Advanced Linux Firewalls

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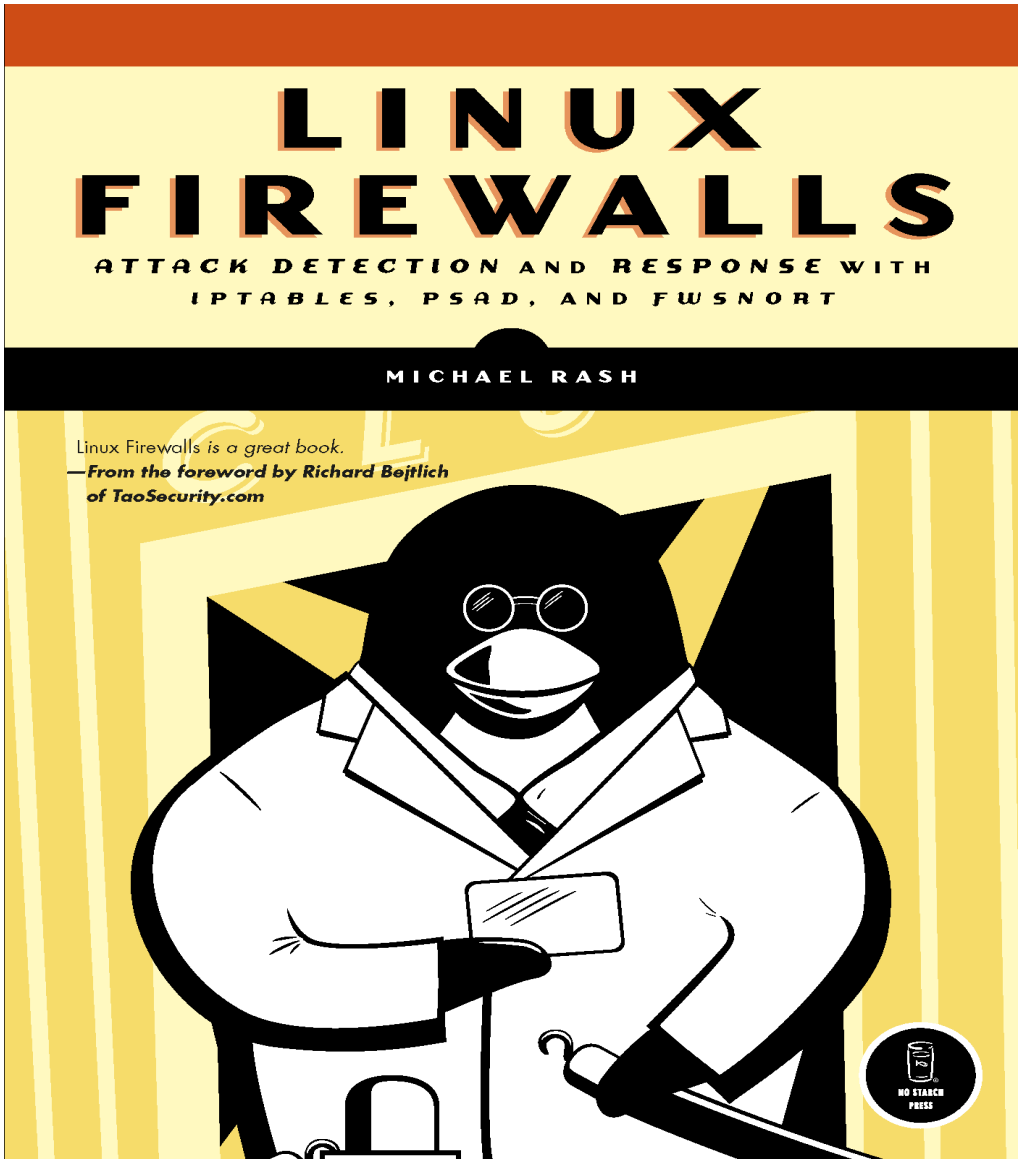
03/12/2008
SOURCE Boston, 2008

Agenda

- Intrusion Detection and Prevention via iptables
  - Snort rule emulation via iptables extensions (fwsnort)
  - iptables log analysis (psad)
- iptables log data visualizations
  - psad + AfterGlow + Gnuplot
- Single Packet Authorization + fwknop-1.9.2 release
- Live Demo

No Starch Press, Oct 2007



Why Talk about iptables in the Context of Intrusion Detection?

- Snort and commercial IDS infrastructure is mature (subject to usual concerns around false positives), but why stop there?
- IDS's can themselves be targeted, both from the detection and code execution standpoints
  - Modified Stick/Snot to send faked attacks over Tor
  - Snort DCE/RPC Preprocessor vulnerability
- Defense-in-depth is important
- Host fragment reassembly issues less of a concern for iptables string matching (more on this later)

IDS and iptables

- Can specify granular packet header tests, and logging format contains nearly all interesting packet header fields
- Can match against connection states
  - Useful for mitigating Stick/Snot style attacks
- String matching in the kernel started in the 2.4 days (patch applied via Netfilter patch-o-matic); made available again in 2.6.14

IDS and iptables (cont'd)

- Kernel textsearch (linux/lib/ts_*) infrastructure
  - Boyer-Moore and Knuth-Morris-Pratt algorithms
- String matching enabled by default in recent Linux kernels
- You get network layer defragmentation for free when connection tracking is used – you don't have to rely on proper configuration of frag3; it ***is*** the defragmentation algorithm of the host
- String matching within the *filter* table happens after network defrag

How About Intrusion Prevention?

- Plenty of reasons *NOT* to respond (false positives, possibility of attacker abuse, possibility of fingerprinting the response mechanism)
- However:
  - Can envision scenarios where controlling the shape of application layer data that can talk to local sockets is a good thing – iptables can enforce the DROP target (this is ***prevention*** instead of just some weak ***response*** mechanism)
  - Some automated attacks do not bother with obfuscation/encryption – target rich environment
  - Sometimes it is not easy to patch a production server whose uptime must remain high (assuming a patch even exists)

fwsnort

- Translates Snort signatures into “equivalent” iptables rules using string match extension and Netfilter connection tracking subsystem
- All translated Snort signatures are placed within user-defined chains, to which packets are jumped from built-in chains (INPUT, OUTPUT, and FORWARD)
- Maintains strict separation from existing iptables policy
- Approximately 60% of all Snort-2.3.3 rules (remember this is an IDS supplement) can be translated

fwsnort (cont'd)

- Emulation of Snort config variables such as $HOME_NET and $EXTERNAL_NET
- Reporting via LOG target (integrates with psad)
- Whitelists via the RETURN target
- Blacklists via the DROP or REJECT targets
- Snort signature info stored with the iptables comment match in kernel-space
- iptables is inline by definition; easy to configure fwsnort to use the DROP or REJECT targets

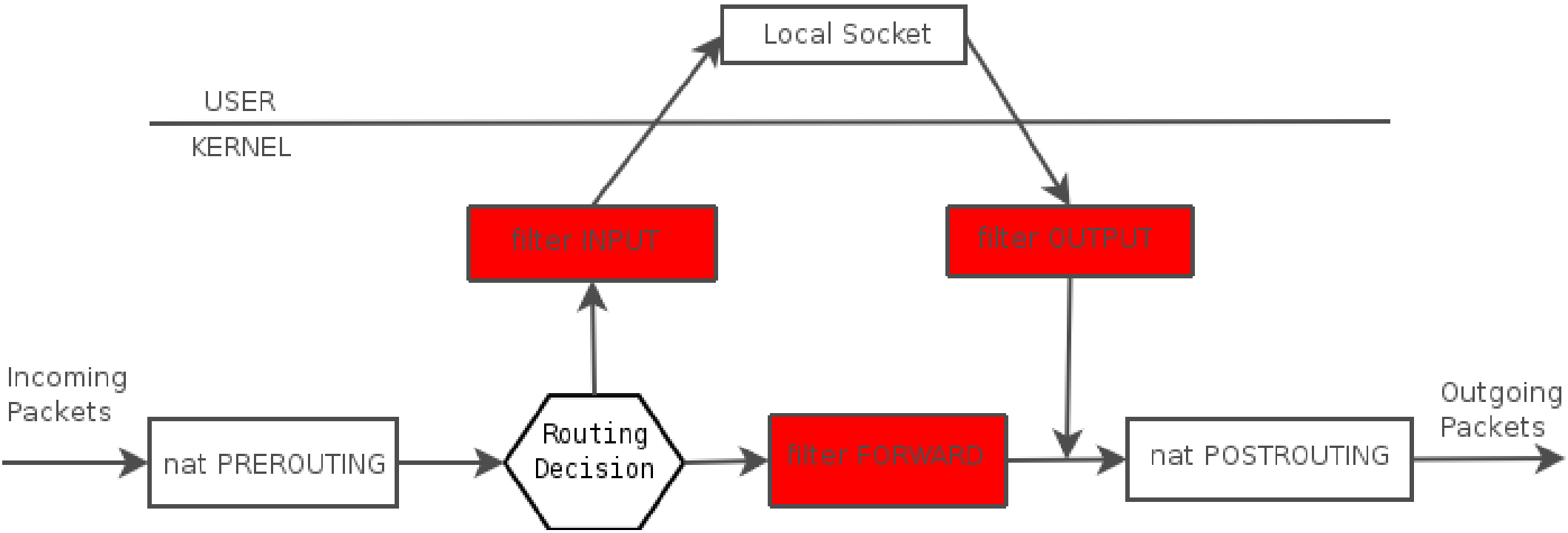
psad

- iptables log analyzer
- Email and syslog reporting
- Fwsnort integration
- DShield integration
- iptables LOG visualization with AfterGlow and Gnuplot
- Built-in passive OS fingerprinting derived from p0f (requires --log-tcp-options)
- IP options decoding (requires --log-ip-options)

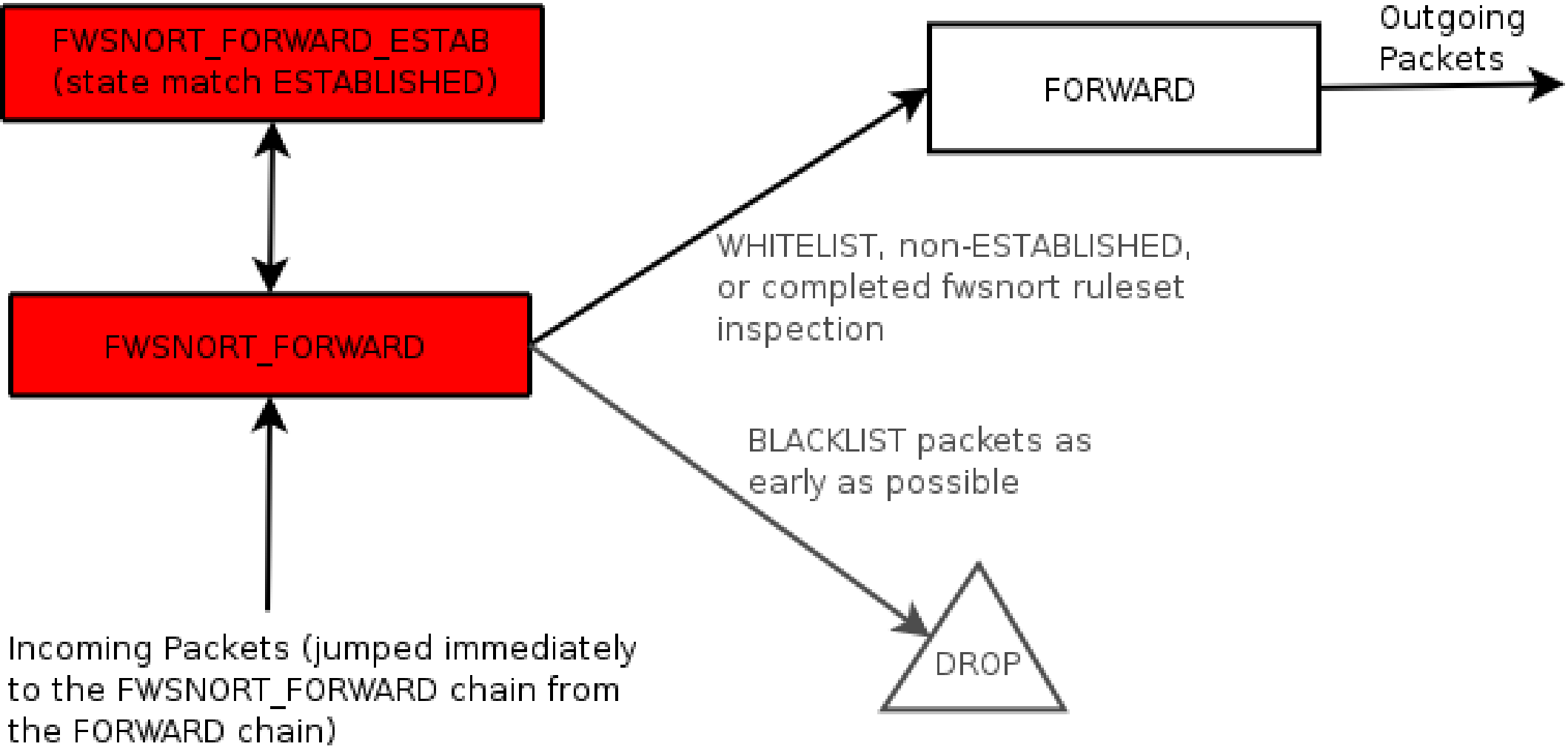
psad (cont'd)

- Can detect Snort signatures that do not require application layer tests (source routing attempts, low ttl values, ICMP source quench, Nachi worm, etc.). This is all possible by virtue of iptables LOG format completeness.
- Detection of many port scan types generated by Nmap
- Timeout-based auto-blocking (optional, and can be restricted to application layer matches with fwsnort)
- Whitelists/Blacklists

iptables Packet Flow



fwsnort Packet Flow



Example Snort Rule: nmap Execution via Web Server

alert tcp $EXTERNAL_NET any -> $HTTP_SERVERS $HTTP_PORTS

(msg:"WEB-ATTACKS nmap command attempt"; **flow**:to_server,established; **content**:"nmap%20"; nocase; classtype:web-application-attack; sid:1361; rev:5;)

fwsnort Translation

```
$IPTABLES -A FWSNORT_FORWARD_ESTAB -d
192.168.10.0/24 -p tcp --dport 80 -m string
--string "nmap%20" --algo bm -m comment --
comment "msg: WEB-ATTACKS nmap command
attempt; classtype: web-application-attack;
rev: 5; FWS:0.9.0;" -j LOG --log-tcp-
options --log-prefix "[1] SID1361 ESTAB "
```

“BLEEDING-EDGE VIRUS” Signature (Multiple Content Fields)

alert tcp $EXTERNAL_NET $HTTP_PORTS -> $HOME_NET any (msg: "BLEEDING-EDGE VIRUS Trojan-Spy.Win32.Bancos Download"; flow: established,from_server; **content**:"[AspackDie!]"; **content**:"|0f 6d 07 9e 6c 62 6c 68 00 d2 2f 63 6d 64 9d 11 af af 45 c7 72 ac 5f 3138 d0|"; classtype: trojan-activity; reference:url,securityresponse.symantec.com/avcenter/venc/data/pwsteal.bancos.b.html; sid: 2001726; rev:6;)

(translated)

$IPTABLES -A FWSNORT_FORWARD_ESTAB -d 192.168.10.0/24 -p tcp --sport 80 **-m string --string "[AspackDie!]"** --algo bm **-m string --hex-string "|0f 6d 07 9e 6c 62 6c 68 00 d2 2f 63 6d 64 9d 11 af af 45 c7 72 ac 5f 3138 d0|"** --algo bm -m comment --comment "msg: BLEEDING-EDGE VIRUS Trojan-Spy.Win32.Bancos Download; classtype: trojan-activity; reference: url,securityresponse.symantec.com/avcenter/venc/data/pwsteal.bancos.b.html; rev: 6; FWS:0.9.0;" -j LOG --log-ip-options --log-tcp-options --log-prefix "[640] SID2001726 ESTAB "

Supported Snort Rule Options

- All Snort rule header options
- content
- flow (conntrack)
- flags
- offset
- depth
- dsize (length match)
- itype
- icode
- ttl (ttl match)
- tos (tos match)
- ipopts
- ip_proto
- resp

Unsupported Snort Rule Options: Lost in Translation

- pcre
- flowbits
- byte_test <-- u32 module (coming soon – 2.6 support added)
- byte_jump <-- u32 module (coming soon – 2.6 support added)
- asn1
- window <-- included in iptables logs
- isdataat
- id <-- included in iptables logs

Unsupported Snort Rule Options (cont'd)

- icmp_id <-- included in iptables logs
- icmp_seq <-- included in iptables logs
- seq <-- included with --log-tcp-sequence
- ack <-- included with --log-tcp-sequence
- sameip <-- included in iptables logs
- There are a few others - those that are logged can be analyzed by psad

Introducing iptables Logs

TCP

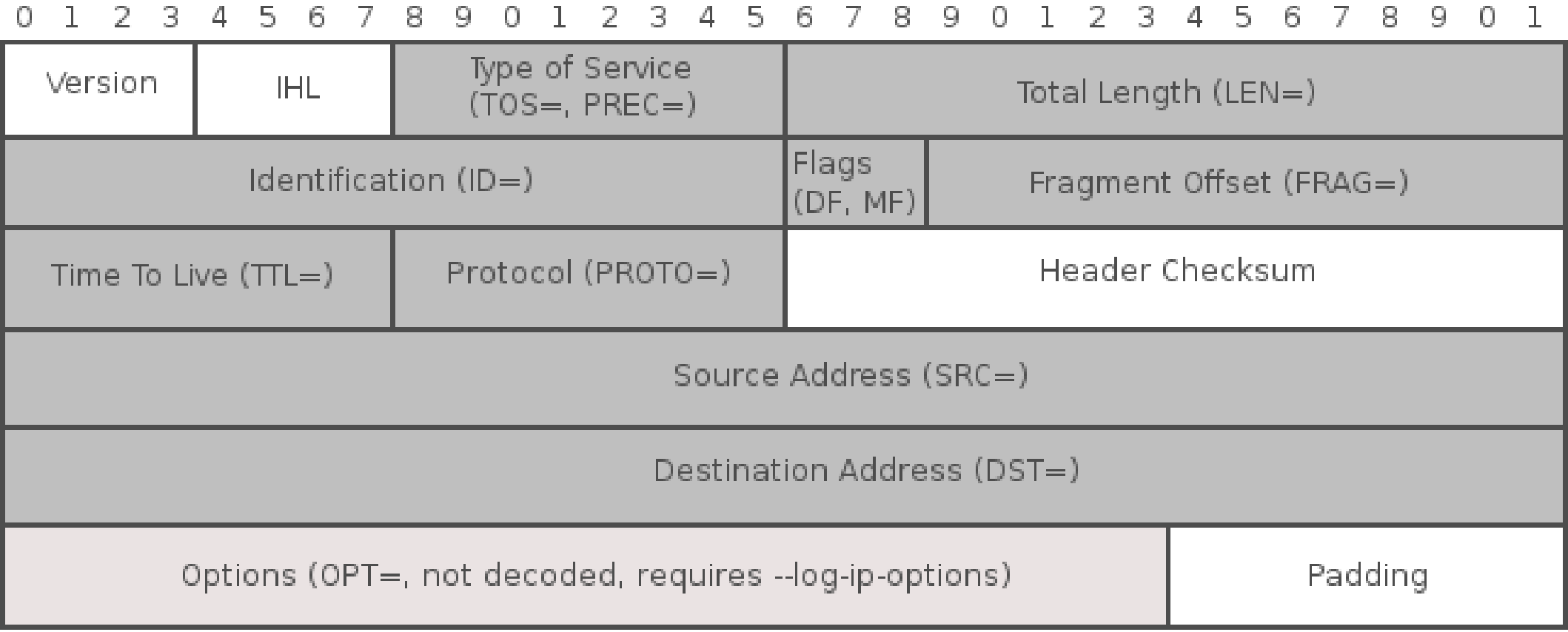
UDP

ICMP

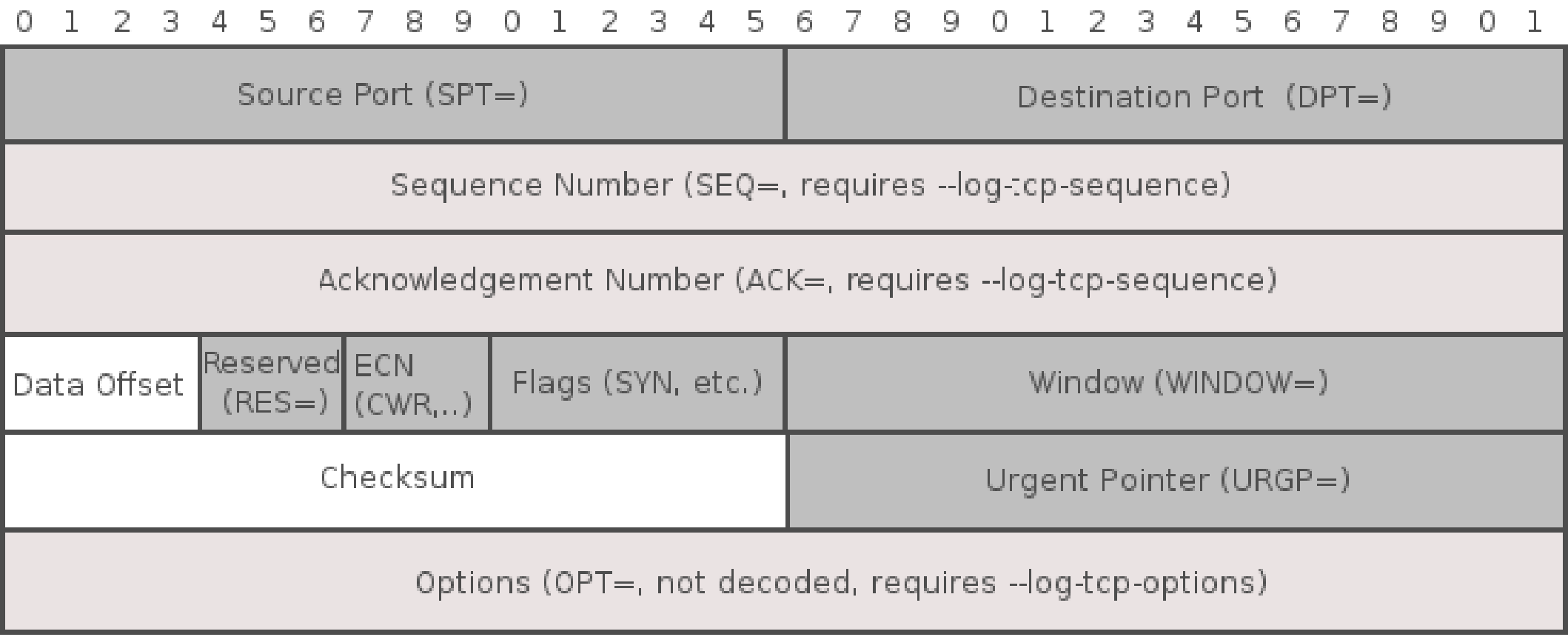
iptables TCP Log Message

```
Mar 11 20:21:22 minastirith kernel: [199]
SID1361 ESTAB IN=eth1 OUT=
MAC=00:13:d3:38:b6:e4:00:13:46:c2:60:44:08:
00 SRC=192.168.10.3 DST=192.168.10.1 LEN=60
TOS=0x00 PREC=0x00 TTL=63 ID=11112 DF
PROTO=TCP SPT=28778 DPT=80 WINDOW=5840
RES=0x00 ACK PSH URGP=0 OPT
(0101080A02A041D20CC386B1)
```

iptables IP Header Coverage



iptables TCP Header Coverage



Passive OS Fingerprinting

- Required IP/TCP header fields for p0f:
  - Initial TTL
  - TCP window size
  - DF bit
  - SYN packet size
  - TCP options and order specification

p0f Signature Match with psad

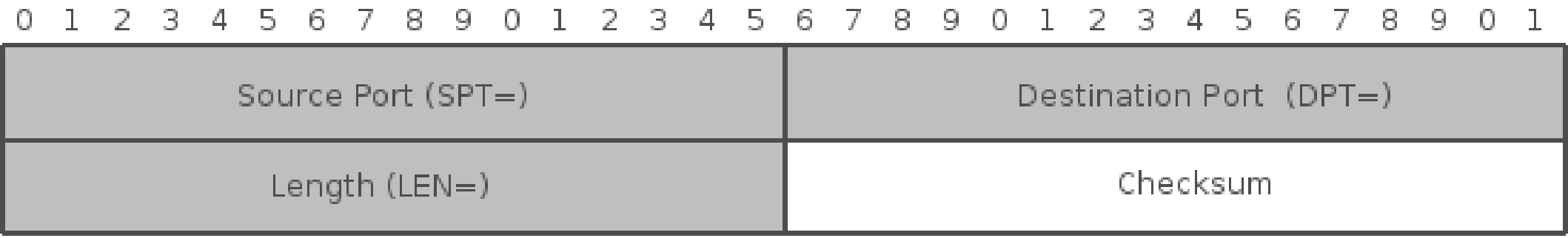
```
Mar  8 23:23:48 minastirith kernel: DROP
IN=eth0 OUT= MAC=00:13:46:3a:41:4b:
00:90:1a:a0:1c:ec:08:00 SRC=208.53.138.16
DST=71.N.N.N LEN=60 TOS=0x00 PREC=0x00 TTL=55
ID=23249 DF PROTO=TCP SPT=54155 DPT=3128
WINDOW=5840 RES=0x00 SYN URGP=0 OPT
(020405B40402080A04C4FF5B00000000001030307)
```

S4:64:1:60:M*,S,T,N,W7: Linux:2.6:8:Linux 2.6.8 and newer

iptables UDP Log Message

```
Mar 11 20:50:54 minastirith kernel: [153]
SID2001597 IN=eth0 OUT=
MAC=00:13:d3:38:b6:e4:00:13:46:c2:60:44:08:
00 SRC=192.168.10.3 DST=192.168.10.1 LEN=40
TOS=0x00 PREC=0x00 TTL=63 ID=29758 DF
PROTO=UDP SPT=32046 DPT=61 LEN=20
```

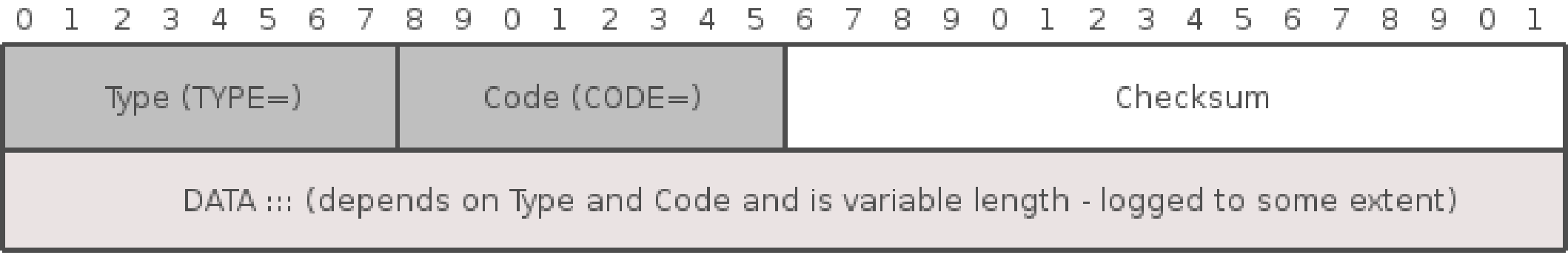
iptables UDP Header Coverage



iptables ICMP Log Message

```
Mar 11 20:57:18 minastirith kernel: [98]
SID2003294 IN=eth0 OUT=
MAC=00:13:d3:38:b6:e4:00:13:46:c2:60:44:08:
00 SRC=192.168.10.3 DST=192.168.10.1
LEN=128 TOS=0x00 PREC=0x00 TTL=63 ID=53466
PROTO=ICMP TYPE=8 CODE=0 ID=27459 SEQ=0
```

iptables ICMP Header Coverage



How About an iptables Log Data Source?

Honeynet Project Scan Challenges

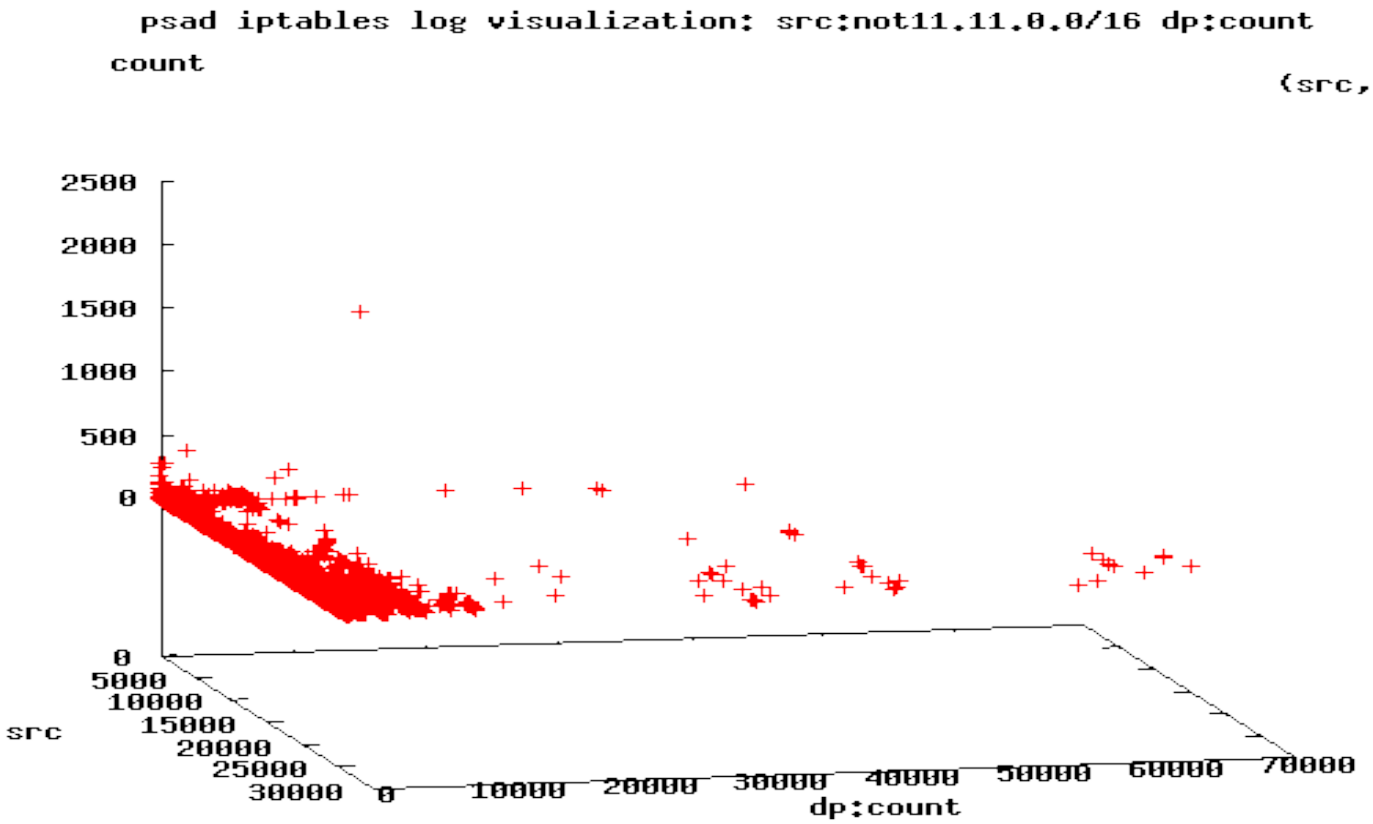
Honeynet Scan Challenge #34

- Challenge summary:
  - Challenge information and analysis can be found here: http://www.honeynet.org/scans/scan34/
  - Both Snort and iptables log data made available to the community (39MB of iptables data)
  - Contains port scans, port sweeps, traffic from worms, and outright compromises of Honeynet systems

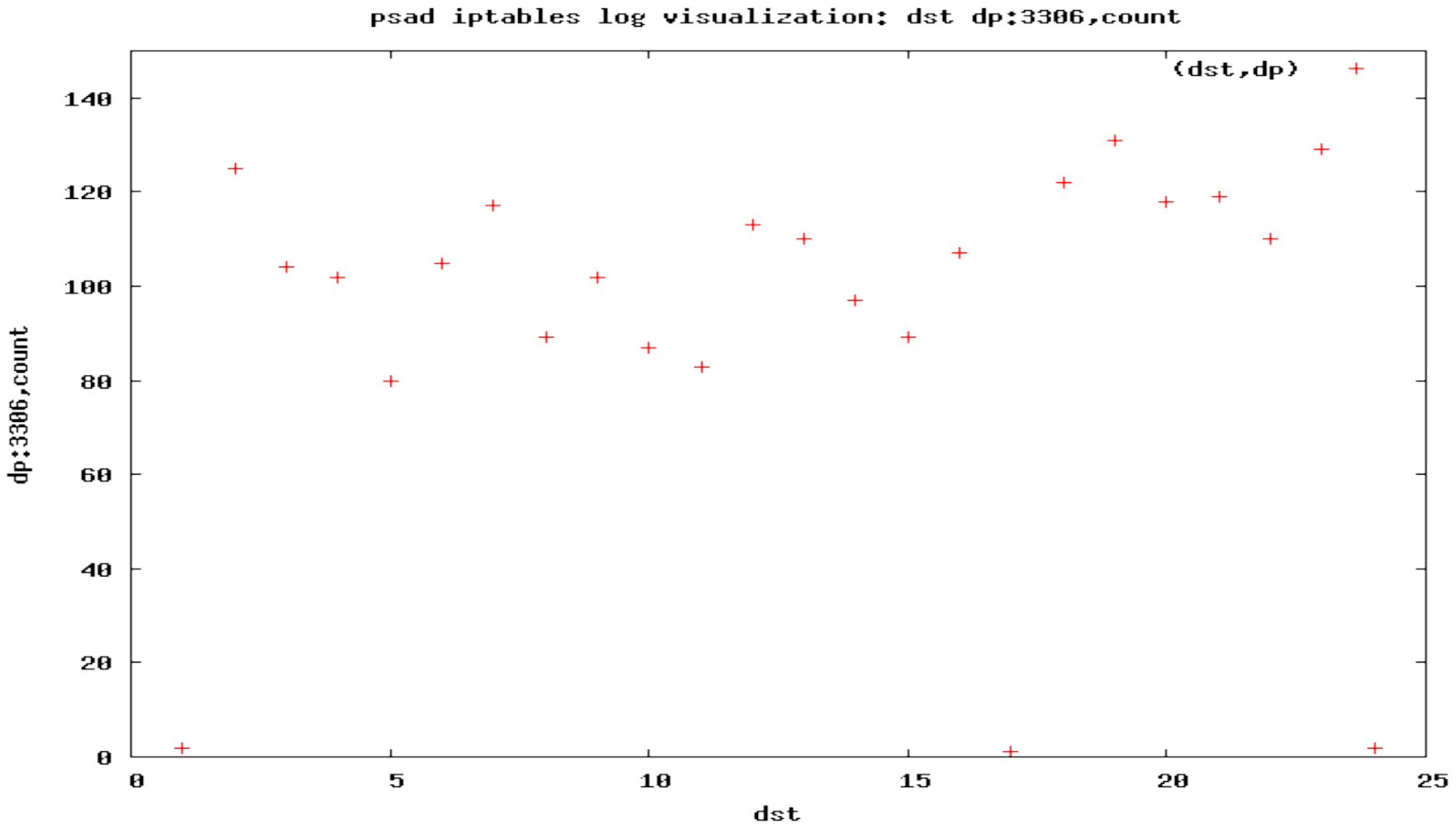
Port Sweep Visualization

```
psad -m iptables.data --gnuplot --
CSV-fields  src:not11.11.0.0/16
dp:count   --gnuplot-graph points--
gnuplot-3d --gnuplot-view 74,77 --
gnuplot-file-prefix portsweep
```

Visualizing Port Sweeps (IP vs. Destination Port vs. Packet Count)



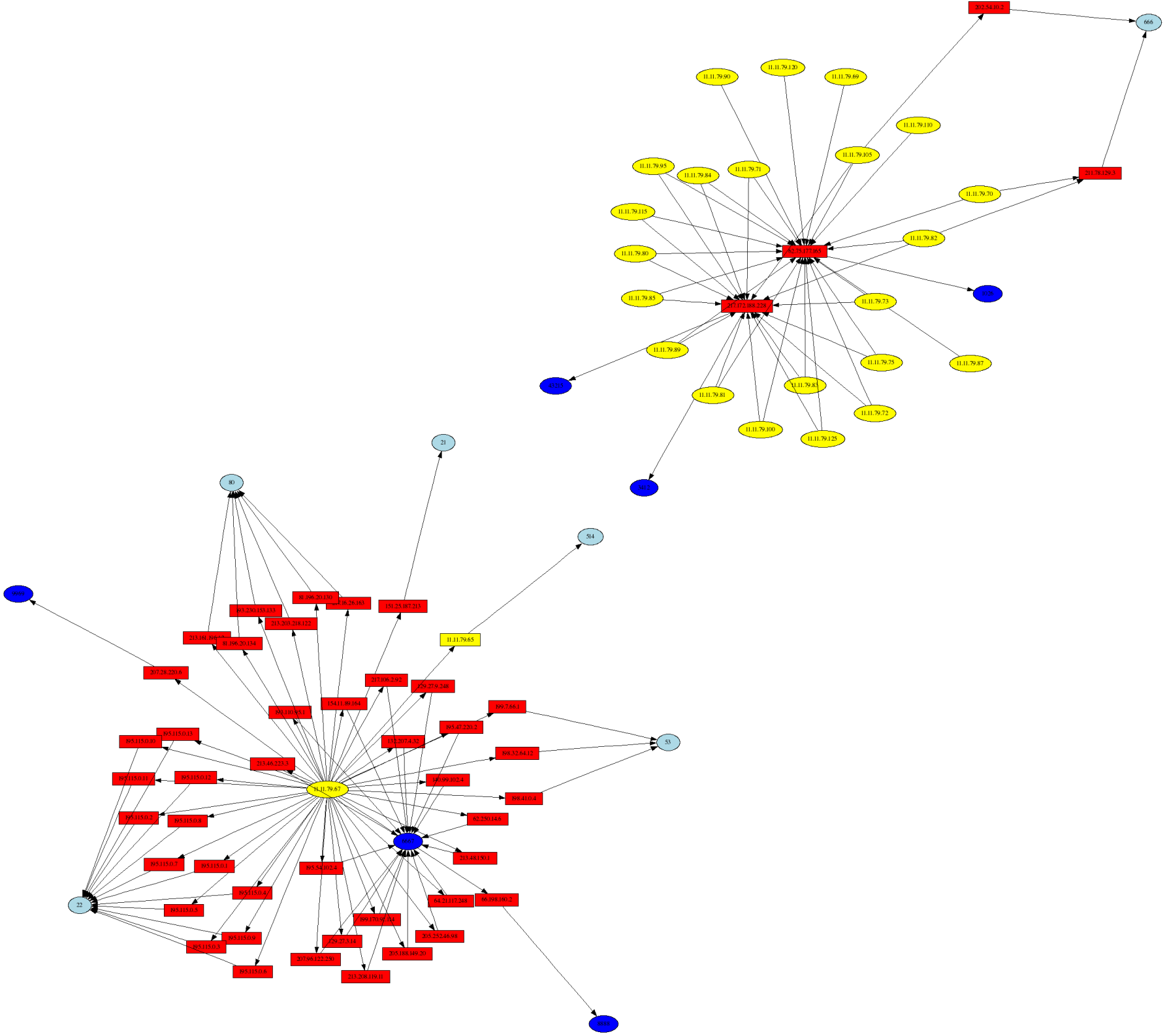
The Top Port Sweeper: 200.216.205.189 vs. TCP/3306



Honeynet Visualizations: Compromised Hosts

- Look for outbound connections from honeynet hosts with AfterGlow (see http://www.secviz.org)

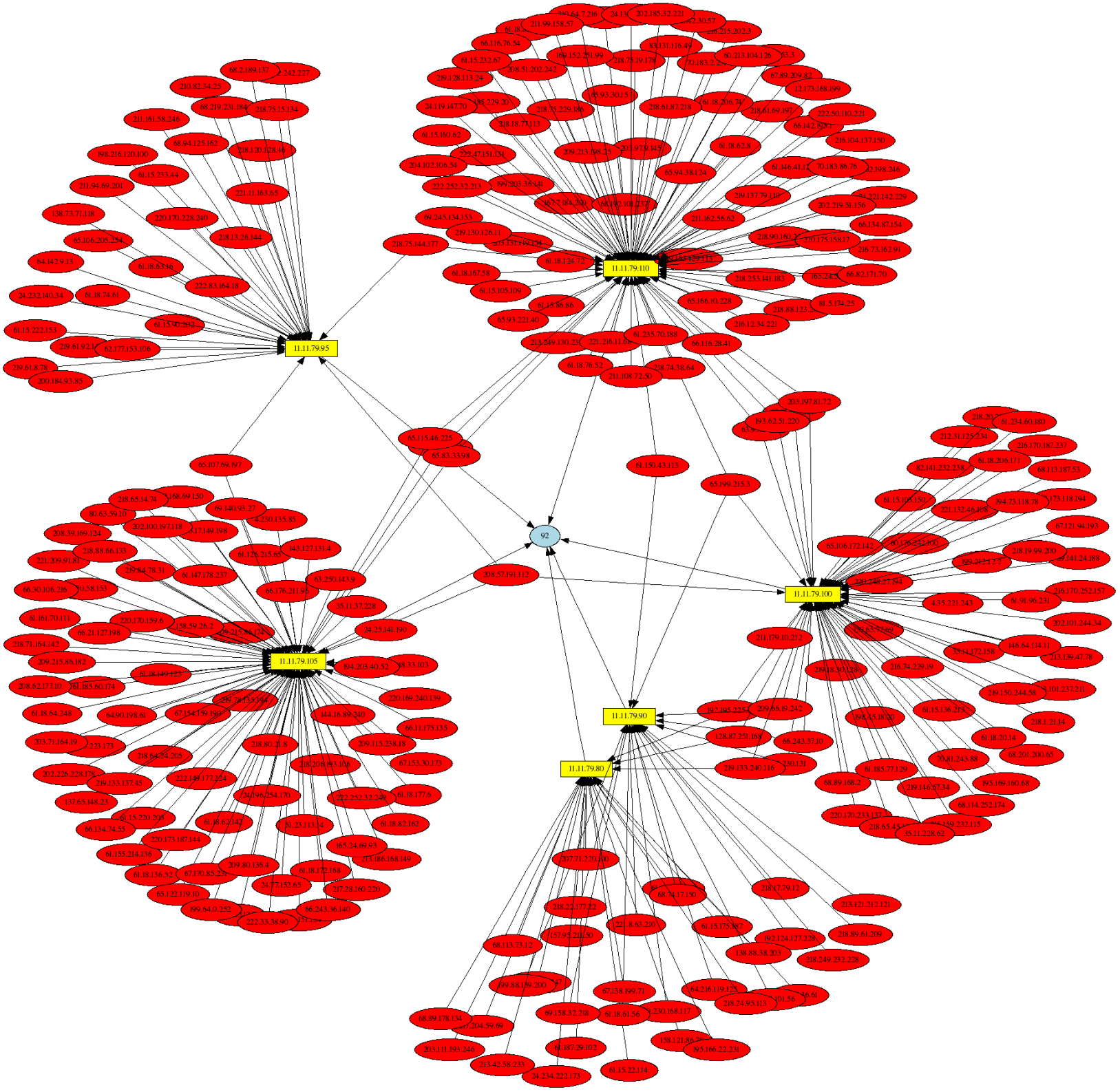
```
# psad --CSV -m iptablessyslog --CSV-fields
"src:11.11.79.0/24 dst dp" | perl
afterglow.pl -c color.properties |neato
-Tgif -o outbound_connections.gif
```


302.54.10.2
666
11.11.79.90
11.11.79.120
11.11.79.69
11.11.79.110
11.11.79.105
11.11.79.95
11.11.79.84
11.11.79.71
211.78.139.3
11.11.79.70
11.11.79.115
11.11.79.82
11.11.79.80
62.75.177.165
1026
11.11.79.85
217.172.188.228
11.11.79.73
11.11.79.89
11.11.79.75
11.11.79.87
11.11.79.83
11.11.79.81
11.11.79.72
11.11.79.100
11.11.79.125
21
80
514
81.196.20.130
151.25.187.213
213.203.218.122
11.11.79.65
207.28.220.6
217.106.2.92
154.11.89.164
53
213.46.223.3
11.11.79.67
62.250.14.6
213.48.180.1
22
64.21.117.248
66.198.160.2
205.252.46.98
205.188.149.20
213.208.119.11

Nachi Worm Visualization

- Look for 92-byte ICMP echo requests

```
# psad --CSV -m iptablessyslog --CSV-fields
"src dst ip_len:92" --CSV-max 300 --CSV-regex
"PROTO=ICMP.*TYPE=8" | perl afterglow.pl -c
color.properties |neato -Tgif -o
nachi_worm.gif
```


11.11.79.110
11.11.79.95
11.11.79.100
11.11.79.105
11.11.79.90
11.11.79.80
92

Enhancing iptables Log Data

- Use --log-ip-options
- Use --log-tcp-sequence
- Use --log-tcp-options
  - More attacks can be detected, and operating systems can be passively fingerprinted

Passive Authorization

- Basic idea:
  - Combine a default-drop packet filter with a passive mechanism to authenticate (and authorize) clients
  - The security benefit is derived from a reduction in the complexity of code that an arbitrary IP address can interact with. Every function has a non-zero probability of containing a security vulnerability
  - This is *NOT* security through obscurity; this is concealment (similar to passwords and encryption keys)

Port Knocking

- Uses packet headers to transmit information => serious protocol limitations
  - Difficult to protect against replay attacks
  - Low data transfer capability implies asymmetric encryption is not feasible
  - Knock sequences trivially busted from any source with spoofed duplicate packets
  - Port knocking sequences look like port scans to any IDS/IPS that is watching

Single Packet Authorization

- “Next-generation port knocking”
  - Uses application layer data
  - Replay attacks easily thwarted
  - Supports asymmetric ciphers
  - Only a single packet is transmitted, so much less likely to trigger IDS/IPS alarms

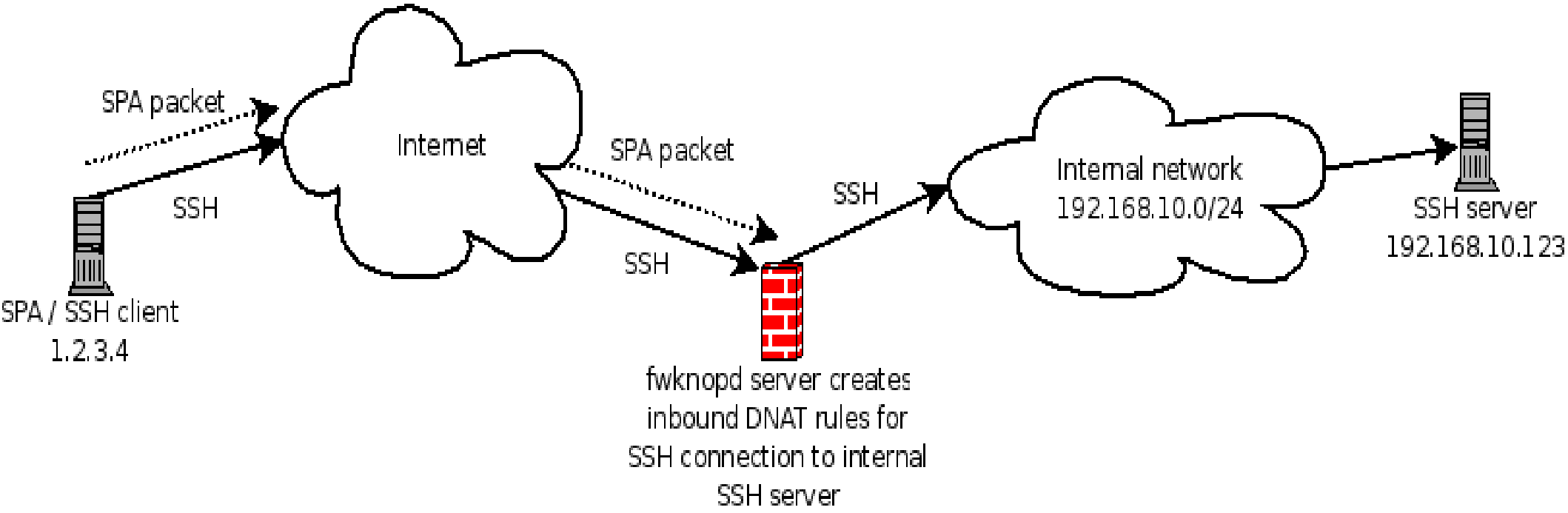
fwknop Features

- fwknopd “server” includes support for iptables and ipfw firewalls (Linux, Mac OS X, and FreeBSD).
- fwknop client includes support for Linux, Mac OS X, FreeBSD, Windows 2000, XP (under Cygwin) or via the Windows UI (developed by Sean Greven)
- SPA packets are encrypted either via Rijndael or with an asymmetric algorithm supported by GnuPG
- Supports outbound and inbound NAT (SNAT and DNAT, with DNAT support new in fwknop-1.9.0)

New in fwknop-1.9.2

- Client-derived firewall access timeouts
- Removal of encoded “Salted__” prefix from Rijndael SPA packets
- Support for Linux “cooked” interfaces (e.g. PPPoE)
- Selectable digest algorithms for replay attack detection (SHA256, SHA1, or MD5)
- Blacklist exclusions for SPA packets
  - Special thanks to the SPAPICT team (Calsoft security enthusiasts + students from the Pune Institute of Computing Technology: http://tech.groups.yahoo.com/group/spapict/) who contributed many of the new features in fwknop-1.9.2.

fwknop Forward access via DNAT rules



fwknop SPA Packet Format

- random number (16 bytes)
- username
- timestamp
- software version
- message type and content:
- 0 => command mode / command to execute
- 1 => access mode / IP,proto,port
- 2 => forward access mode / IP,proto,port / internalIP,externalNATPort
- (optional) server_auth (post 0.9.2 release)
- message digest (SHA256 / SHA1 / MD5)

Example SPA Packets

- Clear text message (fields are base64 encoded before encrypted):
  - **5514438870168371**:cm9vdA==:1203874973:1.9.2-pre6:1:MTI3LjAuMC4yLHRjcC8yMg==:yAynmuufyi/93SyVRViiB4MXKBhN/93cb+Ceu5cUUf4
- Two SPA packets (encrypted with the Rijndael cipher):
  - 9aoMEM9Jr5vHTdvKbx+phe3In6onbGLezoRpLD4y1YmcGW1udNGM1mAi/8b2s41aOhabyFvNzyxChfYSp7hPusjzLyRhwStmDzFFazHxzNmBh9xsgAvrGLqmmQzYhS++7XmtIH2D8hPjpaDGaGzs1nZPxGpZ2mQ5bjhBkutwcrkqCbe9wZf0o
  - /buclg8gNM4+WlDclkXkTyWJqEdEmHJwh+g4lrgAal09CYkPV9501z52zp00e/bRu5Oe/bKOJeD8hvEWK3LdOyVvuxfPWT9cDF7FG6xF/Rk4FhjcDPkaqVZb4CpMr7Yqr2wyL5Lxqy6YI7rt2ZdqaVGBIdGtzlHLOoXnz5j4mC1+H6hxa7e0pO

Future Work

- Web proxy that creates SPA packets on behalf of anyone with a web browser
- Integration with the pf firewall on OpenBSD
- Integration with additional clients (scp, sftp, mail clients, etc.)
- Firefox SPA extension
  - fwknop is open source, please submit patches!

Live Demo...

References

- “Security Data Visualization”: http://www.nostarch.com/securityvisualization.htm
- “SecViz – Security Visualization”: http://www.secviz.org
- Raffael Marty's Blog and AfterGlow project: http://raffy.ch/blog/
- MRTG: http://oss.oetiker.ch/mrtg/ (psad support coming soon)
- Gnuplot: http://www.gnuplot.info/

References (cont'd)

- "*An Analysis of Port Knocking and Single Packet Authorization*": http://www.securethoughts.net/spa/
- "*Single Packet Authorization with fwknop*": http://www.cipherdyne.org/fwknop/docs/SPA.html
- "*Enhancing Firewalls: Conveying User and Application Identification to Network Firewalls*": http://pages.cpsc.ucalgary.ca/~degraaf/
- Wikipedia on Port Knocking: http://en.wikipedia.org/wiki/Port_knocking
- Hakin9 on Port Knocking and SPA: http://mscoder.org/en/haking/articles_html.html
- Linux Journal articles:
  - http://www.linuxjournal.com/article/9565
  - http://www.linuxjournal.com/article/9621

Questions?

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