Packet Filter (pf)

An Extended Introduction

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pf - History

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  - Ideas from the other approaches were merged
- OpenBSD 3.0 (*December 1, 2001*) first release with pf

Ports

- **November 5, 2002** – *Joel Wilsson* to NetBSD
- **March 25, 2003** – *Pyun YongHyeon* to FreeBSD
- **June 27, 2003** – KAME integrates source from OpenBSD current
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- **Ports might behave differently!**
  - FreeBSD 5-STABLE will be compatible to OpenBSD 3.5
  - NetBSD is level with OpenBSD 3.5 at the moment
  - KAME seems to track OpenBSD-current (on and off)

Releases

- OpenBSD makes a relase aprox. every 6 month
- pf still gains a **lot** of features with every release
- Overlapping release cycles might cause considerable deltas between OpenBSD and the various ports
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- **Check the documentation!**

pf - Features

Basics

- Ruleset based configuration
  - Anchors allow nesting [a]
  - Tables allow dynamic adaption of rules [a]
  - Interface address management [b]
- Default (logical) order required
  1. Macro and table definitions
  2. (Global) Options
  3. Traffic Normalization (*scrub*)
  4. Network address translation (*NAT*) and redirection
  5. Filtering rules
- **Last** matching rule wins
  - This can be changed with the ‘quick’ keyword
- Macros allow easier reading/writing and understanding of rules

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- TCP normalization
  - TCP reassembly
  - Illegal flag combinations (nmap)
  - TCP options
  - PAWS (Protection Against Wrapped Sequence Numbers)
- Enforce minimum TTL

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Scrubbing also helps to hide peer uptimes and thus can prevent NAT detection

NAT and redirection

- BINAT – bidirectional address translation
- NAT – source address translation
  - static port – prevents sourceport rewrite
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The **sticky-address**-option can be applied to *random* and *round-robin* to improve the redirection mapping

Filtering - Attributes

pf is an IP-level (OSI Layer 3) firewall, but also keeps track of TCP and UDP (OSI Layer 4) . . .

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- Direction
- Address family
- Source/Destination IP(-range)
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- ToS
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- **Out**going

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- IPv4 “inet”
- IPv6 “inet6”

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- "any"
- "no-route"
- "self"
- IPv4 dotted quad (127.0.0.1)
- IPv6 coloned hex (2001:200:0:8002:203:47ff:fea5:3085)
- CIDR compatible since OpenBSD 3.3
- Hostname (freebsd.org)
- Netmasks can be applied
- pf can (dynamically) extract addresses from a local interface

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- (IP)Protocol number
- Protocol name/alias (etc/protocols)

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- ‘lowdelay’
- ‘throughput’
- ‘reliability’
- Explicit hex-code

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- Disallow (default)
- Allow

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- Type
- Code

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- Source/Destination port(-range)
- Flags
- Socket credentials (‘owner’ of the sending/receiving application)
- *OS type* (passiv fingerprinting of the initial SYN packet)

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pf filters on everything and provides understandable syntax

Filtering - Stateful

States are fast:

- Indexed in a reb-black tree => fast lookup (O(lg(n)))
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States increase security:

- Control who initiates a connection
- Apply additional sanity checks to TCP connections
  - Segments must be in the window
  - Restes must be on the edge of the window
  - Window scaling available
  - pf must ‘see’ the initial handshake (flags S/SA)
- Help to gather accounting information (pfflowd e.g.)
- Additional peer protection against ISN prediction attacks available with *modulate state* and *synproxy*

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States are also used to keep track of address translations.

Filtering - Tables

Tables provide sophisticated means to manage large, sparse address lists.

- Can take hosts and networks
- Most specific match is returned
- ‘Not’ modifier
- Implemented as radix tree => fast lookups (as known from routing tables)
- 64Bit statistics counters for every table entry (easy accounting)

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Short example

pf - Advanced notes

Interesting options

- timeouts
  - Set fragment cache time
  - Set cleanup intervals
  - Finetune TCP handshake timeouts
  - Finetune UDP/ICMP/other state hold time
  - **adaptive.start adaptive.end**
    Used to scale timeouts according to current state load. As the total number of states increase, unused states die more quickly.
- limits
  - States
  - Fragements
  - Source-tracking nodes

- [pf - History](#)
- [pf - Features](#)
- [pf - Advanced notes](#)
  - ❖ Interesting options
  - ❖ Stateful I
  - ❖ Stateful II
  - ❖ Anchors
  - ❖ Misc
- [ALTQ (short)](#)
- [CARP](#)

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Stateful rule options:

- Per-rule timeouts
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- **source-track**
  - Per-*client* limits
  - Maximum number of peers
  - Maximum connections per peer

Modulate state:

- Randomize the initial sequence numbers of a (TCP) connection
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Synproxy states:

- Gateway completes the 3-way handshake
- Gateway initiates connection with the destination
- Further traffic is a normal stateful connection
  Same mechanisms used as for modulate-state connections

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Useful to protect *web*- and *DB*-server against SYN-flood attacks.

Anchors

- Structure rulesets
- Easily changeable
- Good for script actions
- Used by authpf
- Can be ‘limited’ to:
  - Direction (in/out)
  - Interface
  - Address family
  - Protocol
  - Host definition

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- **New in 3.6**: Recursive anchors

Misc

- Skip-steps
  - Jump over rules that cannot match
  - Optimize ruleset evaluation
  - **New in 3.6**: Ruleset optimization
- Tagging
  - Only with stateful rules
  - Allows to seperate classification and policy
  - Used to support layer 2 filtering
- OS Fingerprints
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  - Only for the initial SYN packet
  - **This can be spoofed! Not a security tool**

ALTQ (short)

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- Can be used to control bandwidth allocation and packet priorization
- Most effective in front of a bandwidth bottleneck (i.e. on the uplink gateway)

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Detailated per-application evaluation is required to implement ALTQ

ALTQ and pf

- pf gained ALTQ linkage in OpenBSD 3.3
- Stateful pass rules assign thier traffic to a queue
- 'Lowdelay' and empty ACKs can be treated specially
- Queues are setup from the ruleset directly

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CARP

Basics

The Common Address Redundancy Protocol is a **free** replacement for VRRP

- Multiple hosts share a common MAC address (but only the master replys)
- The master advertises via multicast
- Variable advertisement intervals
  - ✦ Most frequent advertiser becomes master
  - ✦ Failover after (3 * advertisement interval)
- Advertisement protected by SHA1 HMAC
  - ✦ HMAC covers logical addresses (which are not part of the advertisement)
  - ✦ **Pending**: Replay protection
- Supports IPv4 **and** IPv6
- Supports layer 2 load balancing (ARP based)

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- The master advertises via multicast
- Variable advertisement intervals
  - Most frequent advertiser becomes master
  - Failover after (3 * advertisement interval)
- Advertisement protected by SHA1 HMAC
  - HMAC covers logical addresses (which are not part of the advertisement)
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- Supports IPv4 **and** IPv6
- Supports layer 2 load balancing (ARP based)

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CARP and pf(sync)

In order to support firewall/gateway redundancy every firewall must know about open connections (=states). The pfsync pseudo interface enables state synchronization:

- Each Firewall send out state changes via multicast
  - Insert
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- States have an unique ID
- Best effort synchronization
  Tends towards complete state view on every firewall
- Mechanisms to limit bandwidth and processing overhead
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Example setup

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More CARP

But CARP can not only do 'simple' firewall failover.

- Load balancing
  - Built-in ARP source-hash
  - pf and RDR/NAT
  - DNS round-robin
- Use it on servers
- ...

More complicated example

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More complicated example

Questions

Links

These slides are at: http://people.freebsd.org/ mlaier/sucon.pdf

- OpenBSD
- OpenBSD pf
- FreeBSD
- FreeBSD pf
- NetBSD
- NetBSD pf
- DragonFly BSD
- DragonFly BSD
- p0f
- ALTQ additional reading
- CARP additional reading

Support

If you like pf, please

Buy OpenBSD CD-Sets! Support the developers!

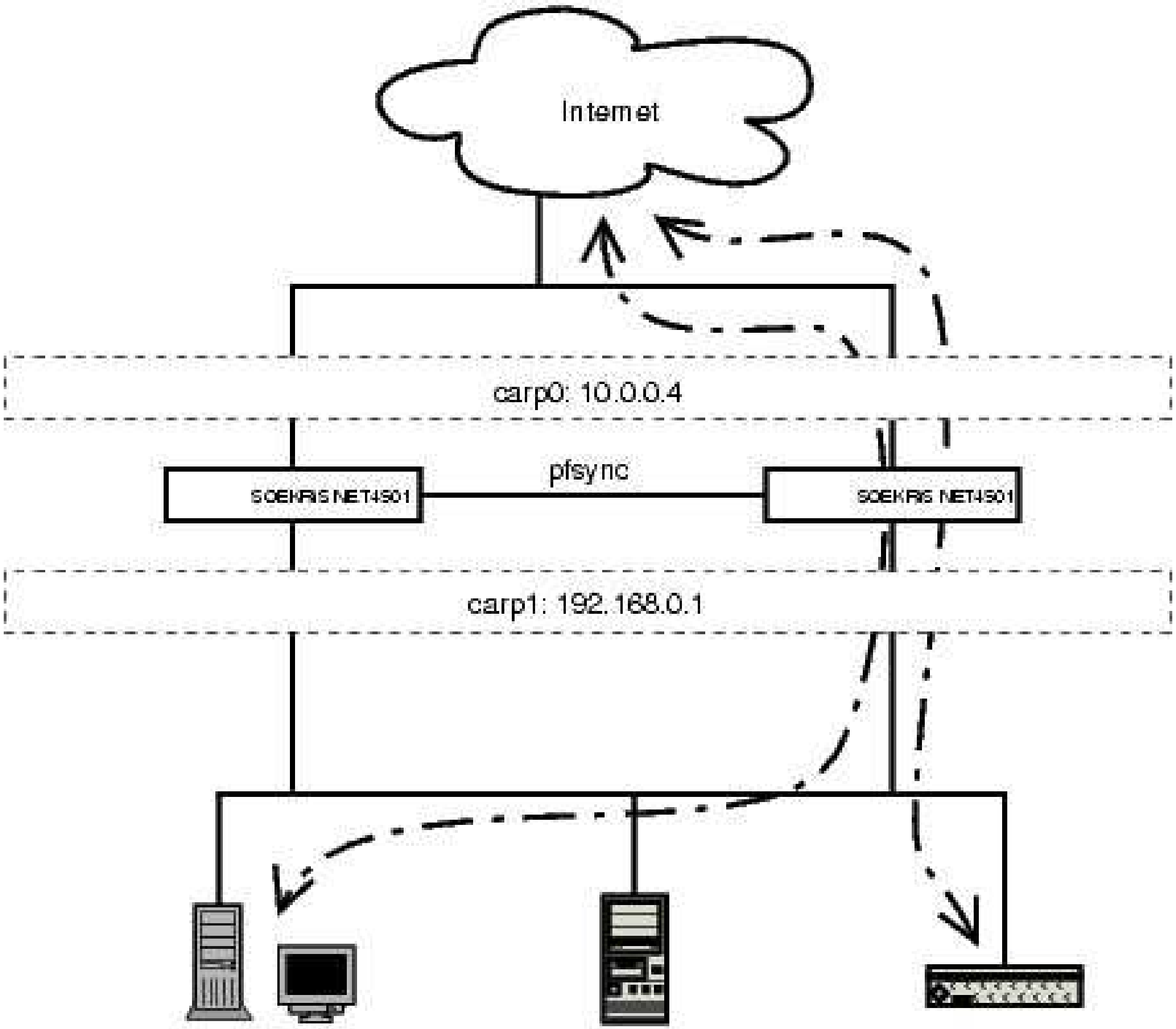
Examples

Table - Example


```
pf.test:
  table <test> persist { 10/8, 10.0.10/24, !10.0.10.1 }
  block all
  pass out to <test> keep state
# pfctl -ef pf.test
# ping -c 1 10.0.0.10 && ping -c 2 10.0.10.10
# ping -c 1 10.0.10.1
PING 10.0.10.1 (10.0.10.1): 56 data bytes
ping: sendto: Operation not permitted
^C
# pfctl -t test -vTshow
   10.0.0.0/8
        Cleared:     Wed Sep  1 19:57:38 2004
        In/Block:    [ Packets: 0                 Bytes: 0                 ]
        In/Pass:     [ Packets: 0                 Bytes: 0                 ]
        Out/Block:   [ Packets: 0                 Bytes: 0                 ]
        Out/Pass:    [ Packets: 1                 Bytes: 84                ]
   10.0.10.0/24
<...>
        Out/Pass:    [ Packets: 2                 Bytes: 168               ]
  !10.0.10.1
        Cleared:     Wed Sep  1 19:57:38 2004
        In/Block:    [ Packets: 0                 Bytes: 0                 ]
        In/Pass:     [ Packets: 0                 Bytes: 0                 ]
        Out/Block:   [ Packets: 0                 Bytes: 0                 ]
        Out/Pass:    [ Packets: 0                 Bytes: 0                 ]
```

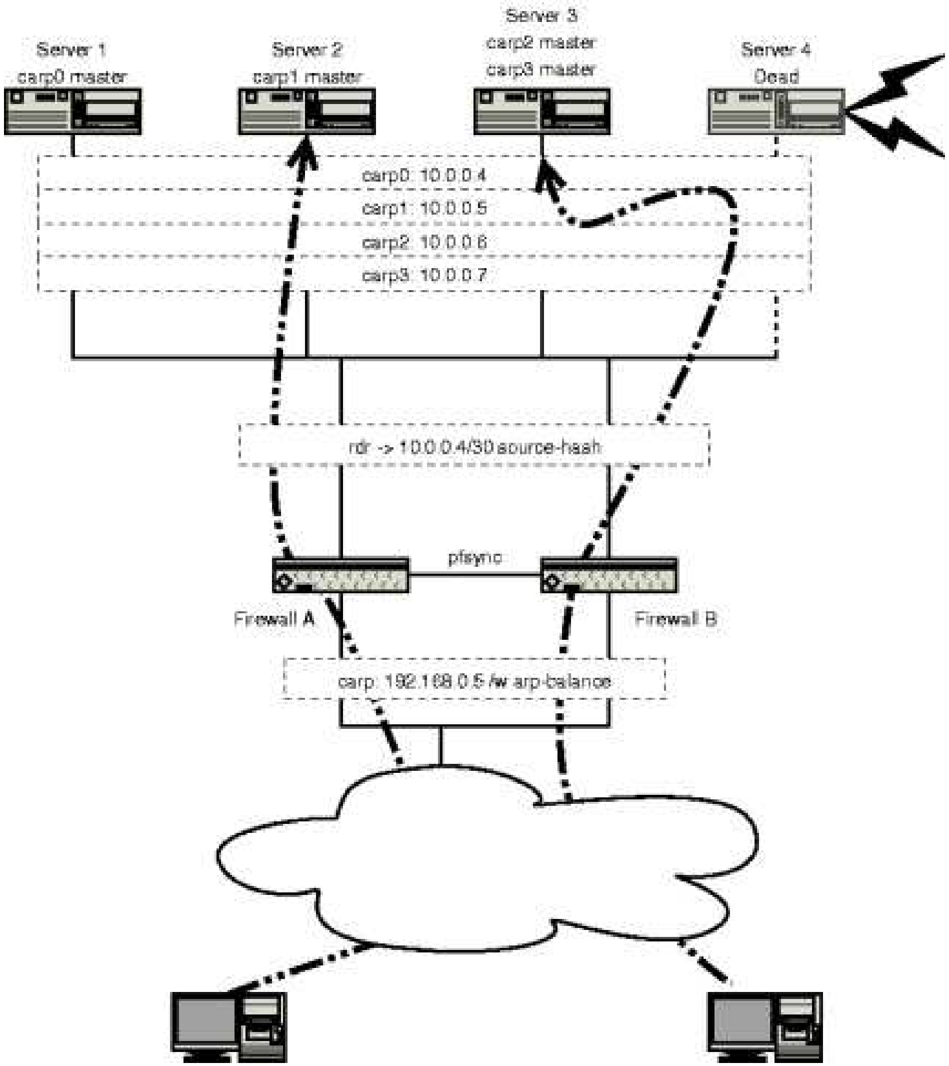
. . . back

CARP - Simple



. . . back

CARP - Advanced



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