DDoS protection

Using Netfilter/iptables

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Who am I

- Name: Jesper Dangaard Brouer
  - Linux Kernel Developer at Red Hat
  - Edu: Computer Science for Uni. Copenhagen
    - Focus on Network, Dist. sys and OS
  - Linux user since 1996, professional since 1998
    - Sysadm, Kernel Developer, Embedded
  - OpenSource projects, author of
      - ADSL-optimizer, CPAN IPTables::libiptc, IPTV-Analyzer
    - Patches accepted into
      - Linux kernel, iproute2, iptables, libpcap and Wireshark
  - Organizer of Netfilter Workshop 2013

What will you learn?

- Linux Kernel is vulnerable to simple SYN attacks
- End-host mitigation's already implemented in kernel
  - show it is not enough
- Kernel: serious "listen" socket scalability problem
  - solution is stalled ... how to work-around this
- Firewall-based solution: synproxy (iptables/netfilter)
- How fast is stateful firewalling
  - Where is our pain points
  - Learn Netfilter tricks: boost performance a factor 10

First: Basic NIC tuning 101

- All tests in presentation
- Basic tuning
  - First kill “irqbalance”
  - NIC hardware queue, are CPU aligned
  - Disable Ethernet flow-control
    - Intel ixgbe hw/driver issue
      - single blocked hw queue blocks others
      - Fix in kernel v3.5.0 commit 3ebe8fdeb0 (ixgbe: Set Drop_EN bit when multiple Rx queues are present w/o flow control)

Focus: Flooding DoS attack

- **D**enial **of S**ervice (DoS) attacks
- Focus: TCP flooding attacks
  - Attacking the 3-**W**ay **H**and**S**hake (3WHS)
  - End-host resource attack
    - SYN flood
    - SYN-ACK floods
    - ACK floods (3rd packet in 3WHS)
  - Attacker often spoofs src IP
- Described in RFC 4987:

  TCP SYN Flooding Attacks and Common Mitigations

Linux current end-host mitigations

- Jargon RFC 4987 (TCP SYN Flooding Attacks and Common Mitigations)

- Linux uses hybrid solution
  - SYN “cache”
    - Mini request socket
    - Minimize state, delay full state alloc
  - SYN “backlog” of outstanding request sockets
  - Above limit, use SYN “cookies”

Details: SYN "cache" savings

- Small initial TCB (Transmission Control Block)
- struct request_sock (size 56 bytes)
  - mini sock to represent a connection request
- But alloc size is 112 bytes
  - SLAB behind have sizeof(struct tcp_request_sock)
  - Structs embedded in each-other
    - 56 bytes == struct request_sock
    - 80 bytes == struct inet_request_sock
    - 112 bytes == struct tcp_request_sock
- Full TCB (struct inet_sock) is 832 bytes

(note, sizes will increase/change in more recent kernels)

Details: Increasing SYN backlog

- Not recommended to increase for DoS
  - Only increase, if legitimate traffic cause log:
    - “TCP: Possible SYN flooding ...”
- Increasing SYN backlog is not obvious
  - Adjust all these:
    - /proc/sys/net/ipv4/tcp_max_syn_backlog
    - /proc/sys/net/core/somaxconn
    - Syscall listen(int sockfd, int **backlog**);

SYN cookies

- Simplified description
  - SYN packet
    - don't create any local state
  - SYN-ACK packet
    - Encode state in SEQ# (and TCP options)
  - ACK packet
    - Contains SEQ#+1 (and TCP timestamp)
    - Recover state
  - SHA hash is computed with local secret
    - Validate (3WHS) ACK packet state

Details: SYN-cookies

- SYN cookies SHA calculation is expensive
- SNMP counters (Since kernel v3.1)
  - **TCPReqQFullDoCookies** : number of times a SYNCOOKIE was replied to client
  - **TCPReqQFullDrop** : number of times a SYN request was dropped because syncookies were not enabled.
- Always on option
  - /proc/sys/net/ipv4/tcp_syncookies = 2

So, what is the problem?

- Good End-Host counter-measurements
- Problem: LISTEN state scalability problem
  - Vulnerable for all floods
    - SYN, SYN-ACK and ACK floods
- Numbers: Xeon CPU X5550 10G ixgbe
  - NO LISTEN socket:
    - 2.904.128 pkts/sec -- SYN attack
  - LISTEN socket:
    - 252.032 pkts/sec -- SYN attack
    - 336.576 pkts/sec -- SYN+ACK attack
    - 331.072 pkts/sec -- ACK attack

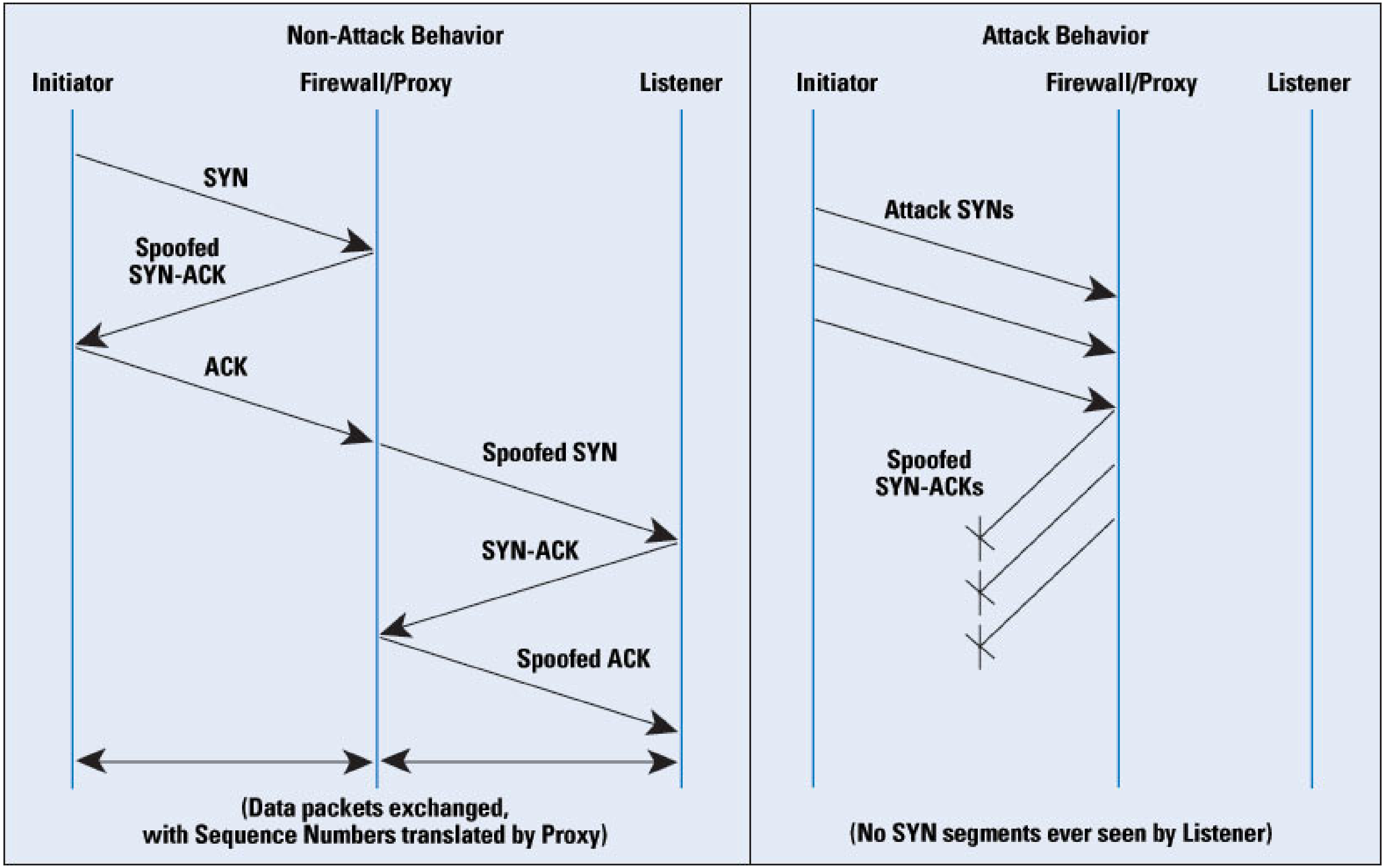
Problem: SYN-cookie vs LISTEN lock

- Main problem:
  - SYN cookies live under LISTEN lock
- I proposed SYN brownies fix (May 2012)
  - http://thread.gmane.org/gmane.linux.network/232238
  - Got rejected, because not general solution
    - e.g. don't handle SYN-ACK and 3WHS
  - NFWS2013 got clearance as a first step solution
    - Need to “forward-port” patches
    - (Bug 1057364 - RFE: Parallel SYN cookies handling)

Firewall and Proxy solutions

- **Network-Based** Countermeasures
  - Wesley M. Eddy, describes SYN-proxy
    - In Cisco: The Internet Protocol Journal - Volume 9, Number 4, 2006, link: http://goo.gl/AC1AAZ
  - Netfilter: iptables target **SYNPROXY**
    - Avail in kernel 3.13 and RHEL7
      - By Patrick McHardy, Martin Topholm and Me
    - Also works on localhost
    - General solution
      - Solves SYN and ACK floods
    - Indirect trick also solves SYN+ACK

SYN proxy concept



Conntrack performance(1)

- SYNPROXY needs conntrack
  - Will that be a performance issue?
- Base performance:
  - 2.964.091 pkts/sec -- NO LISTEN sock + no iptables rules
  - 244.129 pkts/sec -- LISTEN sock + no iptables rules
- Loading conntrack: (SYN flood, causing new conntrack)
  - 435.520 pkts/sec -- NO LISTEN sock **+ conntrack**
  - 172.992 pkts/sec -- LISTEN sock **+ conntrack**
- Looks bad...
  - but I have some tricks for you ;-)

Conntrack performance(2)

- Conntrack (lock-less) **lookups are *really* fast**
  - Problem is insert and delete conntracks
  - Use to protect against SYN+ACK and ACK attacks
- Default netfilter is in TCP “loose” mode
  - Allow ACK pkts to create new connection
  - Disable via cmd:

    ```
    sysctl -w net/netfilter/nf_conntrack_tcp_loose=0
    ```
- Take advantage of state “INVALID”
  - Drop invalid pkts *before* reaching LISTEN socket

  -
    ```
    iptables -m state --state INVALID -j DROP
    ```

Conntrack perf(3) ACK-attacks

- **ACK attacks**, conntrack performance
- Default “loose=1” and pass INVALID pkts
  - 179.027 pkts/sec
- Loose=0 and and pass INVALID pkts
  - 235.904 pkts/sec (listen lock scaling)
- Loose=0 and and DROP INVALID pkts
  - 5.533.056 pkts/sec

Conntrack perf(4) SYN-ACK attack

- **SYN-ACK attacks**, conntrack performance
  - SYN-ACKs don't auto create connections
  - Thus, changing “loose” setting is not important
- Default pass INVALID pkts (and “loose=1”)
  - 230.348 pkts/sec
- Default DROP INVALID pkts (and “loose=1”)
  - 5.382.265 pkts/sec
- Default DROP INVALID pkts (and “loose=0”)
  - 5.408.307 pkts/sec

Synproxy performance

- **Only conntrack SYN attack problem left**
  - Due to conntrack insert lock scaling
- Base performance:
  - 244.129 pkts/sec -- LISTEN sock + no iptables rules
- Loading conntrack: (SYN flood, causing new conntrack)
  - 172.992 pkts/sec -- LISTEN sock **+ conntrack**
- **Using SYNPROXY**
  - **2.869.824** pkts/sec -- LISTEN sock + **synproxy** + conntrack

iptables: synproxy setup(1)

Using SYNPROXY target is complicated

- SYNPROXY works on untracked conntracks

In “raw” table, “notrack” SYN packets:

```
iptables -t raw -I PREROUTING -i $DEV -p tcp -m tcp --syn \
 --dport $PORT -j CT --notrack
```

iptables: synproxy setup(2)

- More strict conntrack handling
  - Need to get unknown ACKs (from 3WHS) to be marked as INVALID state
    - (else a conntrack is just created)

Done by sysctl setting:

```
/sbin/sysctl -w net/netfilter/nf_conntrack_tcp_loose=0
```

iptables: synproxy setup(3)

- Catching state:
  - UNTRACKED == SYN packets
  - INVALID == ACK from 3WHS

Using SYNPROXY target:

```
iptables -A INPUT -i $DEV -p tcp -m tcp --dport $PORT \
    -m state --state INVALID,UNTRACKED \
    -j SYNPROXY --sack-perm --timestamp --wscale 7 --mss 1460
```

iptables: synproxy setup(4)

- Trick to catch SYN-ACK floods
  - Drop rest of state INVALID, contains SYN-ACK

```
iptables -A INPUT -i $DEV -p tcp -m tcp --dport $PORT \
    -m state --state INVALID -j DROP
```

- Enable TCP timestamping
  - Because SYN cookies uses TCP options field

```
/sbin/sysctl -w net/ipv4/tcp_timestamps=1
```

iptables: synproxy setup(5)

- Conntrack entries tuning
  - Max possible entries 2 Mill
    - 288 bytes * 2 Mill = 576.0 MB

```
net/netfilter/nf_conntrack_max=2000000
```

  - IMPORTANT: Also adjust hash bucket size
    - /proc/sys/net/netfilter/nf_conntrack_buckets writeable
    - via /sys/module/nf_conntrack/parameters/hashsize
    - Hash 8 bytes * 2Mill = 16 MB

```
echo 2000000 > /sys/module/nf_conntrack/parameters/hashsize
```

Performance SYNPROXY

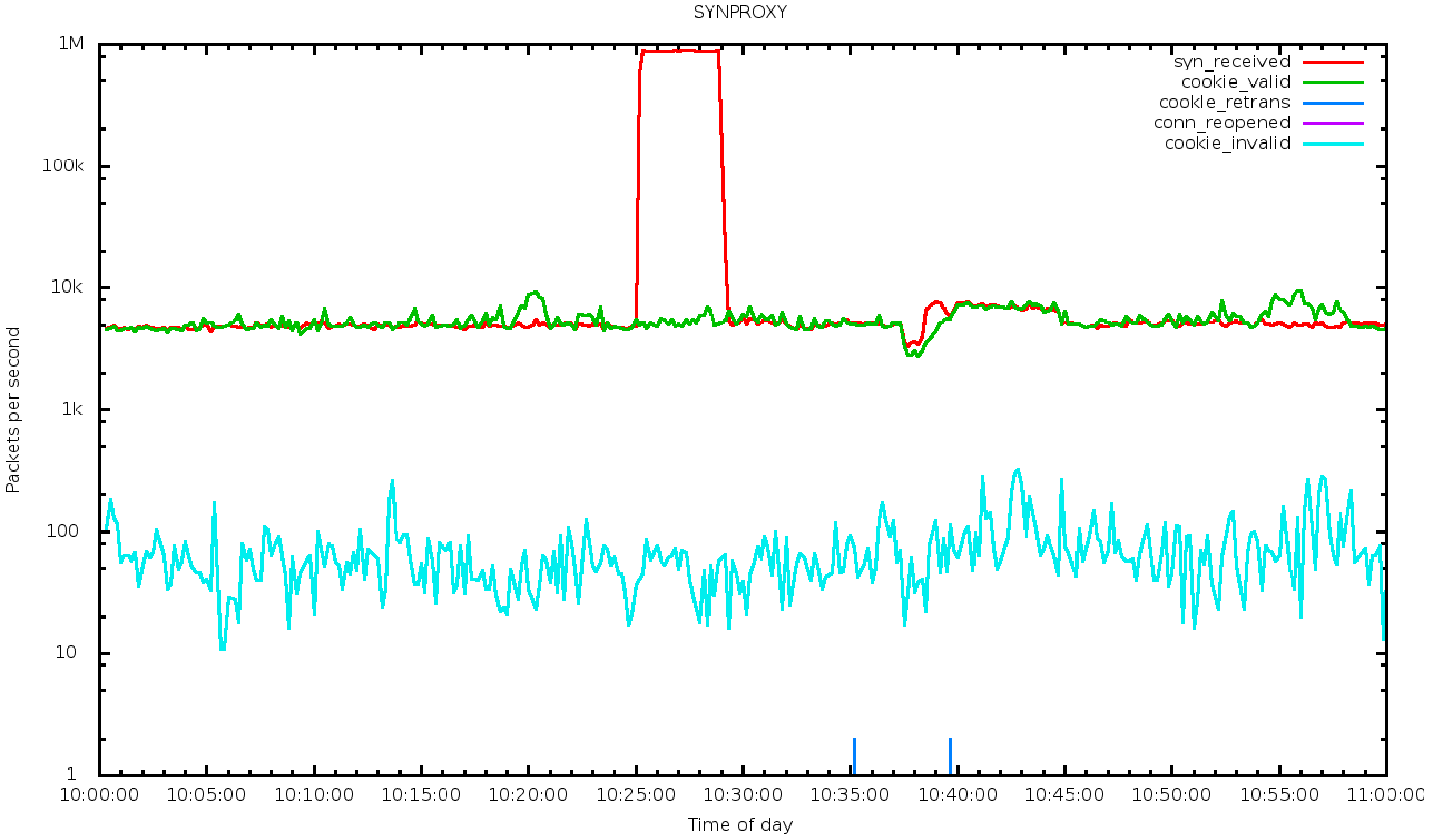
- Script iptables_synproxy.sh avail here:
  - https://github.com/netoptimizer/network-testing/blob/master/iptables/iptables_synproxy.sh

- Using SYNPROXY under attack types:
  - 2.869.824 pkts/sec – SYN-flood
  - 4.948.480 pkts/sec – ACK-flood
  - 5.653.120 pkts/sec – SYN+ACK-flood

SYNPROXY parameters

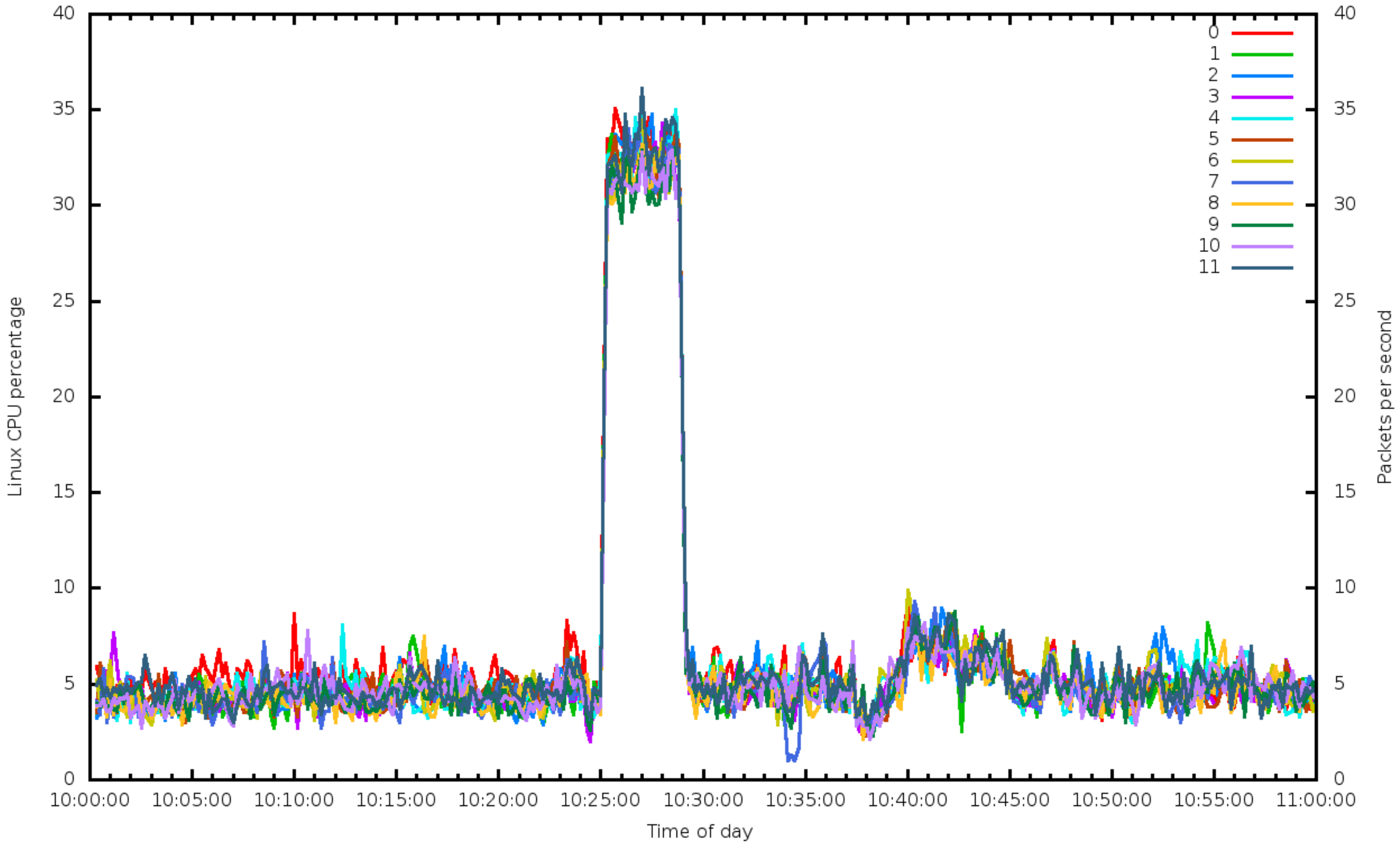
- The parameters given to SYNPROXY target
  - Must match the backend-server TCP options
  - Manual setup (helper tool nfsynproxy)
  - Only one setting per rule
  - Not useful for DHCP based network
- *Future plan*
  - Auto detect server TCP options
  - Simply allow first SYN through
    - Catch SYN-ACK and decode options
    - (RHBZ 1059679 - RFE: Synproxy: auto detect TCP options)

Real-life(1): Handle 900 Kpps



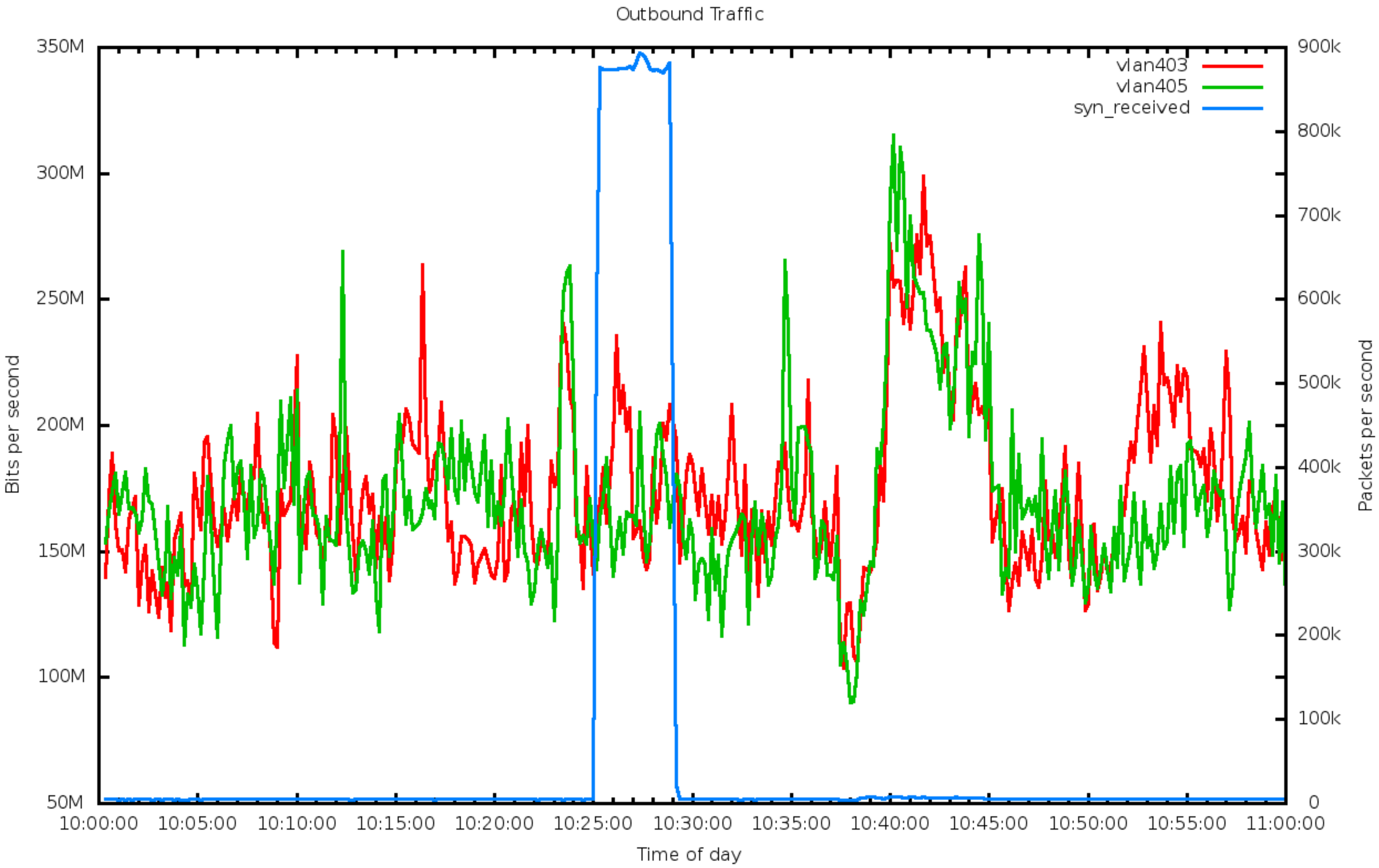
Real-life(2): SHA sum expensive

- SYN cookie SHA sum is expensive
  - Bug 1057352 - RFE: Improve SYN cookies calculations



SoftIRQ

Real-life(3): Out traffic normal



Issue: Full connection scalability

- Still exists: Scalability issue with full conn
  - Made it significantly more expensive for attackers
    - (they need real hosts)
- Future work: fix scalability for
  - Central lock: LISTEN socket lock
  - Central lock: Netfilter new conntracks (Work-in-progress)

Fixing central conntrack lock

- Conntrack issue
  - Insert / delete conntracks takes central lock
  - Working on removing this central lock
    - (Based on patch from Eric Dumazet)
    - (RHBZ 1043012 - "netfilter: conntrack: remove the central spinlock")
- Preliminary results, SYN-flood
- No LISTEN socket to leave out that issue
  - 435.520 pkts/sec – conntrack with central lock
  - 1.626.786 pkts/sec – conntrack with parallel lock

Hack: Multi listen sockets

- Hack to work-around LISTEN socket lock
  - Simply LISTEN on several ports
  - Use iptables to rewrite/DNAT to these ports

Hack: Full conn hashlimit trick(1)

- Problem: Full connections still have scalability
- Partition Internet in /24 subnets
  - (128*256*256 / 2097152 = 4 max hash list)
- Limit SYN packets e.g. 200 SYN pps per src subnet
- Mem usage: fairly high
  - Fixed: htable-size 2097152 * 8 bytes = 16.7 MB
  - Variable: entry size 104 bytes * 500000 = 52 MB

Hack: Full conn hashlimit trick(2)

- Using hashlimit as work-around
  - Attacker needs many real hosts, to reach full conn scalability limit

```
iptables -t raw -A PREROUTING -i $DEV \
  -p tcp -m tcp --dport 80 --syn \
  -m hashlimit \
   --hashlimit-above 200/sec --hashlimit-burst 1000 \
   --hashlimit-mode srcip    --hashlimit-name syn \
   --hashlimit-htable-size 2097152 \
   --hashlimit-srcmask 24 -j DROP
```

Alternative usage of "socket" module

- Avoid using conntrack
  - Use xt_socket module
    - For local socket matching
    - Can filter out 3WHS-ACKs (and other combos)
      - Parameter --nowildcard
      - Problem can still be invalid/flood ACKs
      - Mitigate by limiting e.g.hashlimit
  - Didn't scale as well as expected
- https://github.com/netoptimizer/network-testing/blob/master/iptables/iptables_local_socket_hack.sh

The End

- Thanks to Martin Topholm and One.com
  - For providing real-life attack data
- Download slides here:
  - http://people.netfilter.org/hawk/presentations/devconf2014/
- Feedback/rating of talk on:
  - http://devconf.cz/f/37
- If unlikely(time for questions)
  - Questions?

Extra Slides

Disable helper auto loading

- Default is to auto load conntrack helpers
  - It is a security risk!
    - Poking holes in your firewall!
  - Disable via cmd:

```
echo 0 > /proc/sys/net/netfilter/nf_conntrack_helper
```

- Controlled config example:

```
iptables -t raw -p tcp -p 2121 -j CT --helper ftp
```

- Read guide here:

  https://home.regit.org/netfilter-en/secure-use-of-helpers/