NPF: a new packet filter

Zoltán Arnold Nagy
zoltan@NetBSD.org

bsd_day(2011)

Slovak University of Technology,
Bratislava, Slovakia
November 5, 2011

- What is a packet filter?

- What is a packet filter?
  - A boolean valued function ($f : \mathbb{P} \to \mathbb{B}$)

- What is a packet filter?
  - A boolean valued function ($f : \mathbb{P} \rightarrow \mathbb{B}$)
- How can it be implemented?

- What is a packet filter?
  - A boolean valued function ($f : \mathbb{P} \to \mathbb{B}$)
- How can it be implemented?
  - boolean expression tree
  - directed acyclic control flow graph
  - if-then-else hell

A sea of firewalls

- IPFilter (ipf)
- FreeBSD's ipfw
- OpenBSD's pf
- NetBSD's npf

How NPF started out

- Sponsored by The NetBSD Foundation
- Written by Mindaugas Rasiukevicius (rmind@) from scratch, altought the design was inspired by the Berkeley Packet Filter
- First imported to -current in August 2010
- Will be widely available with the 6.0 release
- First step in improving NetBSD's networking capabilities
- Second step: removing the big kernel lock (proposal deadline: Oct 31st)

Google Summer of Code

- Goal: The program's goal is to promote open-source software development among students and get them actually involved

Google Summer of Code

- Goal: The program's goal is to promote open-source software development among students and get them actually involved
- Mentoring organizations apply with a set of proposed projects

Google Summer of Code

- Goal: The program's goal is to promote open-source software development among students and get them actually involved
- Mentoring organizations apply with a set of proposed projects
- Students apply for organizations with a proposal based either on a proposed project or a new one

Google Summer of Code

- Goal: The program's goal is to promote open-source software development among students and get them actually involved
- Mentoring organizations apply with a set of proposed projects
- Students apply for organizations with a proposal based either on a proposed project or a new one
- Organizations get a number of slots for students

Google Summer of Code

- Goal: The program's goal is to promote open-source software development among students and get them actually involved
- Mentoring organizations apply with a set of proposed projects
- Students apply for organizations with a proposal based either on a proposed project or a new one
- Organizations get a number of slots for students
- Mentoring organizations get $500 per student, students get $5000

Google Summer of Code

- Goal: The program's goal is to promote open-source software development among students and get them actually involved
- Mentoring organizations apply with a set of proposed projects
- Students apply for organizations with a proposal based either on a proposed project or a new one
- Organizations get a number of slots for students
- Mentoring organizations get $500 per student, students get $5000
- It has been running since 2005
  - 2011: 175 mentoring organizations, 1115 students
- NetBSD has participated every year so far with a high success rate
  - 2011: 9 projects, 8 projects ended with success
- My GSoC proposal for 2011 was to add IPv6 support to NPF
  - currently not in -current (soon!)
  - available from `https://github.com/zoltan/ipv6-npf`

Motivations and goals

- There are a few existing firewalls
- It's easier to design a new firewall from ground up than to clean up existing codebases
- Design goals for NPF:
  - MP-safety and locklessness for scalable MP performance
  - Fast tree- and hash-based lookup support for tables
  - Stateful packet filtering
  - N-Code processor, a general bytecode engine
  - Keep configuration syntax changes to a minimum
  - Modularity, extensibility: an extension API for developers, hooking support
  - Last but not least: simplicity
- Of course it's portable, uses pfil(9) hooks; DragonFlyBSD is considering adoption
- Please keep in mind: it's a moving target currently

Usage

- `npfctl` can be used to communicate with /dev/npf via ioctls
  - start, stop, reload, flush, stats, tables, sessions, ...
- Rules will be compiled to a bytecode, and it will be loaded as ruleset(s)
- Current parser will be replaced by a new one by Martin

What can it do today?

- Rule syntax is nearly identical to other firewalls
- Group support
- Rule procedures (connection-based packet transformations)
  - IP ID randomization
  - enforcement of TCP minimum TTL
  - enforcement of TCP Maximum Segment Size (MSS)
  - logging
- Tables support
- Application-level gateways (ALGs)

```
int_if = "wm0"
ext_if = "wm1"
table "1" type "tree" dynamic
procedure "rid" { normalize (random-id) }
procedure "log" { log npflog0 }
group (name "external", interface $ext_if) {
    block in quick from <1>
    pass out quick from $ext_if keep state apply "rid"
    pass in quick proto tcp to $ext_if port ssh apply "log'
    ...
}
group (name "internal", interface $int_if) {
    block in all
    pass in quick from <1>
    pass out quick all
}
group (default) { block all }
```

Inside

N-code engine:

- General purpose bytecode engine, 32-bit words, 4 registers available
- The firewall configuration is compiled to our bytecode format, then loaded
- CISC and RISC-like instructions
- The packets are processed as a byte-stream

Efficient internal structures

- npf_addr (in6_addr, 128-bit) for addresses (the first 32 bit is used for IPv4 addresses)
- uint8_t for masks
  - instead of generating the appropriate npf_addr value from 255.255.255.0 or /24, we just store the mask (¡=128)
  - tradeoff: CPU for memory

Inside

Let's see what we can work with...

```
typedef struct {
        /* Information flags. */
        uint32_t                npc_info;
        /* Pointers to the IP v4/v6 addresses. */
        npf_addr_t *            npc_srcip;
        npf_addr_t *            npc_dstip;
        /* Size (v4 or v6) of IP addresses. */
        int                     npc_ipsz;
        size_t                  npc_hlen;
        int                     npc_next_proto;
        /* IPv4, IPv6. */
        union {
                struct ip       v4;
                struct ip6_hdr  v6;
        } npc_ip;
        /* TCP, UDP, ICMP. */
        union {
                struct tcphdr   tcp;
                struct udphdr   udp;
                struct icmp     icmp;
        } npc_l4;
} npf_cache_t;
```

Current TODO list

- Replace red-black trees with Patricia (radix) trees for tables

Current TODO list

- Replace red-black trees with Patricia (radix) trees for tables
- Pregenerate an array for masks

Current TODO list

- Replace red-black trees with Patricia (radix) trees for tables
- Pregenerate an array for masks
- Support per-rule statistics

Current TODO list

- Replace red-black trees with Patricia (radix) trees for tables
- Pregenerate an array for masks
- Support per-rule statistics
- Multiple address per interface support on interface-based rules
- Dynamic interface tracking
  - Let's say you have a rule based on an interface instead of an address...
  - ...you compile and load the rules...
  - ...then change the interface's address?
- Control fragmentation on a per-interface basis

Current TODO list

- Replace red-black trees with Patricia (radix) trees for tables
- Pregenerate an array for masks
- Support per-rule statistics
- Multiple address per interface support on interface-based rules
- Dynamic interface tracking
  - Let's say you have a rule based on an interface instead of an address...
  - ...you compile and load the rules...
  - ...then change the interface's address?
- Control fragmentation on a per-interface basis
- Stateful NAT64 [RFC 6146]
- IPv6-to-IPv6 Network Prefix Translation (NPTv6) [RFC 6296]

Current TODO list

- Replace red-black trees with Patricia (radix) trees for tables
- Pregenerate an array for masks
- Support per-rule statistics
- Multiple address per interface support on interface-based rules
- Dynamic interface tracking
  - Let's say you have a rule based on an interface instead of an address...
  - ...you compile and load the rules...
  - ...then change the interface's address?
- Control fragmentation on a per-interface basis
- Stateful NAT64 [RFC 6146]
- IPv6-to-IPv6 Network Prefix Translation (NPTv6) [RFC 6296]
- Write more documentation :)

What we haven't covered today and why...

- Performance testing
  - No point in in-place testing, since the locking of the network stack if not fine-grained enough
  - Will do userspace tests once the current codebase is merged
- Packet sniffing

Questions and answers?

Thank you!