. We find 14 IPs (an incredibly small population) that have more than one watermark, and show how the service switches its watermark. In some cases, the switch is within a single day, which would conflate service liveliness with content liveliness. While 14 hosts is an incredibly small subpopulation, this points to some interesting takeaways, namely:

1. We cannot always guarantee that service liveliness means the host is the same.
2. These hosts exhibit strange, non-conformant behavior that is worth investigating further.

What does this mean for security defenders and researchers?

It means that tracking malware families requires both near real-time visibility to the current state of Internet infrastructure AND also the ability to see historical changes over time. Understanding the past provides us context for the current state of the Internet, enriching investigations far more than a single snapshot allows.

Further, when analyzing C2 families, we need to understand both the base behavior of that family as well as additional, more nuanced factors that can affect analysis outcomes. For example, things like the port(s) in question, as well as service vs content liveliness, deepened our analysis. We found that Cobalt Strike services are much shorter lived than Viper services, which belays the importance of treating C2 families uniquely.

Moreover, this analysis showed how liveliness can be defined by the content of the C2 server itself, which can illustrate how a server is changing (or not changing) even in the absence of network presence. Understanding these variations can help the security community produce higher quality analysis.

Chapter Four

Open Directories Time to Live

Open web directories are a cheap, simple, and stealthy way for attackers to host malicious payloads AND they're hard to detect. OpenDirs are used by malware families such as AsyncRAT, SuperShell, Emotet, Mirai and many others.

These are another interesting avenue for us to perform investigations as they are literally open directories or filesystems, often containing payloads and files used for nefarious purposes. Open directories are hosted on the public Internet, which means that not only can attackers find them, but so can we.

To do so, we need to approach the problem differently. While we previously had the benefit of being able to track Cobalt Strike TeamServer via a distinctive watermark, open web directories do not have a specialized field that we can key on. However, we consider the defining characteristic of an open web directory to be the HTTP body, as that is where all the interesting content of the open directory is typically found.

So, we examine the lifespans of open web directories based on their HTTP bodies. We narrowed down our scope to look at only open web directories that are located on an HTTP service for the month of April. To compare the HTTP body of the open directory, we calculate the hash of the HTTP body using TLSH, a rolling hash algorithm. In short, TLSH allows us to compare HTTP content more easily. We calculate the score between the service's current TLSH hash and the service's previous TLSH hash, where 0 is not similar at all and 100 is the same, and we compare the service lifespans of open web directories based on their service liveliness and their TLSH comparisons.

Observable Lifespan vs. Similar Content Lifespan

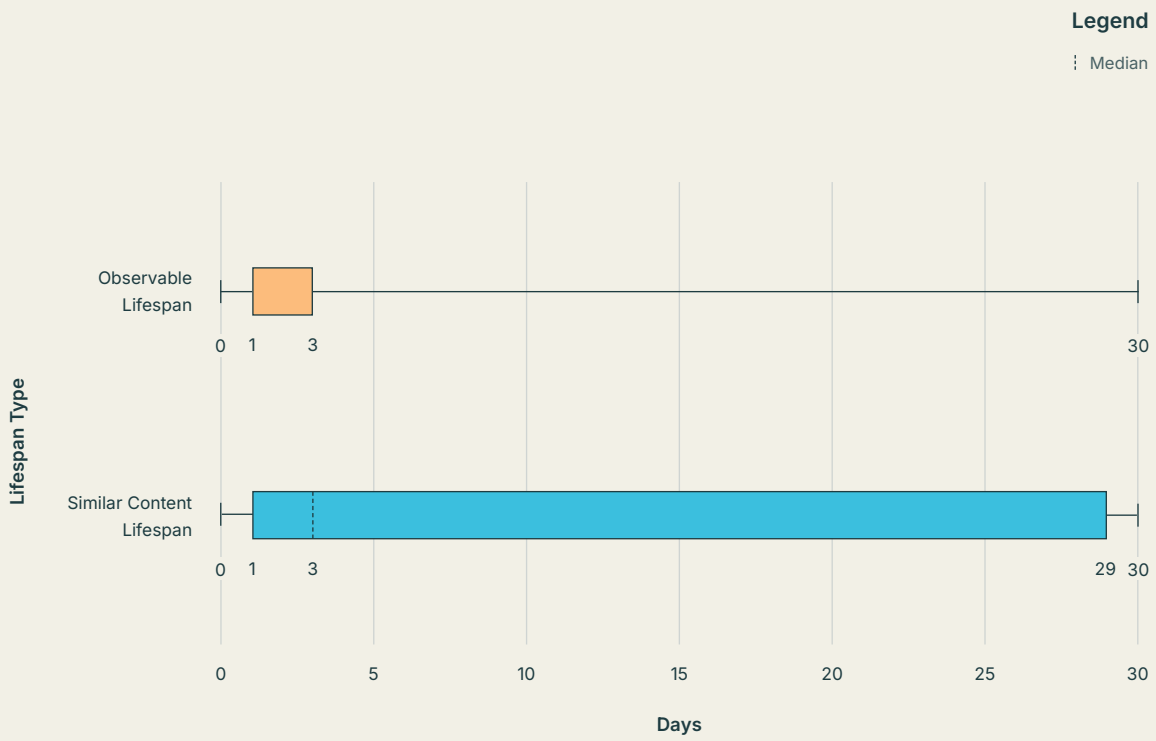


Figure 12. A comparison of observable lifespan and similar content lifespan

Note: Observable Lifespan Q1 and Median both equal 1.0 days; the median line coincides with the box edge.

Analysis

In **Figure 12**, we show the percentiles of network lifespans, or pure observability, vs lifespans based on content similarity:

50%
vanish in <1 day

50%
change contents within ~3 days

We find that open web directories have shorter network lifespans, meaning that almost half of open directories generally come online only to disappear a short while later.

However, when we examine open directories through a content lens, we find their median lifespan is closer to 3 days. This means that even if a web directory blips in and out in terms of network visibility, the content doesn't necessarily change. This distinction is important, as it allows us to understand how much an open directory has changed, a critical component for actor investigations.

What does this mean for defenders?

Having up-to-date Internet visibility is crucial as it provides an accurate representation of hosts and malicious infrastructure in a fast-moving environment. Moreover, understanding ***what*** pieces of infrastructure are available, as well as ***how*** they change are both equally as important. In other words, knowing the content of the infrastructure and having the ability to see the files inside an open directory allows us to track how they are changing and fluctuating over time, in addition to their mere presence.

Chapter Five

Residential Proxy Infrastructure

Beneath the hum of everyday Internet traffic, millions of home and small business devices quietly pull double duty, functioning for their legitimate owners while also relaying traffic for entirely separate purposes. These devices form the backbone of **residential proxy networks**, which route traffic through ordinary consumer equipment.

Not all residential proxies are malicious. Some operate with the full knowledge and consent of their owners – for example, those who rent out their home router's IP address to a commercial proxy service. Owners are often unaware of exactly how their IP will be used, but have willingly placed it in a pool that could serve both benign and questionable purposes.

However, other devices are leveraged without consent. In the cybercrime ecosystem, threat actors commonly compromise routers, smart speakers, and other IoT devices to create residential proxy networks that hide malicious activity behind trusted, geographically diverse IP addresses. This makes them far more difficult to detect or block than data center proxies and gives attackers a layer of anonymity.

In this section, we explore **Operational Relay Boxes (ORBs)**, a particularly stealthy type of malicious proxy, and examine one suspected ORB network, PolarEdge, to illustrate how they function.

Historical C2 Excavations

As discussed earlier in this report, C2 servers are not always as short-lived as commonly assumed. Our analysis of a few prominent malware families showed that, on average, they remained active and responsive for just over a week. This is longer than the anecdotal expectations of hours or days, but still far more short-lived than most other types of infrastructure we track. The downside is that C2 IPs and indicators age quickly – particularly delivery servers – and by the time they are investigated, they often no longer lead to live infrastructure.

However, even when a known C2 IP is no longer active, we can still pivot off it in Censys's historical data to uncover valuable context about an operation. Examining historical artifacts, such as certificates and services, on a single IP can shed light on related infrastructure and provide a sense of the broader scale of an operation.

As our investigation revealed, what might appear at first glance to be an ordinary artifact on a host can take on a very different meaning when analyzed in the context of the services and networks where it is deployed over time. A normal-looking test certificate can become a thread that unravels into a larger and more suspicious pattern.

To demonstrate this approach, we turn to "PolarEdge," a suspected ORB network first reported on by Sekoia[8] researchers that resurfaced with new tactics earlier this year. Starting from just one C2 server, we trace a trail of unusual test certificates and domains that ultimately reveals an extensive network of proxy nodes.

SPOTLIGHT

Pivoting on a PolarEdge Botnet C2

In February 2025, researchers uncovered PolarEdge, an IoT botnet that has been active since at least late 2023. It started out by exploiting CVE-2023-20118[9], a command injection vulnerability in the web interfaces of Cisco Small Business routers, to implant base64-encoded webshells. Its tactics have since evolved into a sophisticated operation leveraging a custom **Mbed TLS (formerly PolarSSL) backdoor** for encrypted command-and-control, log manipulation, and dynamic infrastructure updates.

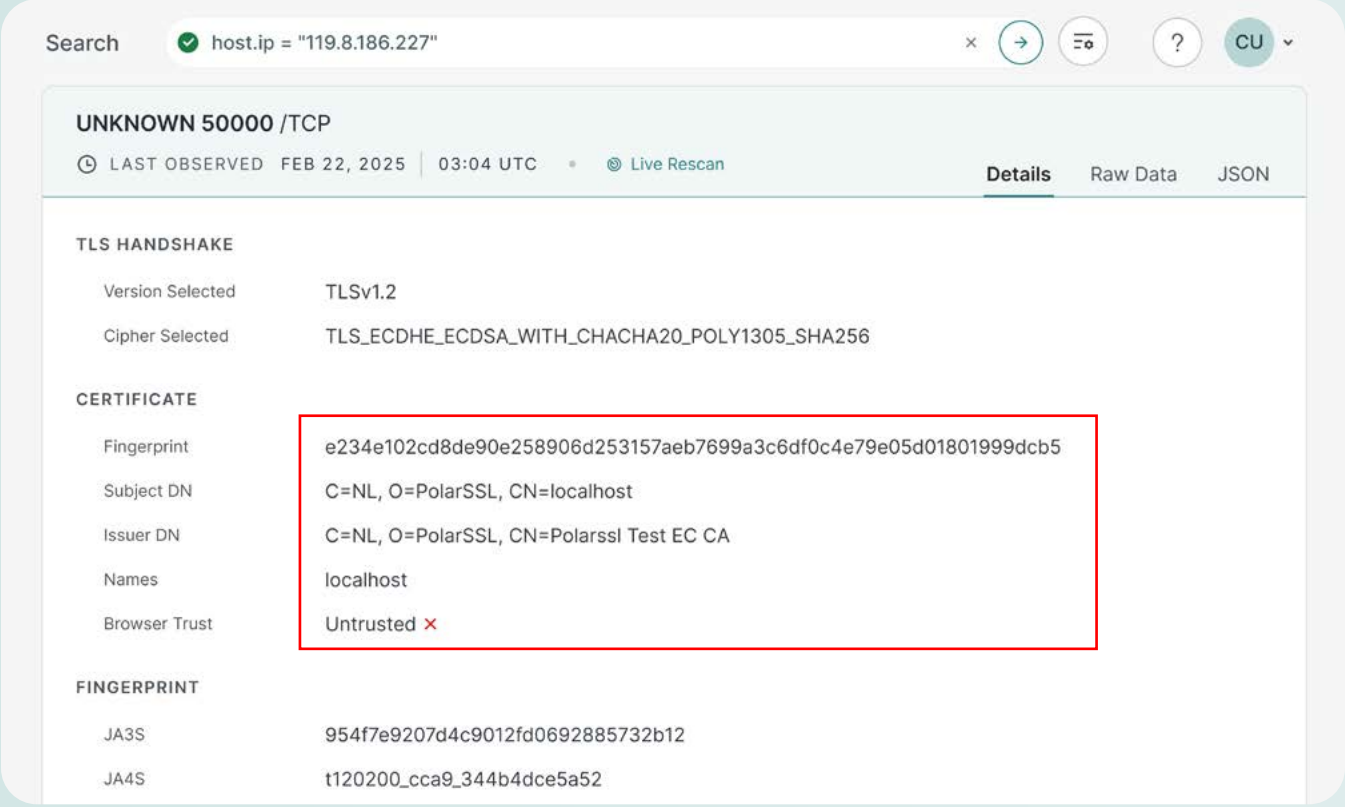


Figure 13. Investigations of host 119.8.186[.]227.

We honed in on a host that was identified by Sekoia as being used to deliver malware payloads: **119.8.186[.]227**, and pivoted to see what additional information we could discover in Censys.

> **The attacker used the IP address 119.8.186[.]227 to distribute these payloads via FTP. This address is located in Singapore and belongs to Huawei Cloud (ASN: 136907). Based on a Censys search, several non-standard TCP ports are open, exposing TLS services associated with either suspicious certificates or those linked to Polar.**
>
> Sekoia Research Team

We can leverage historical scan data in Censys to go back in time to February 11[10], around the time when Sekoia first observed attacker activity, and examine the attributes of this host to identify potentially adjacent infrastructure. At that time, this host was exposing multiple services and certificates, including one tied to the domain "www[.]learningrtc[.]cn" (**3f00058448b8f7e9a296d0cdf6567ceb23895345eae39d472350a27b24efe999**) – a domain linked to a WebRTC development e-book. Tracing this certificate on the web led to a GitHub repository containing an exact match that appeared to be a test certificate from a legitimate project.

On its own, this overlap is not incredibly significant; a legitimate e-book's test certificate was reused on some attacker infrastructure. But when we began looking beyond this specific host, a pattern began to emerge that made this seem less like a coincidence.

Over the past few years, the same e-book certificate has been observed across numerous hosts, many of which expose other suspicious-looking certificates with a "PolarSSL" subject and issuer, across seemingly random high ports above TCP/50000.

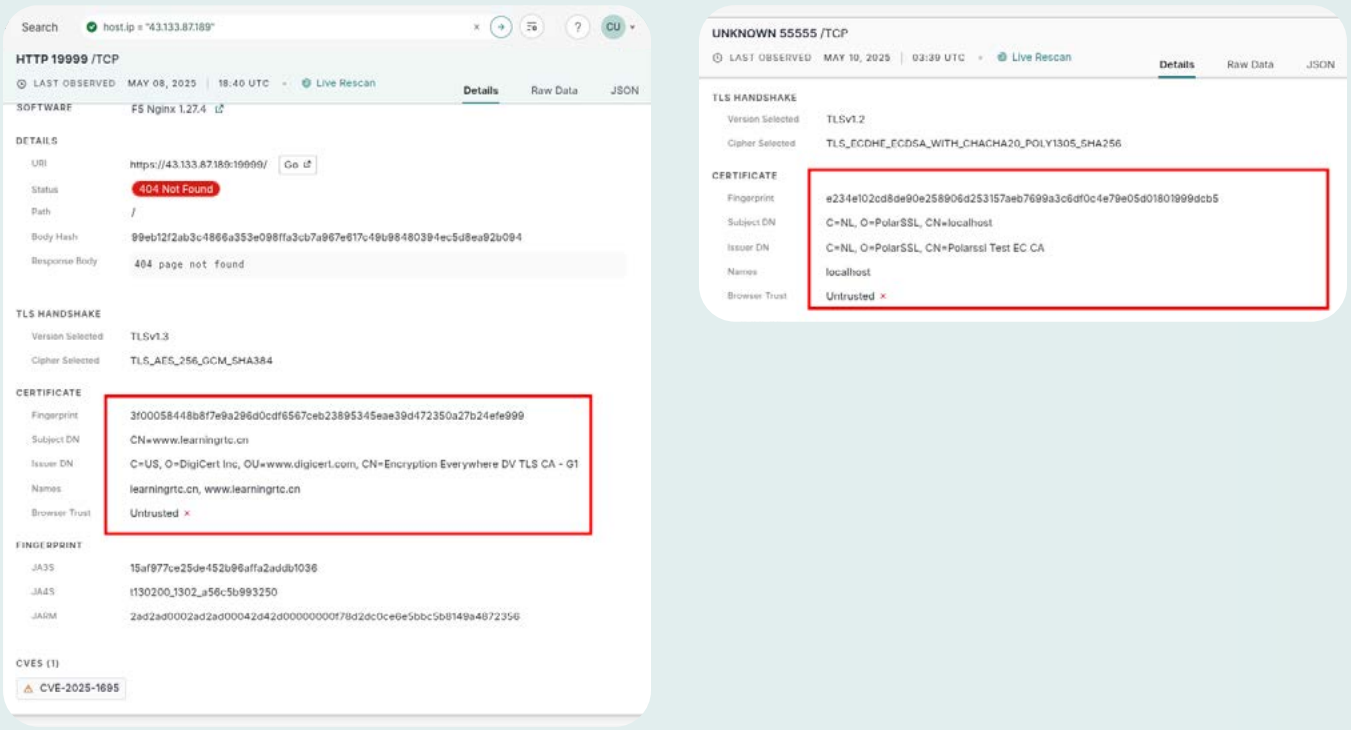


Figure 14. learningrtc[.]cn mixed with a PolarSSL certificate

The original attacker's host (119.8.186[.]227) was also serving these strange PolarSSL certificates on two ports: TCP/50000 and TCP/55555.

This raised the question: Were all these certificates originally legitimate, and only later co-opted for malicious use? And how was the seemingly benign WebRTC e-book certificate connected to the PolarSSL ones? To answer that, we traced the origins of the PolarSSL certificate.

Our early efforts yielded little – unlike the WebRTC cert, there were no public code repositories or documentation referencing its purpose. At first glance, examining its use across the broader internet (and over time) suggested a very strong overlap with the known PolarEdge botnet certificate. However, further review revealed that this cert appears in older versions of Mbed TLS and is included in the project's public test data repository. This means that the overlap we observed does not, by itself, constitute evidence of a direct PolarEdge connection. However, the continued recurrence of these

two specific certificates across different infrastructures indicated there might be operational patterns worth investigating further.

We then shifted our focus to hosts *currently* serving[11] these certificates, and at the time of writing, there were plenty of them, but one host immediately stood out: 8.219.153[.]173[12]. This server was located within the Alibaba Cloud ASN, exposed all of the certificates we had been tracking, and, most importantly, was serving an open directory on a high port (TCP/10000) with some extremely interesting filenames:

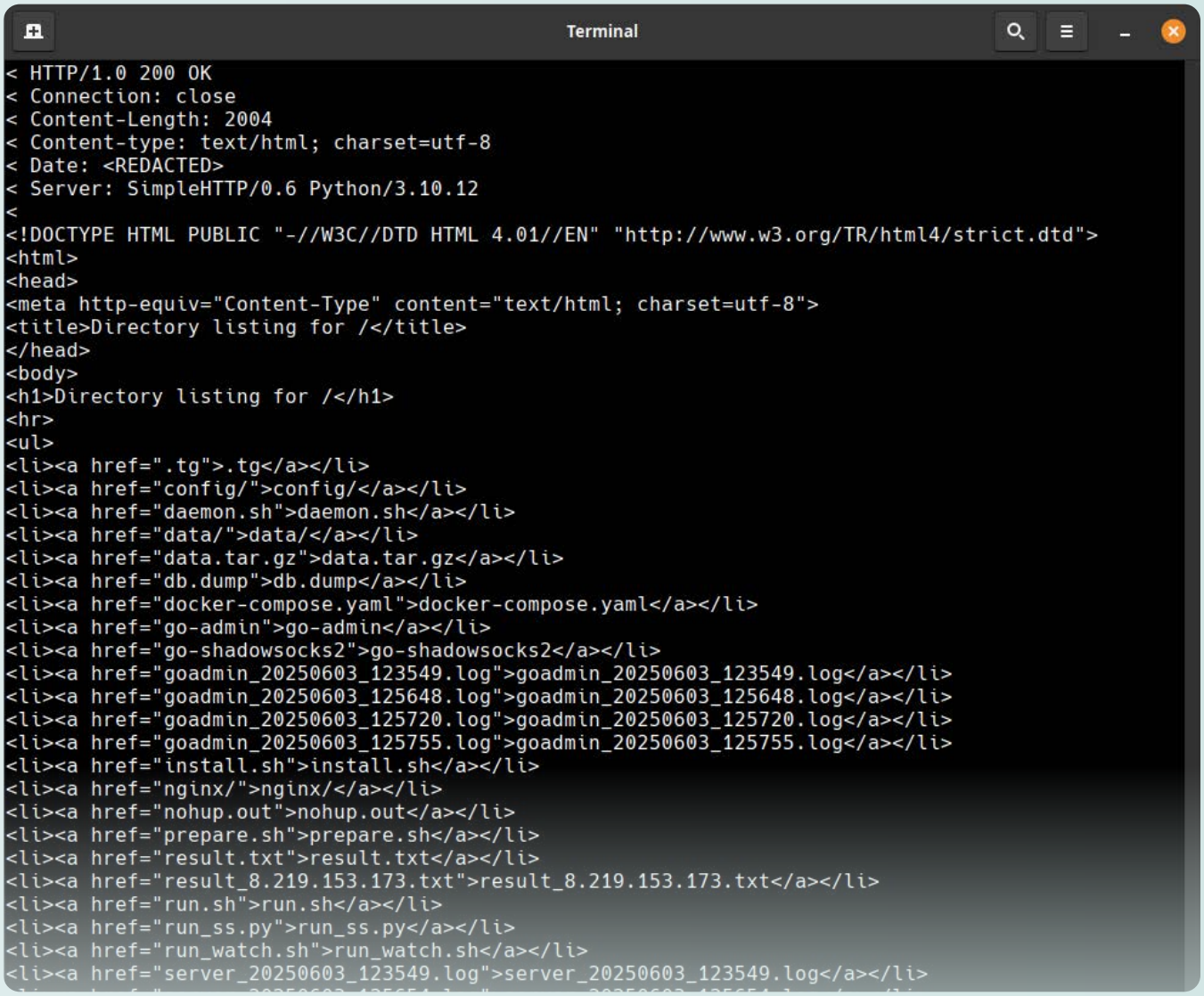


Figure 15. The chance discovery of an open directory provides a rare view into possible botnet operation tooling.

This open directory would prove to be a goldmine, bringing the broader picture into sharper focus. The contents included gigabytes of logs, numerous administrative scripts and configuration files, and a collection of binaries. From this open directory, we found two leads that set the rest of the investigation in motion.

The first was a configuration file, `config/clash.yaml`, belonging to the Clash Proxy[13] service, and buried inside was a single upstream SOCKS5 server pointing to another host, 159.138.83[.]57:55556. While that port was no longer active on that host at the time of writing, it exposed two very recognizable artifacts on other ports: the "PolarSSL" test certificates and the WebRTC certificate on port TCP/19999. That overlap was too strange to ignore.

The second, more surprising discovery was a lone x86-64 ELF binary named "server_multi" with no known ties to any public project (it hadn't even surfaced on VirusTotal[14]). Fortunately, it was compiled with debug symbols intact, making reverse engineering easier. It looked to be a potential **ORB (Operational Relay Box)** management system.

The RPX Server

The x86-64 ELF binary (SHA256 Hash: `827797a9bff728ae6f46abd505e67a15e40b0ba69a8dc92a36fd90d9974c9593`) appeared capable of coordinating (potentially compromised) nodes as proxy relays. The discovery of this component (dubbed "**RPX**" due to several debug statements referencing the source code path "`/rpx`") offered the first glimpse into a potentially dedicated backend tool for managing large-scale proxy infrastructure.

A deeper analysis revealed **that this system was** a reverse-connect proxy server capable of handling SOCKS5 and Trojan protocols, dynamically assigning proxy nodes, and relaying traffic with lightweight DES or XOR encryption.

One of the unusual Mbed TLS test certificates with the "PolarSSL" subject/issuer (`e234e102cd8de90e258906d253157aeb7699a3c6df0c4e79e05d01801999dcb5`) was found embedded in the RPX binary and used for TLS-encrypted SOCKS5 communication. This certificate can be found on thousands of other hosts[15], many of which are served on high ports.

Since we were also able to retrieve a number of log files from this specific open directory, we could see how many proxy nodes were connected to that specific server at any given time by grepping for the string “online nodes”. At its peak, in August of 2025, the system actively managed over 100 proxy nodes simultaneously, which is a clue as to the scale of the operation.

```
2025-06-20 20:54:38 /root/project/rpx/server.c:1890 online nodes: 101,heart beat 60
2025-06-20 20:54:43 /root/project/rpx/server.c:1890 online nodes: 101,heart beat 60
2025-06-20 20:54:48 /root/project/rpx/server.c:1890 online nodes: 101,heart beat 60
2025-06-20 20:54:58 /root/project/rpx/server.c:1890 online nodes: 101,heart beat 60
```

Looking for ORBs

This investigation shows how benign-looking artifacts—such as reused test certificates—can lead to broader insights into probable botnet infrastructure. While a direct link between the RPX system and PolarEdge remains unproven, the recurring overlap in certificates, services, and behavior is a phenomenon that’s likely more than a coincidence. The chance discovery of an open directory provided a rare view into possible proxy network management tooling, offering some perspective on how large-scale IoT botnets may operate. Whether directly tied to PolarEdge or serving as auxiliary infrastructure, these findings highlight the value of historical internet scan data to uncover hidden layers of malicious ecosystems.

Further Reading: the RPX Server

Full investigation details of the RPX proxy management binary, its function, purpose and the open directory that it was discovered on are available on the Censys blog.

Read the Blog

Chapter Six

Conclusions

This report examined adversary infrastructure from multiple angles: Internet-scale trends across malware families, geographies, and networks; the lifespans of C2 services measured both by network availability and content signals; the rise of perimeter-blurring infrastructure such as residential proxies and ORB-like botnets; and how these structural patterns play out in real incidents and disruption efforts. Across these lenses, a consistent lesson emerges: access to the most accurate, up-to-date data on Internet infrastructure is key to understanding and tracking threat actor operations and behavior. Censys helps security practitioners gain this visibility by maintaining the industry's most accurate, comprehensive, and real-time map of Internet infrastructure. Our best-in-class visibility empowers security teams to uncover risks, identify threats, and strengthen defenses.

Censys delivers real-time Internet intelligence and actionable threat insights to global governments, over 50% of the Fortune 500, and leading threat intelligence providers worldwide.

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VISIT
censys.com

CONTACT
hello@censys.com