NPF: a new packet filter

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- What is a packet filter?

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  - A boolean valued function ($f : \mathbb{P} \to \mathbb{B}$)
- How can it be implemented?
  - boolean expression tree
  - directed acyclic control flow graph[1]
  - if-then-else hell

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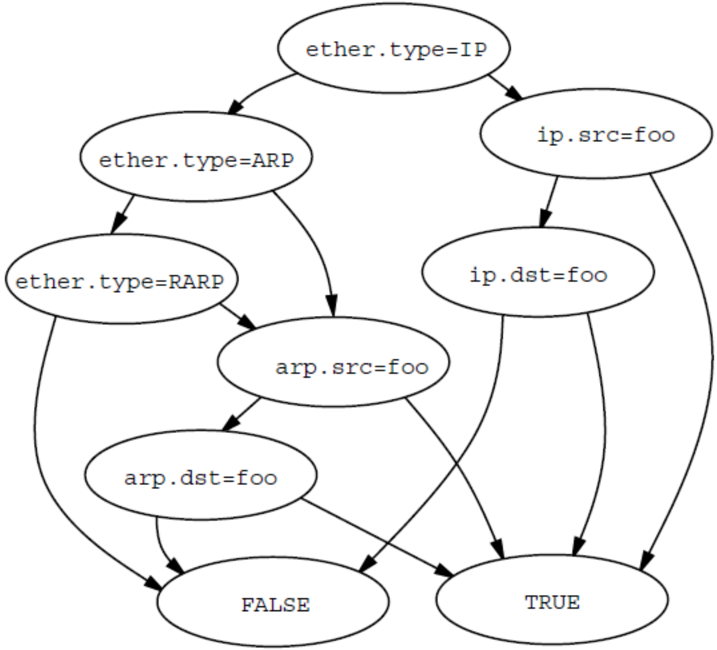
ether.type=IP
ether.type=ARP
ip.src=foo
ether.type=RARP
ip.dst=foo
arp.src=foo
arp.dst=foo
FALSE
TRUE

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

Google Summer of Code

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- 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
    - Already accepted for 2012 as a mentoring organization
- My GSoC proposal for 2011 was to add IPv6 support to NPF
    - committed to -current in November 2011
- Something will happen in 2012 too :-)

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
- Work in progress

Usage

- `npfctl` can be used to communicate with /dev/npf via ioctls
  - start, stop, reload, flush, stats, tables, sessions, ...
- Rules are translated into bytecode, and pushed down to the kernel
- The parser has been recently rewritten by christos@ based on martin@'s code

Features - variables and groups

- Each group has a name and an interface defined
- If there's no deciding rule in the custom group, the default group's rules will be inspected
- It's important to mark any deciding rule final ("quick")

```
ext_if = "wm0"
int_if = "wm1"

group (name "external", interface $ext_if) {
    ...
}

group (name "internal", interface $int_if) {
    ...
}

group (default) {
```

Features - rule procedures

- Allows connection-based packet transformation
- If made pluggable, would allow kernel modules to perform custom packet modifications
- Currently

```
procedure "rid" {
    normalize (random-id)
}

procedure "log" {
    log npflog0
}
```

Features - tables

```
table "1" type tree dynamic
table "2" type hash file "/etc/npf_backlist"

group (default) {
    block in quick from <1>
    block out quick to <2>
}
```

Features - Application Level Gateways

- Some protocols embed lower level information in their payload (think FTP's PORT, SIP, RTSP)
- In order to dynamically handle these, we need to actually process the data
- This is mostly important for NAT setups
- Currently there's only one ALG implemented for ICMP (traceroute support)...

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)

```
ext_if = "wm0"
int_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 the netmask(255.255.255.0 or /24), we just store the mask
  - 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;
```

TODOs after the 6.0 release

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- 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

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- Write more documentation and fix remaining bugs

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- Optimize the ruleset
  - first step could be to prune the graph based on heuristics
  - then to compile it to actual machine code (JIT/LLVM/...)
- Make the network stack lockless, but this is a daunting task

Questions and answers?

Arigatou gozaimashita!