nftables, far more than %s/ip/nf/g

Éric Leblond

Nefilter Coreteam

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Éric Leblond

Hacker and contractor

- Independant Open Source and Security consultant
- Started and developped NuFW, the authenticating firewall
- Core developer of Suricata IDS/IPS

Netfilter Coreteam member

- Work on kernel-userspace interaction
- Kernel hacking
- ulogd2 maintainer
- Port of Openoffice firewall to Libreoffice

History

ipchains (1997)

- Linux 2.2 firewalling
- stateless
- Developped by Paul 'Rusty' Russel

iptables (2000)

- Linux 2.4 firewalling
- Stateful tracking and full NAT support
- in-extremis IPv6 support

Netfilter project

- 'Rusty' Russel developed iptables and funded Netfilter project
- Netfilter coreteam was created to consolidate the community

Features

Filtering and logging

- Filtering
  - on protocol fields
  - on internal state
- Packet mangling
  - Change TOS
  - Change TTL
  - Set mark

Connection tracking

- Stateful filtering
- Helper to support protocol like FTP

Network Address Translation

- Destination Network Address Translation
- Source Network Address Translation

Netfilter inside kernel

Hooks

- Hooks at different points of network stack
- Verdict can be issued and skb can be modified
- To each hook correspond at least table
- Different families
  - filter
  - raw
  - nat
  - mangle
- Loading a module create the table

Connection tracking tasks

- Maintain a hash table with known flows
- Detect dynamic connection opening for some protocols

Major components

Netfilter filtering

- In charge of accepting, blocking, transforming packets
- Configured by ioctl

Connection tracking

- Analyse traffic and maintain flow table
- Cost in term of performance
- Increase security

iptables

- Configuration tools
- Update ruleset inside kernel

The nfnetlink (r)evolution

Nfnetlink

- First major evolution of Netfilter (Linux 2.6.14, 2005)
- Netfilter dedicated configuration and message passing mechanism

New interactions

- NFLOG: enhanced logging system
- NFQUEUE: improved userspace decision system
- NFCT: get information and update connection tracking entries

Based on Netlink

- datagram-oriented messaging system
- passing messages from kernel to user-space and vice-versa

Netlink

Header format

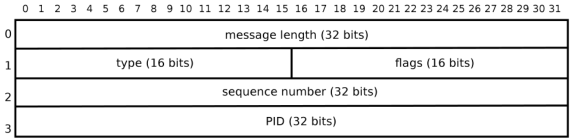


Figure 2. Layout of a Netlink message header

Payload format

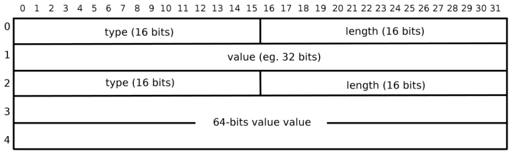


Figure 3. An example of a hypothetical Netlink payload in TLV format

Components created following 2.6.14

conntrack-tools

- conntrackd
  - connection tracking replication daemon
  - provide high availability
  - developped by Pablo Neira Ayuso
- conntrack: command line tool to update and query connection tracking

ulogd2

- logging daemon
- handle packets and connections logging

Latest changes

ipset

- Efficient set handling
- Address list or more complex set
- Reach vanilla kernel in 2011 (Linux 2.6.39)

nfacct

- Efficient accounting system
- Appeared in 2012

Kernel code

How much code

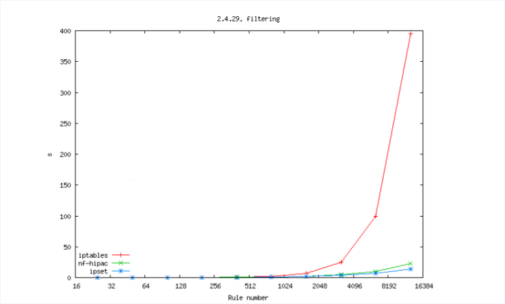
- 70000 LOC reside in kernelspace
- around 50000 LOC in user-space

Iptables extensions

- 111 iptables extensions.
- Various tasks:
  - tcp
  - cluster
  - bpf
  - statistic

Performance

Adding a rule



The problem

- Atomic replacement of ruleset
  - Sent from kernel to userspace
  - Modified and sent back by userspace
- Huge performance impact

Dynamic ruleset

Network gets dynamic

- Firewall can’t be static anymore
  - Cloud
  - IP reputation
- Combinatory explosion : one rule per-server and protocol

Set handling

- Set handling is made via ipset
- Efficient but not as integrated as possible

Code duplication

Different filtering family

- Netfilter classic filtering
- Brigde filtering
- Arp filtering
- IPv4 and IPv6

Matches and target

- Similar code in numerous Netfilter module
- Nothing is shared
- Manual parsing

Problem due to binary blob usage

ABI breakage

- Binary exchange between userspace and kernel
- No modification possible without touching kernel

Trusting userspace

- Kernel is parsing a binary blob
- Possible to break the internal parser

Integration via exec

Frontend and iptables

- No officially available library
- Frontend fork iptables command

libiptables

- Available inside iptables sources
- Not a public library
- API and ABI breakage are not checked during version upgrade

Lack of flexible table and chains configurations

Module loading is the key

- Chains are created when module init
- Induce a performance cost even without rules

No configuration is possible

- Chains are hardcoded
- FORWARD is created on a server

Nftables

A new filtering system

- Replace iptables and the filtering infrastructure
- No changes in
  - Hooks
  - Connection tracking
  - Helpers

A new language

- Based on a grammar
- Accessible from a library

Netlink based communication

- Atomic modification
- Notification system

History

Introduced in 2008

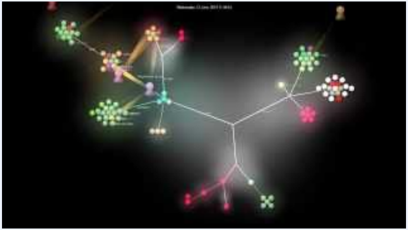
- Developped and presented by Patrick McHardy at NFWS2008
- Presentation took 3 hours
- Alpha stage in 2008

Development did stop

- Patrick McHardy did not finish the code alone
- Nobody did join the effort

Video Interlude

The video



`http://www.youtube.com/watch?v=DQp1AI1p3f8`

Video generation

- Video generated with gource
- Various git history have been merged
- File path has been prefixed with project name

What explanations ?

Should have "Release often release early" ?

- Started by Patrick McHardy only
- Almost complete work presented during NFWS 2008
- Complex to enter the project

Too early ?

- No user were demanding for that explicitly
- Ipset was available and fixing the set issue
- Solution for dynamic handling was sufficient

Development restarted in 2012

Funding by Sophos/Astaro

- Pablo Neira Ayuso get funded by Astaro
- Work restart in 2012

Gaining momemtum

- Tomasz Bursztyka joined the development team
  - Work on Connman
  - Lack of libs was painful to him
  - Start to hack on nftables
- Google summer of code
  - 3 students
  - Some good results

A filtering based on a pseudo-state machine

Inspired by BPF

- 4 registers
- 1 verdict
- A extensive instructions set

Add Some Magic ?

```
reg = pkt.payload[offset, len]
reg = cmp(reg1, reg2, EQ)
reg = pkt.meta(mark)
reg = lookup(set, reg1)
reg = ct(reg1, state)
```

Easy creation of new matches

```
reg1 = pkt.payload[offset_src_port, len]
reg2 = pkt.payload[offset_dst_port, len]
reg = cmp(reg1, reg2, EQ)
```

Architecture

Kernel

- Tables: declared by user and attached to hook
- User interface: nfnetlink socket
  - ADD
  - DELETE
  - DUMP

Userspace

- libmnl: low level netlink interaction
- libnftables: library handling low-level interaction with nftables Netlink's API
- nftables: command line utility to maintain ruleset

Dynamic chain loading

Chain are created on-demand

- Chain are created via a specific netlink message
- Non-user chain are:
  - Of a specific type
  - Bound to a given hook

Current chain type

- filter: filtering table
- route: old mangle table
- nat: network address translation table

From userspace syntax to kernel

Converting user input

- Operation is made via a netlink message
- The userspace syntax must be converted
  - From a text message following a grammar
  - To a binary Netlink message

Linearize

- Tokenisation
- Parsing
- Evaluation
- Linearization

From kernel to userspace syntax

Kernel send netlink message

- It must be converted back to text

Conversion

- Deliniearization
- Postprocessing
- Textify

Example

```
ip filter output 8 7
  [ payload load 4b @ network header + 16 => reg 1 ]
  [ bitwise reg 1 = (reg=1 & 0x00ffffff ) ^ 0x00000000 ]
  [ cmp eq reg 1 0x00500fd9 ]
  [ counter pkts 7 bytes 588 ]
```

is translated to:

```
  ip daddr 217.15.80.0/24 counter packets 7 bytes 588 # handle 8
```

Kernel

Atomic ruleset update

- atomically commit a set of rule-set updates incrementally
- based on a generation counter/mask
  - 00 active in the present, will be active in the next generation.
  - 01 active in the present, needs to zero its future, it becomes 00.
  - 10 inactive in the present, delete now.

xtables compatibility

- Possible to use old extensions
- Necessary to provide backward compatibility

Notification

Event based notification

- Each rule update trigger an event
- Event is sent to userspace via nfnetlink

Userspace usage

- Implemented in libnftables
- Program can update his view on the ruleset without dump

A limited in-kernel size

- A limited set of operators and instructions
- A state machine
- No code dedicated to each match
  - One match on address use same code as a match on port
  - New matchs are possible without kernel modification

LOC count

- 50000 LOC in userspace
- only 7000 LOC in kernel-space

Less kernel update

Pseudo state machine instruction

- Current instructions cover need found in previous 10 years
- New instruction require very limited code

Development in userspace

- A new match will not need a new kernel
- ICMPv6 implementation is a single userspace patch

Example of ICMPv6

```
include/datatype.h |  2 ++
include/payload.h  | 14 +++++++++++
src/parser.y       | 33 +++++++++++++++++++++++++++---
src/payload.c      | 59 +++++++++++++++++++++++++++++++++++++++++++++++++
src/scanner.l      |  4 ++
5 files changed, 109 insertions(+), 3 deletions(-)
```

Example of ICMPv6

```
static const struct datatype icmp6_type_type = {
        .type           = TYPE_ICMP6_TYPE,
        .name           = "icmpv6_type",
        .desc           = "ICMPv6 type",
        .byteorder      = BYTEORDER_BIG_ENDIAN,
        .size           = BITS_PER_BYTE,
        .basetype       = &integer_type,
        .sym_tbl        = &icmp6_type_tbl,
};

#define ICMP6HDR_FIELD(__name, __member) \
        HDR_FIELD(__name, struct icmp6_hdr, __member)
#define ICMP6HDR_TYPE(__name, __type, __member) \
        HDR_TYPE(__name, __type, struct icmp6_hdr, __member)

const struct payload_desc payload_icmp6 = {
        .name           = "icmpv6",
        .base           = PAYLOAD_BASE_TRANSPORT_HDR,
        .templates      = {
                [ICMP6HDR_TYPE]         = ICMP6HDR_TYPE("type", &icmp6_type_type, icmp6_type),
                [ICMP6HDR_CODE]         = ICMP6HDR_FIELD("code", icmp6_code),
                [ICMP6HDR_CHECKSUM]     = ICMP6HDR_FIELD("checksum", icmp6_cksum),
                [ICMP6HDR_PPTR]         = ICMP6HDR_FIELD("parameter-problem", icmp6_pptr),
                [ICMP6HDR_MTU]          = ICMP6HDR_FIELD("packet-too-big", icmp6_mtu),
                [ICMP6HDR_ID]           = ICMP6HDR_FIELD("id", icmp6_id),
                [ICMP6HDR_SEQ]          = ICMP6HDR_FIELD("sequence", icmp6_seq),
                [ICMP6HDR_MAXDELAY]     = ICMP6HDR_FIELD("max-delay", icmp6_maxdelay),
        },
};
```

Basic utilisation

File mode

```
nft -f ipv4-filter
```

Command line mode

```
nft add rule ip filter input tcp dport 80 drop
nft list table filter -a
nft delete rule filter output handle 10
```

CLI mode

```
# nft -i
nft> list table
<cli>:1:12-12: Error: syntax error, unexpected end of file, expecting stri
list table
           ^
nft> list table filter
table filter {
  chain input {
   ip saddr 1.2.3.4 counter packets 8 bytes 273
```

Set handling

Interests of sets

- One single rule evaluation
- Simple and readable ruleset
- Evolution handling

Anonymous set

```
nft add rule ip global filter \
    ip daddr {192.168.0.0/24, 192.168.1.4} \
    tcp dport {22, 443} \
    accept
```

Named set

```
nft add set global ipv4_ad { type ipv4_address;}
nft add element global ipv4_ad { 192.168.1.4, 192.168.1.5}
nft delete element global ipv4_ad { 192.168.1.5}
nft add rule ip global filter ip saddr @ipv4_ad drop
```

Mapping

Principle and interest

- Associative mapping linking two notions
- A match on the key trigger the use of the value
- Using addresses, interfaces, verdicts

Examples

- Anonymous mapping:

```
# nft add rule filter output ip daddr vmap \
    {192.168.0.0/24 =\> drop, 192.168.0.1 =\> accept}
```

- Named mapping:

```
# nft -i
nft> add map filter verdict_map { type ipv4_address  => verdict; }
nft> add element filter verdict_map { 1.2.3.5 => drop}
nft> add rule filter output ip daddr vmap @verdict_map
```

Usage example

```
set web_servers {
  type ipv4_address
  elements = { 192.168.1.15, 192.168.1.5}
}
map admin_map {
  type ipv4_address => verdict
  elements = { 192.168.0.44 => jump logmetender, \
               192.168.0.42 => jump logmetrue, 192.168.0.33 => accept}
}
chain forward {
  ct state established accept
  ip daddr @web_servers tcp dport ssh ip saddr map @admin_map
  ip daddr @web_servers tcp dport http log accept
  ip daddr @web_servers tcp dport https accept
  counter log drop
}
chain logmetender {
  log limit 10/minute accept
}
chain logmetrue {
  counter log accept
}
}
```

Transition and evolution

A complete iptables compatibility

- iptables-nftables
  - Binary compatible with iptables
  - Using nftables framework
- Same kernel can be used with two systems
- A progressive update

A high level library

- To be used by frontends
- Or by network manager systems

Conclusion

A huge evolution

- Solving iptables problem
- An answer to new usages
  - Set handling
  - Complex matches

Availability for end 2013, beginning 2014

- Finalizing iptables compatibility
- High level library
- Debug and some functionalities

Questions ?

Do you have questions ?

Thanks to

- Netfilter team
- Astaro/Sophos for financing the development
- Google for GSoC 2013

More information

- Netfilter : `http://www.netfilter.org`
- Nftables quick & dirty : `https://t.co/cM4zogob8t`

Contact me

- Mail: `eric@regit.org`
- Twitter: @Regiteric