Network Management with the OpenBSD Packet Filter Toolset

BSDCan 2025

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Administratrivia / Useful info

- Wifi network:

  guOttawa

- Slides downloadable from

  https://nxdomain.no/~peter/pf_fullday.pdf

  (do it now! keep for later!)

Peter Hansteen

- Sysadmin, OpenBSD user since before the millennium
- Wrote The Book of PF, now in its third edition
- Blog at bsdly.blogspot.com about (lack of) sanity in IT
- Works at Tietoevry Create
- Yes, I'll do another book any decade now

Massimiliano Stucchi

- IPv6 "Enthusiast"
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Tom Smyth

- working in IT since 2000
- CTO wireless Connect Ltd. an ISP in Ireland
- Opinions are mine and may be my companies also :)
- PF student, an avid reader of the Book of PF
- I really Enjoy networking with OpenBSD
- Maintainer of the NSH network Shell for OpenBSD

Welcome!

- Let’s introduce ourselves

- Let us know:
  - Your name
  - Your organization and role
  - Your favorite BSD
  - Your experience with networking, and with PF
  - Is there anything specific you would like to learn or understand today?

Agenda

1. PF Basics
   - Exercise: Host configuration
2. NAT and Redirects
   - Exercise: Setup a gateway
3. Hosting Services
   - Exercise: Hosting Services, redirects
4. Traffic Shaping
   - Exercise: Setting up queueing
5. Redundancy with CARP+pfsync
   - Exercise: Setting up failover firewalls
6. Tips
7. Troubleshooting
   - Exercise: NAT64
8. End

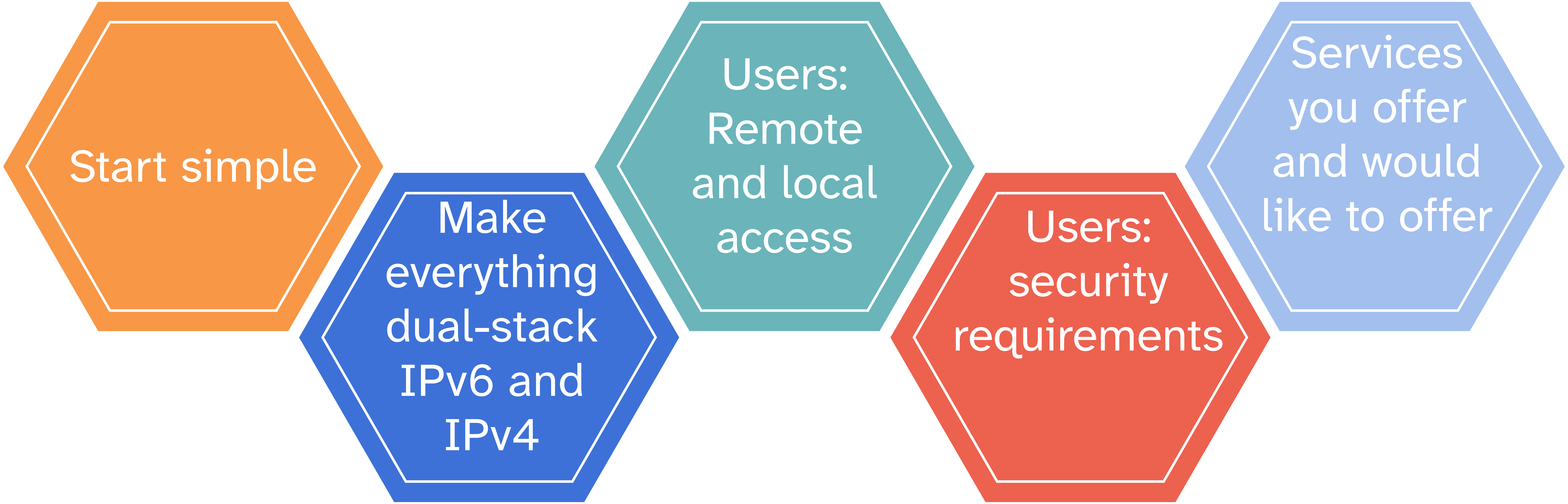
PF Basics

Section 1

At the beginning

- OpenBSD up to 2.9 (2001) used Darren Reed's IPFilter
  - Almost, but not quite BSD licensed
  - No right to distribute changed versions
- IPFilter removed on May 29th, 2001
  - First commit of the new PF code June 24 2001 at 19:48:58 UTC
  - OpenBSD 3.0 release pushed to Dec 1 by the extra effort
- *License audit* of src tree + ports tree followed

Building a maintainable network



Start simple

Make everything dual-stack IPv6 and IPv4

Users: Remote and local access

Users: security requirements

Services you offer and would like to offer

Keep it simple, not stupid

A firewall can

- allow certain packets flowing to or through the firewall device

- drop certain packets flowing to or through the firewall device

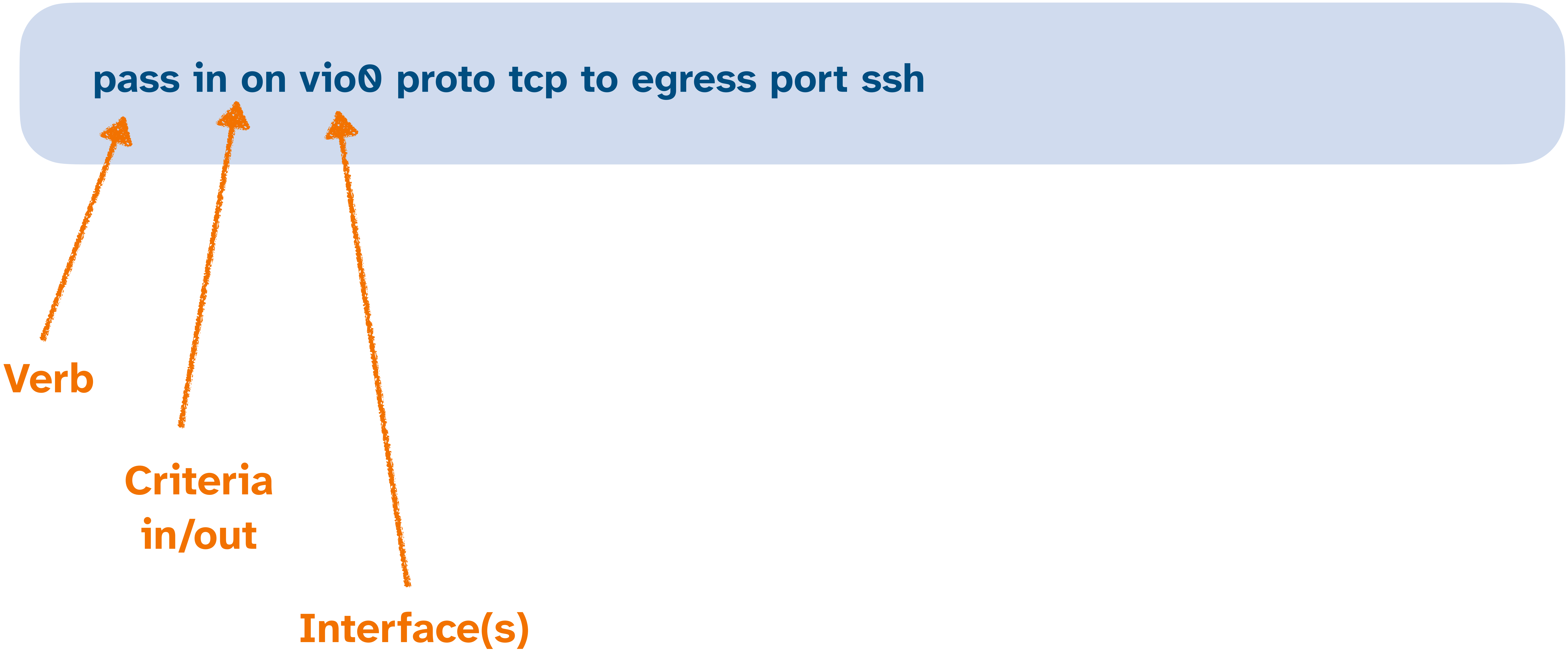
- redirect or NAT packets according to policy

A firewall cannot

- Block inbound Flood Denial of Service attacks that exceed:
  - the inbound interface capacity
  - the CPU I/O / interrupt capacity of the interface

- This is due to:
  - Inbound interface bandwidth limitations
  - CPU I/O interface driver packets per second(PPS) limitations

Basic rule format



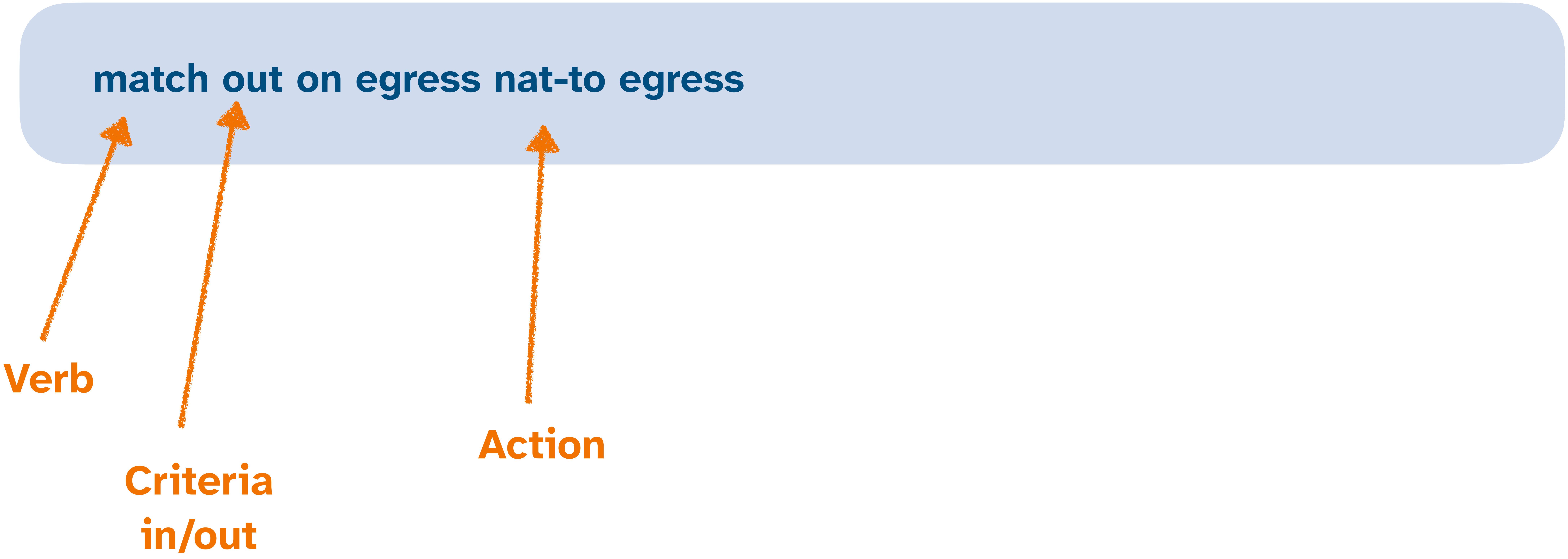
```
pass in on vio0 proto tcp to egress port ssh
```

Verb

Criteria
in/out

Interface(s)

Match rule



```
match out on egress nat-to egress
```

Verb

Criteria
in/out

Action

Ruleset evaluation

- Top to bottom
- Stateful by default
- Rule order matters!

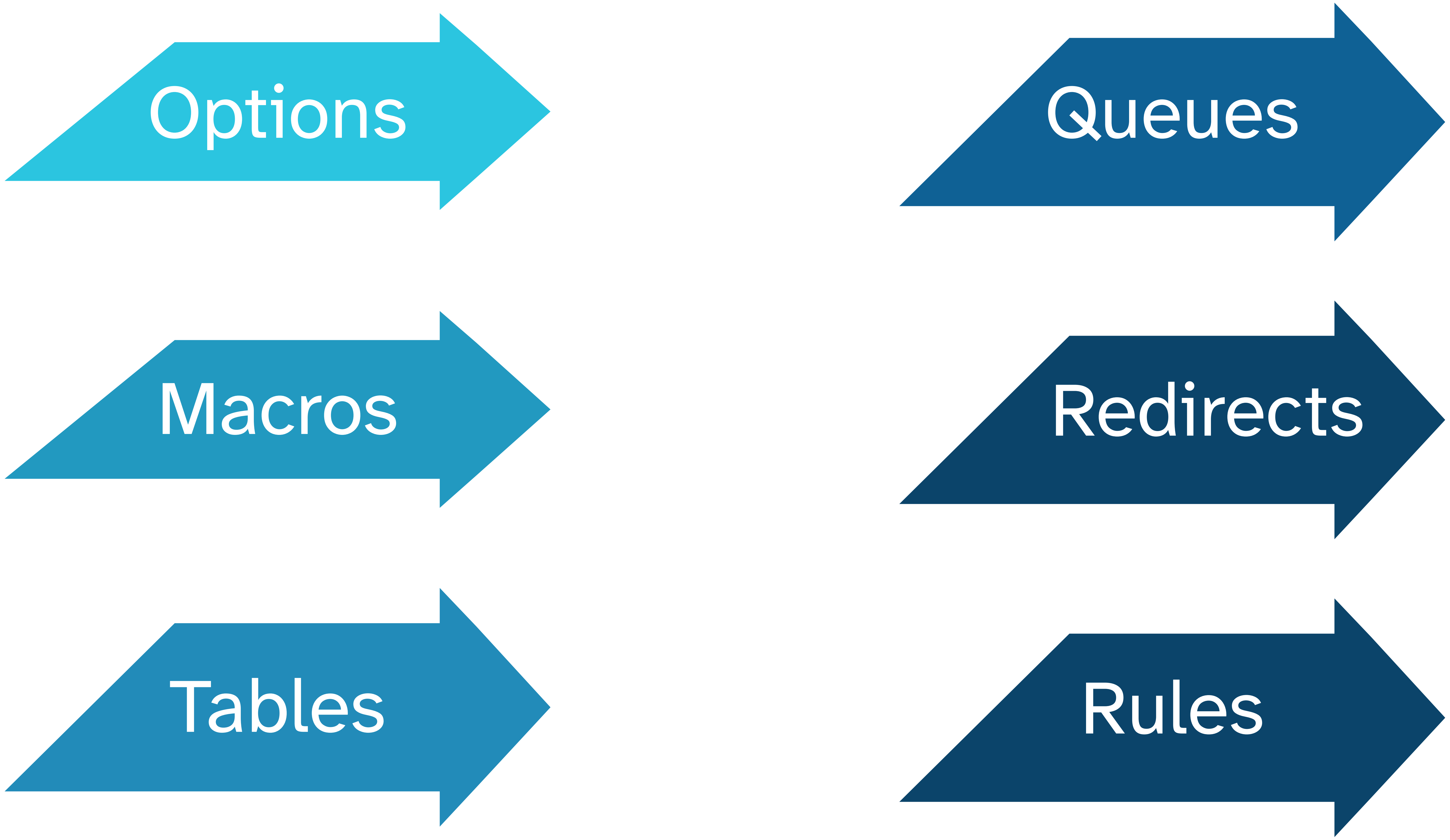
Last match wins!

Unless *quick* is used

Interface groups

- Logically group network interfaces
- Built-in “egress”
  - Interface(s) with default route pointing to them
- Use ifconfig to assign interfaces to groups
- Helps in making rulesets more readable

Components of a ruleset



Options

Queues

Macros

Redirects

Tables

Rules

Options

- General configuration for pf
- Useful for debugging, applying default timeout values, etc.

```
set limit states 1000000
```

- Other examples

```
set debug debug
set loginterface dc0
set timeout tcp.first 120
set timeout tcp.established 86400
set timeout { adaptive.start 6000, adaptive.end 12000 }”
```

Macros

- Content to be expanded
  - Used for interface aliases
  - Or groups of interfaces

```
ext_if=“vio0”
all_ifs=“{ $ext_if lo0 }”
pass in on $ext_inf proto tcp from any to any port 25
```

  - Or groups of ports

```
bacula_ports = “9101:9103”
dmz_hosts = “192.0.2.1 - 192.0.2.254”
```

Tables

- When macros grow too big or long, tables are preferred
- Hold only addresses and networks
  - No port ranges
- Provide fast lookups
- Can be manipulated from outside pf, from the command line

```
table <bruteforce> persist counters

block from <bruteforce>
```

- They do not expand to multiple rules - unlike macros

Tables

- You can load content from files or the CLI

```
table <popflooders> persist counters file "/home/peter/popflooders"
```

- You can save a table content to a file

```
$ doas pfctl -t popflooders  -T show >/home/Peter/popflooders
```

- And you can add/remove entries from the CLI

```
$ doas pfctl -t bruteforce -T add 192.0.2.11 2001:db8::dead:beef:baad:f00d
```

- This way it can be used with daemons like spamd, bgpd and dhcpd

Putting this together

- A simple ruleset would block everything
- And then allow specific ports/protocols or combination thereof

- A very simple ruleset:

```
block
pass from (self)
```

- Would expand to...

Simple ruleset - expanded

```
$ doas pfctl -vnf /etc/pf.conf
block drop all
pass inet6 from ::1 to any flags S/SA
pass on lo0 inet6 from fe80::1 to any flags S/SA
pass on iwm0 inet6 from fe80::a2a8:cdff:fe63:abb9 to any flags S/SA
pass inet6 from 2001:470:28:658:a2a8:cdff:fe63:abb9 to any flags S/SA
pass inet6 from 2001:470:28:658:8c43:4c81:e110:9d83 to any flags S/SA
pass inet from 127.0.0.1 to any flags S/SA
pass inet from 192.168.103.126 to any flags S/SA
```

- This is what a typical home net would look like

Protecting your host

Exercise 1

Connecting to the lab

- Open a browser and go to https://lab1.glevia.ch

- Username is your number on the list
- Password will be indicated by the trainers

- NB: When you see “**X**”, replace it with the number assigned to you
- When you see “**XX**” and your number is below 10, add a zero in front of it

Exercise 1 - First steps

- Check that pf is indeed loaded and running (hint: pfctl)

- Wait until everyone has connected in order to proceed

Exercise 1 - Network configuration

- Configure the external interface on gateway
  - *vi /etc/hostname.vio0*

```
inet 10.255.255.X/24
!route add 0/0 10.255.255.254
inet6 fd18:b5d:cafe::X/64
!route add -inet6 2000::/3 fd18:b5d:cafe::a
!route add -inet6 fd00::/8 fd18:b5d:cafe::a
```

- And then configure the DNS servers
  - *vi /etc/resolv.conf*

```
nameserver 10.255.255.254
nameserver fd18:b5d:cafe::a
```

- Last: *sh /etc/netstart*

Exercise 1 - On gateway

- Start with a block ruleset - (vi /etc/pf.conf)

```
block
pass quick inet6 proto tcp from fd18::/16 to port ssh
 pass quick inet6 proto icmp6 from fd18::/16
```

- Allow traffic to be generated from the host and allow ICMPv6

```
pass from self
```

- And then reload pf.conf

```
 # pfctl -vnf /etc/pf.conf
# pfctl -f /etc/pf.conf
```

- NB: You should reload like this after every statement in the exercises

Exercise 1 - Tests

- From your gateway, ping a host
  - First IPv6, then IPv4

```
# ping6 fd18:b5d:cafe::a
 PING fd18:b5d:cafe::a (fd18:b5d:cafe::a): 56 data bytes
 64 bytes from fd18:b5d:cafe::a: icmp_seq=0 hlim=64 time=0.548 ms
 64 bytes from fd18:b5d:cafe::a: icmp_seq=1 hlim=64 time=0.492 ms
 64 bytes from fd18:b5d:cafe::a: icmp_seq=2 hlim=64 time=0.494 ms
```

```
# ping stucchi.ch
PING stucchi.ch (45.129.224.40): 56 data bytes
64 bytes from 45.129.224.40: icmp_seq=0 ttl=56 time=6.264 ms
64 bytes from 45.129.224.40: icmp_seq=1 ttl=56 time=6.273 ms
64 bytes from 45.129.224.40: icmp_seq=2 ttl=56 time=6.117 ms
```

Exercise 1 - tcpdump is your friend

- Read logged traffic from your pflog0 interface

```
# doas tcpdump -nettti pflog0
```

- What do you see ?

- How can you put this information to good use ?

Exercise 1 - Wrap Up

- Does ping work?
- Do other commands work?
  - working from total block, proceed to make restricted workstation
  - name resolution
  - http and https
- Access public web sites, other Internet resources
- What would it take to access the other lab hosts?

Gateway, NAT and Redirects

Section 2

How do we improve on what we’ve done?

- Make a 'firewall':
  - a point of policy enforcement
  - a gateway
  - filter for other hosts
  - redirection tricks

Introducing NAT

- **N**etwork **A**ddress **T**ranslation (RFC1631 onwards)
- 'Hide' several hosts behind 1 or more public addresses, using RFC1918 addresses
- Can be used by ISPs for conserving scarce IP addresses in large networks (CG-NAT) 100.64.0.0/10
- Does not allow for direct communication with hosts behind it
- It is <u>NOT</u> a security mechanism!

NAT Rules in pf

- Today's pf has a special syntax for NAT:

```
match out on $ext_if inet nat-to ($ext_if)
```

- Remember egress ? You can use it to simplify this rule

```
match out on egress inet nat-to (egress)
```

A (filtering) gateway

"I decide which packets pass"

Enable forwarding

- Temporarily on the command line with sysctl:

```
# sysctl net.inet.ip.forwarding=1
# sysctl net.inet6.ip6.forwarding=1
```

- Make permanent in /etc/sysctl.conf:

```
net.inet.ip.forwarding=1
net.inet6.ip6.forwarding=1
```

The minimal gateway

- Do you *NAT* for *IPv4*? Of course you do.
- Do you run *IPv6*? Of course you do.

```
ext_if=vio0
int_if=vio1
match out on egress inet nat-to ($ext_if)
block all
pass proto tcp from { self, $int_if:network }
```

- *The* pass *rule, without* inet *or* inet6, *applies to* ***both***

Keep in mind: *This is a point of policy enforcement*

A point of policy enforcement

- Now some policy, and macros

```
ext_if=vio0
int_if=vio1
client_out = "{ ftp-data, ftp, ssh, domain, pop3, auth, nntp, http, \
    https, 2628, 5999, 8000, 8080 }"
udp_services = "{ domain, ntp }"
match out on egress inet nat-to ($ext_if)
block
pass quick proto { tcp, udp } to port $udp_services keep state
pass proto tcp from $int_if:network to port $client_out
pass proto tcp to self port ssh
```

- What services do *your* clients consume?

Letting dhcpd(8) direct access

- OpenBSD dhcpd(8) can interact with your ruleset via tables.

  Add this to your /etc/rc.conf.local:

```
dhcpd_flags="-L leased_ip_table -A abandoned_ip_table -C changed_ip_table vio1"
```

- *Then instrument your your /etc/pf.conf -*

Letting dhcpd(8) direct access

```
ext_if=vio0
int_if=vio1
table <abandoned_ip_table> persist counters
table <changed_ip_table> persist counters
table <leased_ip_table> persist counters
client_out = "{ ftp-data, ftp, ssh, domain, pop3, auth, nntp, http, \
                https, 2628, 5999, 8000, 8080 }"
udp_services = "{ domain, ntp }"
match out on egress inet nat-to ($ext_if)
block
pass quick proto { tcp, udp } to port $udp_services keep state
pass proto tcp from <leased_ip_table> to port $client_out
pass proto tcp to self port ssh
```

- Only pass traffic from hosts with active leases from *me*

Redirects (and divert-to)

- Modern PF has two classes of redirect:

- rdr-to on match and pass rules - rewrite destination address while filtering (locally or even to other hosts

```
pass in on egress to port www rdr-to $webserver
```

- divert-to on match and pass rules - divert() socket for local use

```
pass in on egress to port smtp divert-to 127.0.0.1 port spamd
```

FTP Proxy

- If your users need to access FTP services, ftp-proxy is what you need
- FTP does not easily pass through a block firewall, some help is needed

```
$ doas rcctl enable ftpproxy6
```

- Or for IPv4

```
$ doas rcctl enable ftpproxy
```

- and then add an anchor and divert rules to your config ->

FTP Proxy, pf.conf part

- Add anchors + redirecting **pass** rules to your ruleset

```
anchor "ftp-proxy/*"
## ...
pass in quick inet proto  tcp to port ftp divert-to 127.0.0.1 port 8021
pass in quick inet6 proto tcp to port ftp divert-to ::1 port 8021
pass out proto tcp from $proxy to port ftp
```

- There is even a reverse mode (**-R**) for when you host FTP servers, see man ftp-proxy

Accommodating Virtual Private Networks (VPNs)

- SSH: ssh based (ssh tunnels): Already in our baseline (pass port ssh)
- IPsec with UDP key exchange (IKE/ISAKMP):

  Key exchange (IKE): pass proto udp port 500 from $source to $target
  NAT Traversal (NAT-T): pass proto udp port 4500 from $source to $target
  Encapsulating Security Payload
  protocol (ESP): pass proto esp from $source to $target

- Filtering on IPsec encapsulation interfaces:
  pass on enc0 proto ipencap from $source to $target keep state (if-bound)

  - if the enc0 interface is down, traffic will NOT pass assuming block default

Protecting your network

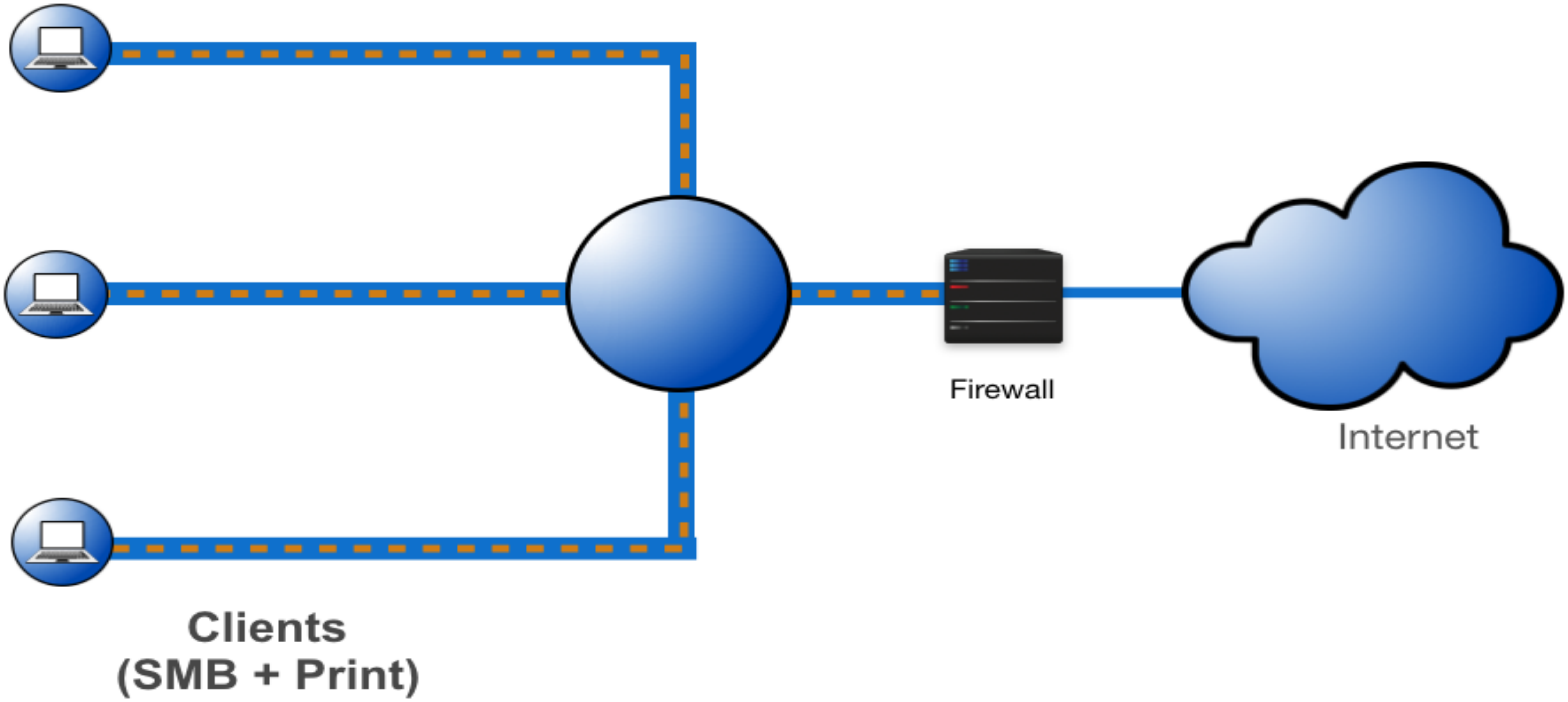
Exercise 2

Excercise 2 - Goals

- Your network grows, you become a gateway

- Extend the configuration to enable the network to access the internet

Excercise 2 - Your network



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Excercise 2

- Turn on forwarding:

```
# sysctl net.inet.ip.forwarding=1
# sysctl net.inet6.ip6.forwarding=1
```

- Set up NAT:

```
match out on egress inet nat-to (egress)
```

Also pass traffic from local net

Excercise 2 - Preparation

- Configure the hosts with the following IPv6 addresses
  - Gateway (vio1): fd18:b5d:**XX**::a/64
  - Host1: fd18:b5d:**XX**::80/64
  - Host2: fd18:b5d:**XX**::25/64
- On Host1 and Host2, set fd18:b5d:**XX**::a as the default IPv6 gateway, and also the following IPv4 addresses
  - Gateway (vio1): 192.168.**X**.1/24
  - Host1: 192.168.**X**.2/24
  - Host2: 192.168.**X**.3/24
- On Host1 and Host2 set 192.168.**X**.1 as the default IPv4 gateway

Excercise 2 - Check your results

- From client 1, ping a host on the internet

- First IPv6

```
# ping6 stucchi.ch
PING stucchi.ch (2a0e:5040:1::80): 56 data bytes
64 bytes from 2a0e:5040:1::80: icmp_seq=1 hlim=56 time=7.414 ms
64 bytes from 2a0e:5040:1::80: icmp_seq=2 hlim=56 time=6.333 ms
64 bytes from 2a0e:5040:1::80: icmp_seq=3 hlim=56 time=6.441 ms
```

- Then IPv4

```
# ping stucchi.ch
PING stucchi.ch (45.129.224.40): 56 data bytes
64 bytes from 45.129.224.40: icmp_seq=0 ttl=56 time=6.264 ms
64 bytes from 45.129.224.40: icmp_seq=1 ttl=56 time=6.273 ms
64 bytes from 45.129.224.40: icmp_seq=2 ttl=56 time=6.117 ms
```

Excercise 2b: FTP

- Try fetching ftp://ftp.ripe.net/pub/stats/ripencc/delegated-ripencc-extended-latest

```
# wget ftp://ftp.ripe.net/pub/stats/ripencc/delegated-ripencc-extended-latest
```

Check your result

If it didn't work, configure ftp-proxy and try again

Hosting Services

Section 3

Hosting services behind your gateway

- Now you actually want some '**pass in on egress**' rules :)
- Get your specifications clear, put in writing:
  - your services and the ports they use
  - the names could be in /etc/services already
  - the hosts (IP addresses) that run the services
  - decide who/what/where to be reachable for/from
- Check services requiring extra help (i.e. proxying).

Proxies and other helpers

- OpenBSD comes with several proxies and other service helper programs in the base system:
  - ftp-proxy (you guessed it)
  - relayd (load balancing and lots more)
  - spamd (if you run SMTP - annoy spammers)

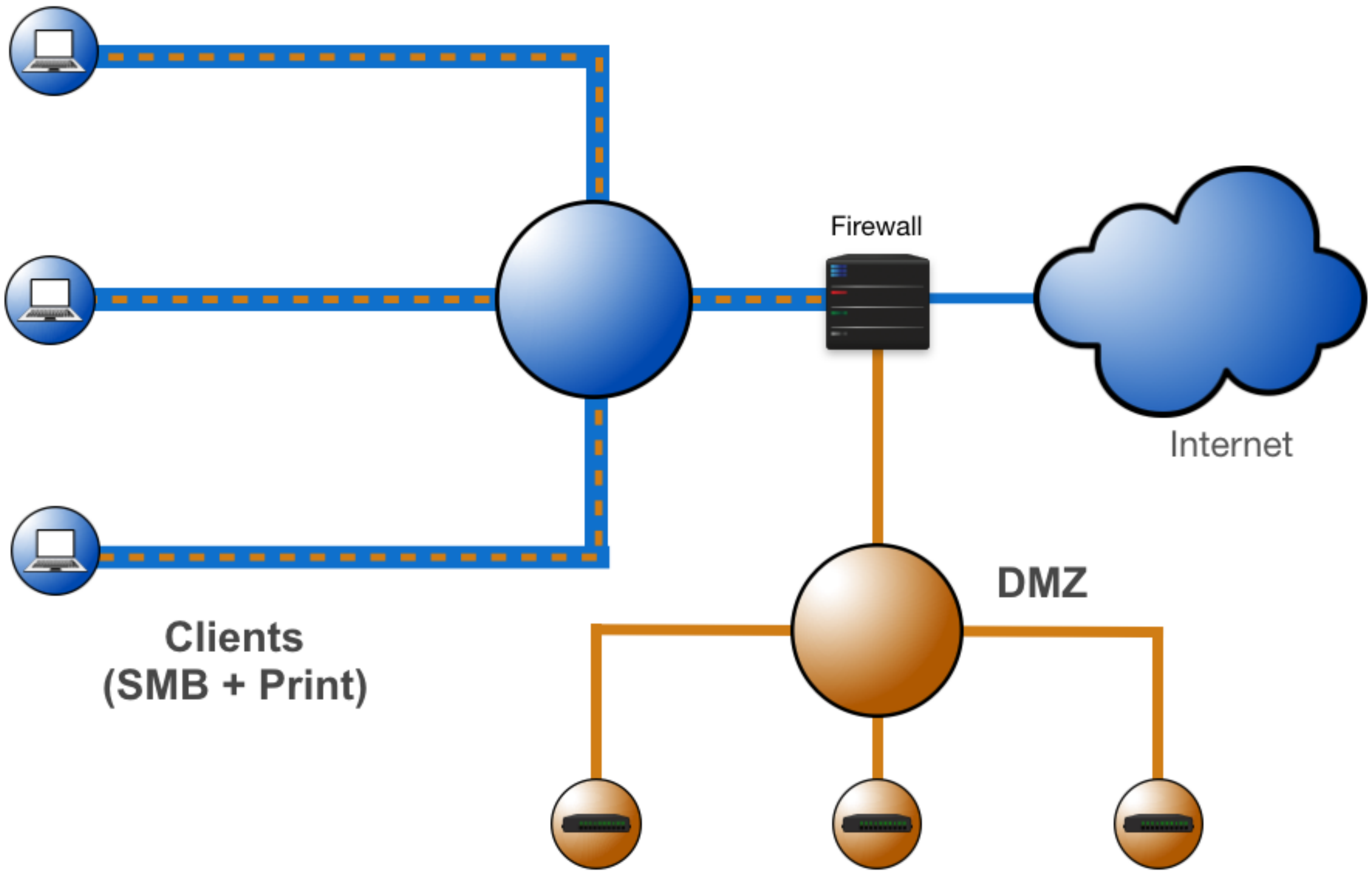
- There are also such things as squid and varnish (web proxies) in packages

- Clients and services in the same subnet? Or do the DMZs?

DMZ - Defined

- '***D****e-****M****ilitarized* ***Z****one*'
- when a group of host needs special treatment
- attached to separate interfaces(s), separate sub-rulesets
- And *YES*, you can have several
- Think multiple customers, *N* environments each

DMZ - Illustrated



Allowing some services in (1/2)

-
  ```
  ext_if=vio0 # adjust to what your system has
  int_if=vio1 # adjust to what your system has
  client_out = "{ ftp-data, ftp, ssh, domain, pop3, auth, nntp, http, \
                  https, 2628, 5999, 8000, 8080 }"
  udp_services = "{ domain, ntp }"
  webserver = "192.0.2.227"
  webports = "{ http, https }"
  emailserver = "192.0.2.225"
  email = "{ smtp, pop3, imap, imap3, imaps, pop3s }"
  nameservers = "{ 192.0.2.221, 192.0.2.223 }"
  ```
- fetchable as *pf.services01.conf*

Allowing some services in (2/2)

-

```
match out on egress inet nat-to ($ext_if)
block
pass quick proto { tcp, udp } to port $udp_services keep state
pass proto tcp from $int_if:network to port $client_out
pass proto tcp to self port ssh
pass proto tcp to $webserver port $webports
pass proto tcp to $emailserver port $email
pass log proto tcp from $emailserver to port smtp
pass inet proto { tcp, udp } to $nameservers port domain
```

- Now try loading this with **pfctl -vnf /etc/pf.conf** and see what this expands to

Tackling noise (attacks) with state-tracking options

Scenario: ssh bruteforcers

- In our previous ruleset, add

```
table <bruteforce> persist counters
block from <bruteforce>
```

- and change the ssh rule to

```
pass proto tcp to port ssh flags S/SA keep state \
   (max-src-conn 15, max-src-conn-rate 2/10, overload <bruteforce> flush global)
```

- Tune to taste, more info on options in **man pf.conf**
- Remember **pfctl expire**

Tackling noise (attacks) with state-tracking options

- Scenario: WordPress site
- Wordpress is a usual target for many different attacks
- -> Make the attackers suffer by forcing them through smaller "windows"
  - Use tables and block by connection rates
- Mix and match settings, consult man pf.conf and remember pfctl expire
- Also see *Forcing the password gropers through a smaller hole with OpenBSD's PF queues*, *Badness, Enumerated by Robots* (blog posts) + *The Book of PF*

Scenario: Wordpress site

You can re-use the *bruteforce* table or make a separate one, like

```
table <web_brutes> persist counters
 block from <web_brutes>
```

- and change the $webports rule to

```
pass proto tcp to port $webports flags S/SA keep state \
   (max-src-conn 15, max-src-conn-rate 5/10, overload <web_brutes> flush global)
```

Adjust values to taste and actual numbers

- Alternatively, on a gateway that does *not* run WordPress itself -

Scenario: Wordpress site

- You can populate the web_brutes table separately, with a scripted command like

```
grep wp-login /var/www/logs/access.log | awk '{print $1}' | \
  sort -u | xargs doas pfctl -t web_brutes -T add
```

- Again, adjust to taste, add variations (run frequently from crontab)

```
pass proto tcp to port $webports flags S/SA keep state \
  (max-src-conn 15, max-src-conn-rate 5/10, overload <web_brutes> flush global)
```

- (**Wordpressers**: Do these look right? Consult web logs and tcpdump output.)

Annoying spammers with spamd

- spamd(8) is good, clean, fun
- Speaks enough SMTP to do *greylisting*
- Can tarpit known bad senders and generate blacklists by greytrapping

- Default spamd.conf gives you one blacklist import and basics
  - (Hint: no real SMTP service required)

- You can even generate your own blacklists by greytrapping via non-deliverable spamtrap addresses in your own domain(s)

  Also see:

  - *The Book of PF*
  - *In The Name Of Sane Email: Setting Up OpenBSD's spamd(8) With Secondary MXes*
  - *Maintaining A Publicly Available Blacklist*

Annoying spammers with spamd

- Set up tables
- Divert traffic to the spamd process
- Only let the "good guys" pass to the real SMTP daemon

```
table <spamd-white> persist
table <nospamd> persist file "/etc/mail/nospamd"
pass in on egress proto tcp to any port smtp divert-to 127.0.0.1 port spamd
pass in on egress proto tcp from <nospamd> to any port smtp
pass in log on egress proto tcp from <spamd-white> to any port smtp
pass out log on egress proto tcp to any port smtp
```

- Next, enable the service -

Annoying spammers with spamd

- Enable and start the **spamd** service

```
$ doas rcctl enable spamd
$ doas rcctl start spamd
```

- **TIP**: check out smtpctl spf walk <nospamd_domains.txt to feed your nospamd table from live SPF data (in OpenBSD 6.3 onwards),

- See the blog posts *Goodness, Enumerated by Robots. Or, Handling Those Who Do Not Play Well With Greylisting* (2018) and *Three Minimalist spamd Configurations for Your Spam Fighting Needs (With Bonus Points at the End)* (2024)

Scenario: SYN flood vs syncookies

- A common Denial-of-Service (DOS) technique is to send large numbers of SYNs from spoofed addresses, filling up the state table.

- In OpenBSD 6.3 and newer we have the pf.conf option

  ```
  set syncookies
  ```

- The default is off, if you enable with

```
set syncookies on
```

- all SYNs get SYNACK answer, but no resources allocated until ACK received (pending match to pass rule)

- The other option is adaptive with syncookies used only when half open TCP connections reach the **start** percentage, until the **end** level is reached

```
set syncookies adaptive (start 29%, end 15%)
```

Consider: what about that separate DMZ?

- What do you need?
- IP addresses: Segment off or allocate separate address ranges
- Attach each segment to separate interface or VLAN
- Do the ruleset surgery
  - Which services do you run, where
  - Do you need renumbering?
  - What traffic (in and out) is actually required?

Questions?

Questions?

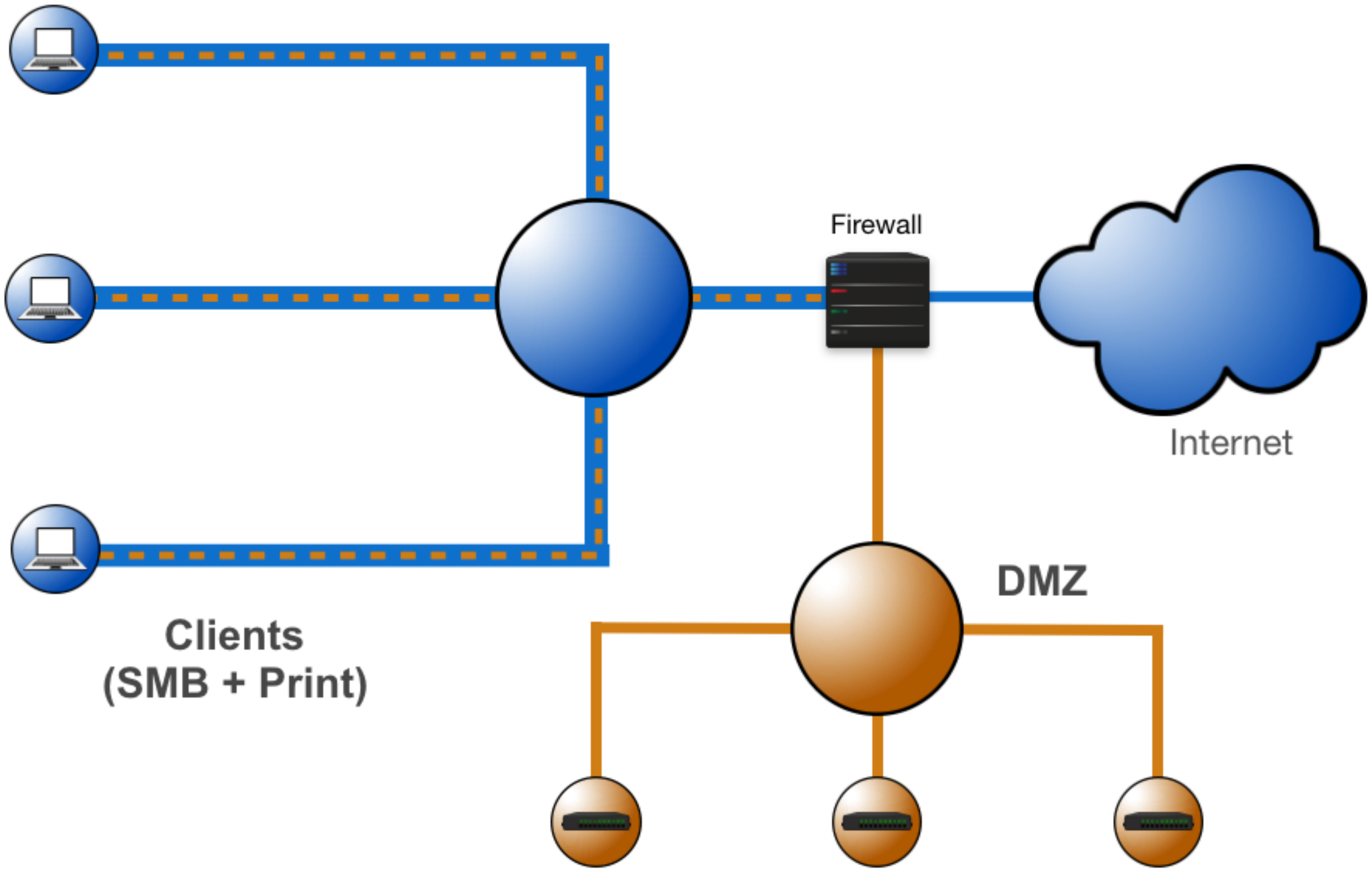
Offering Services

Exercise 3

Excercise 3 - Goals

- You're now offering services
- Host 1 will provide http service
- Host 2 will provide smtp service
- We need to setup:
  - The services
  - Redirects
  - Firewall rules

Excercise 3 - Network



Exercise 3 - on Host1

- We need to configure and start httpd

-
  ```
  # cp /etc/examples/httpd.conf /etc/httpd.conf
  < comment out the HTTPS part >
  # rcctl enable httpd
  # rcctl start httpd
  httpd(ok)
  ```

Exercise 3 - on Host1

- Stop the smtpd daemon

```
# rcctl stop smtpd
```

- Change the config to listen on all interfaces:
  - Change the appropriate line in /etc/mail/smtpd.conf

```
listen on all
```

- Then start the daemon

```
# rcctl enable smtpd
# rcctl start smtpd
smtpd(ok)
```

(It might take a while)

Exercise 3 - on gateway

- /etc/pf.conf (NOTE: no redirects needed for IPv6)

```
webserver_v4 = "$IP_addr_of_host1"
webserver_v6 = "fd18:b5d:XX::80"
webports = "{ http, https }"
emailserver_v4 = "$IP_addr_of_host2"
emailserver_v6 = "fd18:b5d:XX::25"
email = "{ smtp, pop3, imap, imaps, pop3s }"
match in on egress inet proto tcp to egress port $webports rdr-to $webserver_v4
match in on egress inet proto tcp to egress port $email rdr-to $emailserver_v4
pass inet proto tcp to $webserver_v4 port $webports
pass inet proto tcp to $emailserver_v4 port $email
pass log inet proto tcp from $emailserver_v4 to port smtp
pass inet6 proto tcp to $webserver_v6 port $webports
pass inet6 proto tcp to $emailserver_v6 port $email
pass log inet6 proto tcp from $emailserver_v6 to port smtp
```

Exercise 3 - check your work

- Try connecting to the HTTP and SMTP port of your friends/neighbours:

  From Gateway:

```
telnet -6 fd18:b5d:XX::80 80
telnet -4 10.255.255.XX 80
```

  - and for smtp

```
telnet -6 fd18:b5d:XX::25 25
telnet -4 10.255.255.XX 25
```

Tips

- Decide your network topology
  - DMZ (?)
  - Multi-customer (?)
  - Multi-customer, Multi-DMZ(?)
- Segment off your subnets
  - IPv4 (Do you NAT)?
  - IPv6
  - Do you do NAT64?
- Per subnet (customer)
  - Which services do you expose?
  - Write the rules
  - pamper^H^H^H^Hproxying

Traffic Shaping

Section 4

Traffic shaping

- OpenBSD has three separate shaping techniques:
  - priorities (set prio), introduced in OpenBSD 5.0
  - queues, introduced in OpenBSD 5.5, and
  - flows, introduced in OpenBSD 6.2 (aka FQ-CoDel)
- Remember:
  - Traffic shaping is about dropping packets
  - But is only relevant when there's a reason to start dropping
  - Then you get to pick which ones using the traffic shaping tools
- Works only one way, outbound

Traffic shaping with priorities

- In OpenBSD, every packet has a priority

- Possible values are 0 (garbage) through 7 (want!)
  - Default for most traffic is 3.

- So if you want all ssh traffic to move ahead of other traffic you could do a

```
pass proto tcp to port ssh set prio 6
```

and assign specific, non-default (!= 3) values to others.

Beating the FIFO with prio

- By default, packets are serviced on a first come, first served basis
  - or 'First in, First out' (FIFO).
- But: TCP wants ACKs for sent packets within a reasonable time
  - Otherwise the packet is considered lost, and retransmit will follow (transfer stalls).
- ACKs are tiny and have their TOS set to lowdelay, and this trick will cheat the FIFO:

```
match out on $ext_if proto tcp from $ext_if set prio (3, 7)
match in  on $ext_if proto tcp to $ext_if set prio (3, 7)
```

as per the man page -

Beating the FIFO with prio

- as per the man page,

  If two priorities are given, TCP ACKs with no data payload and packets which have a TOS of lowdelay will be assigned to the second one. Packets with a higher priority number are processed first, and packets with the same priority are processed in the order in which they are received.

- See *Prioritizing empty TCP ACKs with pf and ALTQ* by Daniel Hartmeier for the ALTQ way

FQ-CoDel flows for fair bandwidth sharing

- Introduced in *OpenBSD 6.2*, the FQ-CoDel algorithm (see *RFC8290*) defines flows to set up fair sharing for a specified number of simultaneous connections

- Enable for your configuration with something like

```
queue outq on vio0 bandwidth 18M max 18M flows 1024 qlimit 1024 default
```

Estimate your approximate high number of simultaneously actively transmitting sessions, put that number in (up to 32767)

Shaping with HFSC queues - fixed sizes

- When priorities don't quite cut it, you can slice your bandwidth into queues.
- For static shaping, give bandwidth values in absolute values:
- Only leaf queues can be assigned traffic
  - make sure allocations sum up to parent queue allocation
- Unless quotas approach saturation, no actual shaping (dropping) will take place

Shaping with HFSC queues - fixed sizes

```
queue main on $ext_if bandwidth 20M
    queue defq parent main bandwidth 3600K default
    queue ftp parent main bandwidth 2000K
    queue udp parent main bandwidth 6000K
    queue web parent main bandwidth 4000K
    queue ssh parent main bandwidth 4000K
      queue ssh_interactive parent ssh bandwidth 800K
      queue ssh_bulk parent ssh bandwidth 3200K
queue icmp parent main bandwidth 400K
```

Shaping with HFSC queues - fixed assignment

- You can either do queue assignment with match rules:

```
match log quick on $ext_if proto tcp to port ssh queue (ssh_bulk, ssh_interactive)
match in quick on $ext_if proto tcp to port ftp queue ftp
match in quick on $ext_if proto tcp to port www queue http
match out on $ext_if proto udp queue udp
match out on $ext_if proto icmp queue icmp
```

- treat filtering (**block, pass**) in separate rules,
  - or append '**set queue**' to individual pass rules

- Any traffic not explicitly assigned goes in the default queue

Shaping with HFSC queues - flexible allocations (min, max, burst)

- You can build in flexibility:

```
queue rootq on $ext_if bandwidth 20M
     queue main parent rootq bandwidth 20479K min 1M max 20479K qlimit 100
         queue qdef parent main bandwidth 9600K min 6000K max 18M default
         queue qweb parent main bandwidth 9600K min 6000K max 18M
         queue qpri parent main bandwidth 700K min 100K max 1200K
         queue qdns parent main bandwidth 200K min 12K burst 600K for 3000ms
     queue spamd parent rootq bandwidth 1K min 0K max 1K qlimit 300
```

Note here the added *min* and *max* values: combined queue bandwidth can exceed actual sum; this gets you upper and lower bound within physical limits.

- *burst N for M* - allow bursts of that size and length

- *qlimit* - size of the queues holding buffer - larger values may delay (packets are kept longer before sending)

systat(1)

- Available on all the BSDs
  - OpenBSD version has added functionalities
- Offers view into your system's traffic
  - Live queues, states, rules
- Check how your rules are behaving on your system in realtime
- More info in the man page systat(1)

queue monitoring - systat queues

```
   1 users Load 2.56 2.27 2.28                        skapet.bsdly.net 20:55:50

QUEUE                BW SCH  PRI      PKTS   BYTES   DROP_P   DROP_B QLEN BOR SUS  P/S   B/S
rootq on bge0       20M                  0       0        0        0    0            0     0
 main               20M                  0       0        0        0    0            0     0
  qdef               9M            6416363   2338M      136    15371    0          462 30733
  qweb               9M             431590 144565K        0        0    0          0.6   480
  qpri               2M            2854556 181684K        5      390    0           79  5243
  qdns             100K             802874  68379K        0        0    0          0.6    52
 spamd               1K             596022  36021K  1177533 72871514  299            2   136
```

queue monitoring - pfctl

```
  $ doas pfctl -vsq
 [ pkts:          0  bytes:          0  dropped pkts:      0 bytes:      0 ]
 [ qlength:   0/ 50 ]
queue rootq on bge0 bandwidth 20M qlimit 50
 [ pkts:          0  bytes:          0  dropped pkts:      0 bytes:      0 ]
 [ qlength:   0/ 50 ]
queue main parent rootq bandwidth 20M, min 1M, max 20M qlimit 100
 [ pkts:          0  bytes:          0  dropped pkts:      0 bytes:      0 ]
 [ qlength:   0/100 ]
queue qdef parent main bandwidth 9M, min 8M, max 18M default qlimit 50
 [ pkts:    6517150  bytes: 2458545319  dropped pkts:    136 bytes:  15371 ]
 [ qlength:   0/ 50 ]
queue qweb parent main bandwidth 9M, min 8M, max 18M qlimit 50
 [ pkts:     431741  bytes:  148072219  dropped pkts:      0 bytes:      0 ]
 [ qlength:   0/ 50 ]
queue qpri parent main bandwidth 2M, min 700K, max 2M burst 4M for 3000ms qlimit 50
 [ pkts:    2855418  bytes:  186101241  dropped pkts:      5 bytes:    390 ]
 [ qlength:   0/ 50 ]
 queue qdns parent main bandwidth 100K, min 12K burst 600K for 3000ms qlimit 50
```

add another v (pfctl -vvsq) for continuously updating display

Questions?

Questions?

Queueing (traffic shaping)

Exercise 4

Excercise 4 - Goals

- With the configs from exercise 3, now add:

- A set of queues, and

- Statements to add rules to the queues

Exercise 4 - on the gateway

- We need to configure the queues, in pf.conf:

```
queue rootq on $ext_if bandwidth 20M
    queue main parent rootq bandwidth 20479K min 1M max 20479K qlimit 100
        queue defq parent main bandwidth 9600K min 6000K max 18M default
        queue http parent main bandwidth 9600K min 6000K max 18M
        queue smtp parent main bandwidth 9600K min 6000K max 18M
    queue spamd parent rootq bandwidth 1K min 0K max 1K qlimit 300
```

Exercise 4 - on the gateway

- Then we need to assign traffic with match statements, in pf.conf:

```
match in on egress inet proto tcp to egress port $webports rdr-to $webserver_v4 \
    queue http
match in on egress inet proto tcp to egress port $email rdr-to $emailserver_v4 \
    queue smtp
pass inet6 proto tcp to $webserver_v6 port $webports set queue http
pass inet6 proto tcp to $emailserver_v6 port $email set queue smtp
pass log inet6 proto tcp from $emailserver_v6 to port smtp set queue smtp
```

Exercise 4 - Check your work

- Check that the queues have been effectively created:

```
# systat queues
```

- Or, alternatively

```
# pfctl -vsq
```

CARP and pfsync

Section 5

CARP and pfsync

Common Address Redundancy Protocol (CARP)

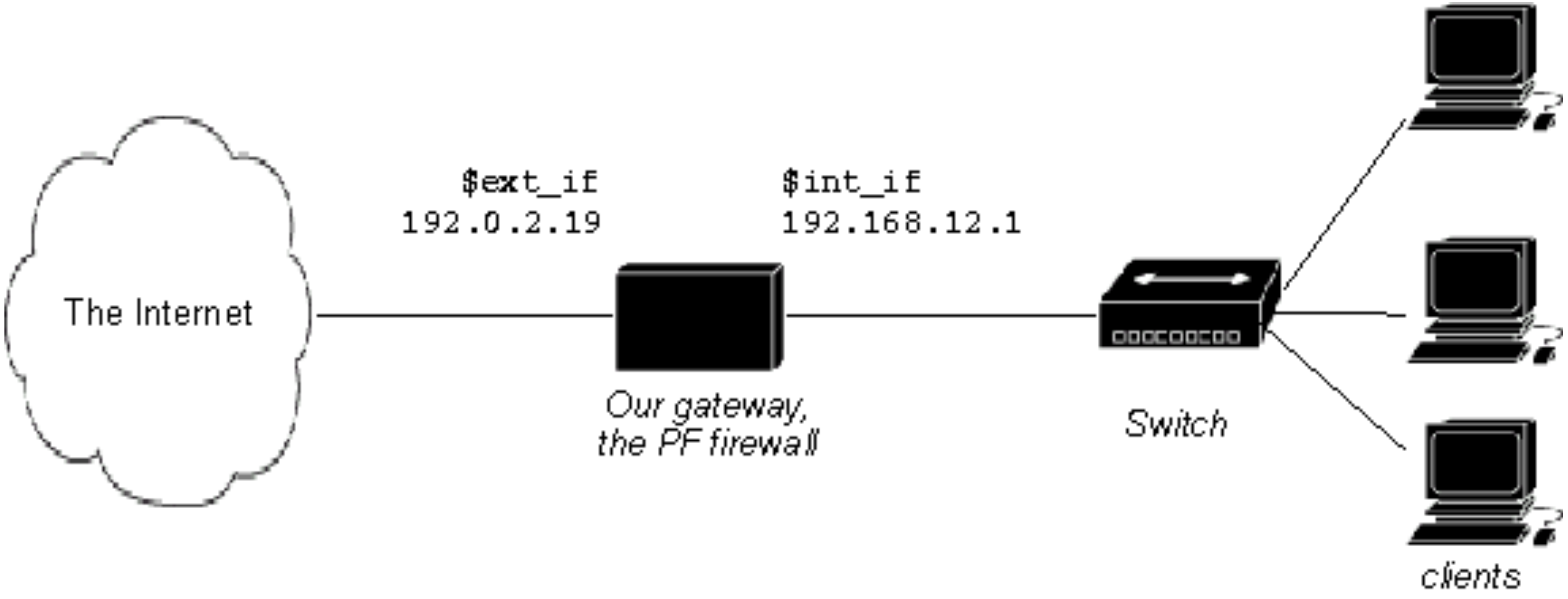
- Introduced with OpenBSD 3.5
- Patent free alternative to VRRP (RFC 2281, 3768, patent owners: Cisco, IBM, Nokia)
- Firewall/server redundancy
- Virtual network interface for automatic failover

pfsync

- Virtual network interface (assigned to physical interface)
- Handles synchronization between PF firewalls (in advance of failover)

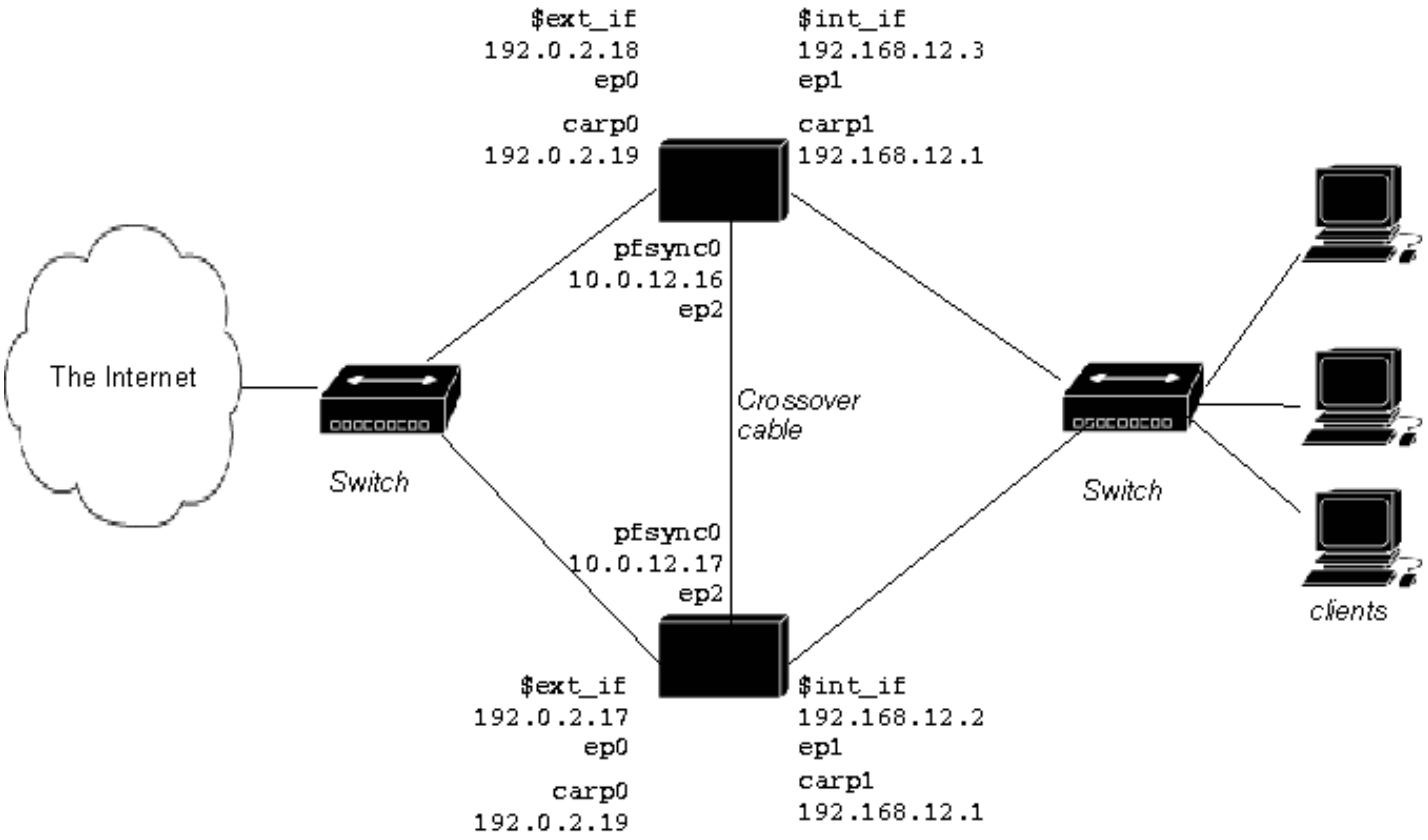
CARP: Project spec

- Our network - How to build a maintainable network:



CARP: Project spec

- Our network becomes:



CARP: Project spec continued

Our network should

- Keep functioning much the same way it did earlier
- Have better availability with no noticeable downtime
- Experience graceful failover with no interruption of active connections

Tall order, huh?

Is your system CARP ready?

- OpenBSD: GENERIC kernel comes with carp and pfsync devices compiled in
- FreeBSD: GENERIC kernel does not have carp or pfsync devices enabled, must be enabled in kernel config

Setting up CARP

- You need the sysctls, check that they are in fact set:

```
$ sysctl net.inet.carp.allow
net.inet.carp.allow=1
$ sysctl net.inet.carp
net.inet.carp.allow=1
net.inet.carp.preempt=0
```

- To let the magic work, we need

```
$ doas sysctl net.inet.carp.preempt=1
```

CARP: ifconfig

- On the master (XX == user #)

```
$ doas ifconfig carp0 10.255.255.X9 carpdev vio0 vhid 1
$ doas ifconfig carp1 192.168.XX.19 carpdev vio1 vhid 2
```

- On the backup

```
$ doas ifconfig carp0 192.255.255.X9 carpdev vio0 vhid 1 advskew 100
$ doas ifconfig carp1 192.168.XX.19 carpdev vio1 vhid 2 advskew 100
```

- NOTE: On OpenBSD 5.7 onwards, explicit **carpdev** is required

- the master announces every (1 + 0/256) seconds
  the backup announces every (1 + 100/256) seconds

- Note: Multicast by default. Use carppeer option for unicast. It' also possible to set the MAC address explicitly with the **lladdr** option.

- Also see Henning Brauer's notes

pfsync

- Use a physically separate net (crossover cable, separate VLAN):

  On the original master

```
$ doas ifconfig pfsync0 syncpeer 10.0.0.2 syncdev vio2
```

- On the initial backup

```
$ doas ifconfig pfsync0 syncpeer 10.0.0.1 syncdev vio2
```

- Store in /etc/hostname.pfsync0 on each host for permanent configuration

What happens to the ruleset?

- Pass CARP traffic on the appropriate interfaces:

```
pass on $carpdevs proto carp keep state
```

- Pass pfsync traffic on the appropriate interfaces

```
pass on $syncdev proto pfsync
```

- Some traffic doesn't make sense to fail over

```
pass in on $int_if from $ssh_allowed to self keep state (no-sync)
```

- PF sees the traffic on the physical interface

CARP config example (master)

- In sysctl.conf

```
net.inet.carp.preempt=1
```

- In **hostname.carp0**

```
pass mekmitasdigoat 10.255.255.X9 carpdev vio0 vhid 1
```

- In **hostname.carp1**

```
pass mekmitasdigoat 192.168.XX.X9 carpdev vio1 vhid 2
```

CARP config example (backup)

- In sysctl.conf

```
net.inet.carp.preempt=1
```

- In **hostname.carp0**

```
pass mekmitasdigoat 10.255.255.X9 carpdev vio0 vhid 1 advskew 100
```

- In **hostname.carp1**

```
pass mekmitasdigoat 192.168.XX.X9 carpdev vio1 vhid 2 advskew 100
```

CARP - remember pfsync

- On the initial master, **hostname.pfsync0**

```
syncpeer 10.0.0.2 syncdev vio2
```

- On the initial backup, **hostname.pfsync0**

```
syncpeer 10.0.0.1 syncdev vio2
```

CARP Ruleset

- /etc/pf.conf essentials, master and backup:

```
ext_if=vio0
int_if=vio1
carpdevs="vio0 vio1"
int_carp=carp1
ext_carp=carp0
match out inet on $ext_if from $int_if:network nat-to ($ext_carp)
```

CARP Load Balancing Mode

- Load balancing mode: Many masters

  First node **/etc/hostname.carp0**

```
pass mekmitasdigoat 192.0.2.19 balancing ip carpnodes 5:100,6:0 carpdev vio0
```

  First node **/etc/hostname.carp1**

```
pass mekmitasdigoat 192.168.12.1 balancing ip carpnodes 3:100,4:0 carpdev vio1
```

- Second node **/etc/hostname.carp0**

```
pass mekmitasdigoat 192.0.2.19 balancing ip carpnodes 5:0,6:100 carpdev vio0
```

  First node **/etc/hostname.carp1**

```
pass mekmitasdigoat 192.168.12.1 balancing ip carpnodes 3:0,4:100 carpdev vio1
```

Load balancing CARP: ifconfig

```
$ ifconfig carp
carp0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> mtu 1500
       lladdr 01:00:5e:00:01:05
       priority: 0
       carp: carpdev vio0 advbase 1 balancing ip
               state MASTER vhid 5 advskew 0
               state BACKUP vhid 6 advskew 100
       groups: carp
       inet 192.0.2.19 netmask 0xffffff00 broadcast 192.0.2.255
       inet6 fe80::200:24ff:fecb:1c10%carp0 prefixlen 64 scopeid 0x7
carp1: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> mtu 1500
       lladdr 01:00:5e:00:01:03
       priority: 0
       carp: carpdev vio1 advbase 1 balancing ip
               state MASTER vhid 3 advskew 0
               state BACKUP vhid 4 advskew 100
       groups: carp
       inet 192.168.12.1 netmask 0xffffff00 broadcast 192.168.12.255
       inet6 fe80::200:24ff:fecb:1c10%carp1 prefixlen 64 scopeid 0x8
pfsync0: flags=41<UP,RUNNING> mtu 1500
       priority: 0
       pfsync: syncdev: vio2 syncpeer: 10.0.12.17 maxupd: 128 defer: off
       groups: carp pfsync
```

Also, run **systat states** on all nodes, watch states, it's good fun :)

CARP and pfsync

Exercise 5

Excercise 5 - Goals

- Set up redundant pair of gateway / firewalls
  - carp0 (external interface)
  - carp1 (internal interface)
  - pfsync0 (state table sync)
- test failover
  - ping carp addresses
  - ping from LAN to pftutorial.net
  - force failover (boot current master)
  - observe results
-

CARP config initial master

- In sysctl.conf

```
net.inet.carp.preempt=1
```

- In **hostname.carp0**

```
pass mekmitasdigoat 10.255.255.X9 carpdev vio0 vhid 1
```

- In **hostname.carp1**

```
pass mekmitasdigoat 192.168.XX.X9 carpdev vio1 vhid 2
```

CARP: config initial backup

- In sysctl.conf

```
net.inet.carp.preempt=1
```

- In **hostname.carp0**

```
pass mekmitasdigoat 10.255.255.X9 carpdev vio0 vhid 1 advskew 100
```

- In **hostname.carp1**

```
pass mekmitasdigoat 192.168.XX.X9 carpdev vio1 vhid 2 advskew 100
```

Excercise 5

- Consider: Clients' default gateway

- Make already configured address virtual and change the physical one on our gateway?

- Or add a virtual address and change the default gateway for clients?

- Discuss :)

Tips

Section 6

Choosing your ISP, a quick guide

- Are they national or regional IX members?
- Do they have geographical redundancy ?
  - or do you need to arrange that for yourself ?
- Do they actually understand your questions about peering, routing, multiple paths?
  - (avoid consumer oriented SOHO-only shops)
- Do they suck?

Getting transit

- Find well peered transit providers
  - Can improve quality and shorten AS paths
  - No capacity problems

- Find your top traffic destinations:
  - Can improve quality
  - Peer with them or find closer upstream
  - Traffic profile from flow collectors can be useful

Common mistakes

- No diversity
  - All reached over same cable
  - All connect to the same transit
  - All have poor onward transit and peering arrangements

- Signing up with too many transit providers
  - Lots of small circuits
  - These cost more per Mbps than larger ones

Basic OpenBGPd configuration, operation and interaction with PF

- **B**order **G**ateway **P**rotocol
  - Manage and exchange route information with BGP peers
- Once you have the ASn registered, do the basic config.
- In your pf.conf:
  - enable BGP to pass between your routers and your peers' -- **TCP and UDP 179**
- **Neat trick:** Define tables in your pf.conf
  - **bgpd** maintains them via pftable attributes on bgpd.conf objects
-

Use cases for OSPF, BGP or ECMP

- OSPF: **O**pen **S**hortest **P**ath **F**irst
  - is a IGP Interior Gateway Protocol
  - Each router maintains link state information for links and networks within your AS
  - Calculates routing cost
  - Use ospf6d for IPv6
  - Use ospfd for IPv4
  - Need to **pass proto ospf** between routers.
- BGP: announces and receives routes
  - can be both an IGP or EGP **E**xterior **G**ateway **P**rotocol
  - highly scalable (Internet scale)
  - can be used for signaling and sending additional information with route announcements
  - Use bgpd
  - need to **pass proto tcp port 179** between routers
-

Use cases for OSPF, BGP or ECMP (cont'd)

- ECMP: **E**qual **C**ost **M**ulti-**P**ath
  - target reachable via more than one route
  - load distribution or redundancy over multiple links
  - **Tip** Use ifstated to handle link downtime.

BCP38, MANRS and Internet peering

- "BCP38" -- Discussed also in another effort
- **M**utually **A**greed **N**orms for **R**outing **S**ecurity (MANRS)
- Define four concrete actions network operators should implement
- Coordination
  - Keep your contacts updated
- Validation
  - Route objects, RPKI, BGPSec
- Anti-spoofing
  - uRPF
  - Filtering on external Interfaces facing external suppliers
  - Drop inbound Traffic with a src IP claiming to be from your networks / private networks.
  - Drop outbound Traffic with a src IP address that is not in your Public IP network range.
- Build a visible community of security-minded operators
- Valuable resource: The Routing Manifesto

Introducing VXLAN in your network

- vxlan - the Virtual eXtensible Local Area Network tunnel interface

- Pushes layer 2 network (Ethernet frames) over layer 3 (IP) tunnels
  - 24-bit vnetid (vs max 4k VLANs)

- Has no built in security
- Intended for 'trusted' (Datacenter, inter-hypervisor) environments
  - Otherwise, consider transport over IPSEC.

- Default transport over UDP 4789 (aka vxlan)
  - make sure that traffic passes between endpoints

Introducing VXLAN in your network

- ifconfig / hostname.vxlan?

```
# ifconfig vxlan0 tunnel 192.168.100.101 192.168.200.201 vnetid 17
# ifconfig vxlan0 10.11.12.100/24
```

```
# ifconfig vxlan0 tunnel 192.168.200.201 192.168.100.101  vnetid 17
# ifconfig vxlan0 10.11.12.101/24
```

pf.conf

```
table <vxendpoints> { 192.168.200.201 192.168.200.204 }
pass from <vxendpoints> to port vxlan
```

Buy Reyk a beer.

Readable and maintainable toolsets

- **Macros**
  - descriptive names, keep uniform
- **Tables**
  - descriptive names
  - consider daemon/scripting interface
- **Interface groups**
  - you know egress already
  - make your own and filter on them
- **Anchors**
  - group rules by common criteria
  - tagging
  - interface or group
- Service names vs port numbers
- **Comments** - yes, you **will** forget why this was a good idea

Useful 3rd party packages (ports) for OpenBSD

OpenBSD base operating system can be supplimented by the following packages and features:

- **pftop** - a curses-based utility for real-time display of active states and rules for pf. It is a cross between top and pfctl -sr and pfctl -ss.
  - pftop can be installed with the following command
    - pkg_add pftop
- nsh network shell
  - nsh can be installed with the following command
    - pkg_add nsh

Now let's add wireless

- Wireless used to be hard, (WPA in particular), now it's 'just another interface'

- 802.11* support in OpenBSD has a,b,g,n, ac only in some drivers (bwfm(4), iwx(4))

- Not all drivers support **hostap**
  - check man pages before buying kit for access point use

- Optionally setup with commercial APs for radio part
  - do DHCP, filtering, authentication and so forth from OpenBSD

-

Questions?

Questions?

Troubleshooting

"It's all your fault. Until you track down and fix the root cause"

Section 7

Troubleshooting 101: ICMP(v6)

- ICMP: Internet Control Message Protocol

- The ping of death scare is almost over, let's enable ping:

```
icmp_types = "{ echoreq, unreach }"
pass inet proto icmp all icmp-type $icmp_types keep state
pass inet proto icmp from $localnet icmp-type $icmp_types
pass inet proto icmp to $ext_if icmp-type $icmp_types
pass inet6 proto icmp6 from $localnet icmp6-type $icmp6_types
pass inet6 proto icmp6 to $ext_if icmp6-type $icmp6_types
```

- echoreq: lets ping do its thing

- unreach: lets you do path MTU discovery (PMTUD)

Troubleshooting 101: ICMP not all messages created equal!

Some ICMP messages are frivolous:

- Type 4 — Source Quench (Deprecated)
- Type 5 — Redirect (if you need this you are doing it wrong)
- Type 6 — Alternate Host Address (Deprecated)
- Type 13 — Timestamp
- Type 14 — Timestamp Reply
- Type 15 — Information Request (Deprecated)
- Type 16 — Information Reply (Deprecated)
- Type 17 — Address Mask Request (Deprecated)
- Type 18 — Address Mask Reply (Deprecated)

Troubleshooting 101: basic diagnostics already in OpenBSD base

- Basic IP connectivity
  - **ping** <host>
  - **traceroute** <host>
  - **telnet** <host> <tcp port>
  - **tcpdump** -i <interfacename>
- **netcat** command - nc
  - **nc** -z <host> <startport>-<endport>

Troubleshooting 101: not all pings were created equal!

ping packets can be manipulated in many ways

- set a specific source address (useful for routers)
  - ping [-I <srcaddress>] <destaddress>
- -set ping packet size (MTU / Path discovery Issues)
  - ping [-s <packet-size>] <destaddress>
- set do not fragment bit (MTU / Fragmentation issues)
  - ping [-D] <destaddress>

Troubleshooting 101: basic diagnostics already in OpenBSD base

DNS functionality basic commands

- ping <hostdnsname>
- telnet <hostdnsname> <tcp port>

in depth dns testing

- dig <hostdnsname>
- nslookup <hostdnsname>

Troubleshooting 101: diagnostic tools available in ports

IP connectivity

- mtr (not the gtk version)
- mtr <host>
- tcp traceroute
- tcptraceroute <host>

Troubleshooting 101: Statistics

- Statistics can be had with pfctl -s info

- For statistics (bytes/packets passed per rule) attach labels per rule

```
pass log proto { tcp, udp } to $emailserver port smtp label "mail-in"
pass log proto { tcp, udp } from $emailserver to port smtp label "mail-out"
```

```
$ doas pfctl -vs rules
pass inet proto tcp from any to 192.0.2.225 port = smtp flags S/SA keep state label "mail-in"
[ Evaluations: 1664158 Packets: 1601986 Bytes: 763762591 States: 0 ]
[ Inserted: uid 0 pid 24490 ]
pass inet proto tcp from 192.0.2.225 to any port = smtp flags S/SA keep state label "mail-out"
[ Evaluations: 2814933 Packets: 2711211 Bytes: 492510664 States: 0 ]
```

Troubleshooting 101: Statistics

- If you need to pass the data to a script
  - Or a database
  - A graphing engine

```
$ doas pfctl -zvsl
  mail-in 1664158 1601986 763762591 887895 682427415 714091 81335176
  mail-out 2814933 2711211 492510664 1407278 239776267 1303933 252734397
```

Troubleshooting 101: log to pflog

- Rules with the **log** keyword log packet data to the pflog device(s)

```
# log blocked packets
block log(all)
# logs initial packet of matching connections:
pass log proto tcp to port ssh
# logs all matching packets:
pass log(all) proto tcp to port ssh log(all)
# logs matches on this and all succeeding rules
pass log(matches) proto tcp to port ssh
# logs all packets matches on this and all succeeding rules
pass log(all, matches) proto tcp to port ssh
match log(all, matches) # log *everything*
```

Troubleshooting 101: tcpdump, read from pflog

- tcpdump is your friend. Let it loose on the pflog device:

```
$ doas tcpdump -n -e -ttt -i pflog0
tcpdump: WARNING: snaplen raised from 116 to 160
tcpdump: listening on pflog0, link-type PFLOG
May 29 21:06:27.165561 rule def/(match) pass in on bge1: 192.168.103.126.15526 >
213.187.179.198.22: . ack 2951513182 win 16332 (DF) [tos 0x10]
May 29 21:06:27.166934 rule 16/(match) pass in on bge0: 158.36.191.135.22 >
213.187.179.198.59516: . ack 1734404306 win 64800 [tos 0x8]
May 29 21:06:27.166939 rule 2/(match) match in on bge0: 158.36.191.135.22 >
213.187.179.198.59516: . ack 1 win 64800 [tos 0x8]
May 29 21:06:27.168340 rule def/(match) pass out on bge1: 213.187.179.198.22 >
192.168.103.126.15526: P 69:153(84) ack 0 win 17520 [tos 0x10]
May 29 21:06:27.169150 rule def/(match) pass out on bge1: 213.187.179.198.22 >
192.168.103.126.15526: P 153:333(180) ack 0 win 17520 [tos 0x10]
```

- **Note**: rule numbers match your *loaded* ruleset

Troubleshooting 101: Hitting and avoiding limits

- On busy systems, you may need to raise limits from default values
- Check with:
-
  ```
  $ doas pfctl -s info
  ```
- versus the output of pfctl -s memory and pfctl -s timeouts
- You may need to bump up from defaults (in /etc/pf.conf):
-
  ```
  # increase state limit from 10'000 states on busy systems
  set limit states 100000
  # increase no of source nodes
  set limit src-nodes 100000
  ```

Troubleshooting 101: quick flow analysis using iftop (package)

Sometimes we need to check what traffic is flowing on a given interface

- iftop ncurses package can be installed and allows visibility on top traffic flows on an interface

- iftop allows that quick diagnostics check without needing a full flow anlaysis infrastructure

- iftop ncurses package can be installed on any OpenBSD system using the following command

  - pkg_add iftop

Troubleshooting 101: using iftop (package) example

- Checking flow on the first intel 1Gbs interface on a router:

```
$ iftop -i em0
           1.91Mb          3.81Mb          5.72Mb          7.63Mb    9.54Mb
 └────────────────────────┴────────────────────────┴───────────────┴─────────────────────────┴────────────────────────

10.0.2.15                  => di-in-f190.1e100.net       23.5Kb  11.8Kb  2.95Kb
                      <=                            3.22Mb   805Kb   201Kb
10.0.2.15                  => dj-in-f106.1e100.net          0b   18.1Kb  6.53Kb
                      <=                               0b    708Kb   218Kb
10.0.2.15                  => dj-in-f94.1e100.net           0b   4.41Kb  1.10Kb
                      <=                               0b   57.5Kb  14.4Kb
10.0.2.15                  => dj-in-f100.1e100.net          0b   4.14Kb  1.03Kb
                      <=                               0b   43.3Kb  10.8Kb
10.0.2.15                  => dh-in-f95.1e100.net        5.69Kb  4.36Kb  1.60Kb
                      <=                             133Kb  29.5Kb  8.06Kb
10.0.2.15                  => dj-in-f119.1e100.net          0b   3.26Kb   834b
                      <=                               0b   19.6Kb  4.91Kb
10.0.2.15                  => ig-in-f94.1e100.net           0b   4.66Kb  1.16Kb
                      <=                               0b   12.8Kb  3.21Kb
10.0.2.15                  => dj-in-f148.1e100.net       12.5Kb  2.49Kb   638b
                      <=                            49.9Kb  9.99Kb  2.50Kb
```

Troubleshooting 101: netflow aka pflow (IPFIX)

- Records TCP/IP flow metadata
  - srcIP
  - dstIP
  - (srcPort, dstPort)
  - startTime
  - endTime
  - Packets
  - Bytes
- OpenBSD has the pflow(4) virtual network interface
  - which generates the datagrams from the state table
- Useful for network monitoring, DDoS protection, etc.

Troubleshooting 101: netflow setup

- Set up a sensor:

```
$ cat /etc/hostname.pflow0
   flowsrc 192.168.103.1 flowdst 192.168.103.252:9995
   pflowproto 10
```

- Instrument your rules

```
set state-defaults pflow
# [ … ]
pass in quick log (all) on egress proto tcp to port ssh flags S/SA keep state \
        (max-src-conn 15, max-src-conn-rate 3/10, overload <bruteforce> flush global, pflow)
```

- Then configure your collector -

Troubleshooting 101: netflow setup

- Configure your collector at the flowdst IP address for analysis and network overlordship.
- Lots of collector options available in ports: nfsen, flow-tools, pmacct, FastNetMon and others.
- More info:
  - Michael W. Lucas: *Network Flow Analysis*
  - and Peter N. M. Hansteen: *Yes, You Too Can Be An Evil Network Overlord - On The Cheap With OpenBSD, pflow And nfsen*.
-

Flow Analyser example Fastnetmon

- Example of a typcial flow anlayser software fastnetmon:
  User can view FastNetMon statistics via the CLI client fastnetmon_client

```
# fastnetmon_client
FastNetMon 1.1.7 master git- Try Advanced edition: https://fastnetmon.com
IPs ordered by: packets
Incoming traffic      1505664 pps 15397 mbps    85 flows
37.203.[redacted]       59184 pps   485 mbps     0 flows
37.203.[redacted]       45040 pps   504 mbps     0 flows
37.203.[redacted]       26924 pps   270 mbps     0 flows
185.55.[redacted]       24211 pps   240 mbps     0 flows
5.134.[redacted]        23872 pps   290 mbps     0 flows
45.11.[redacted]        23634 pps   250 mbps     0 flows
185.55.[redacted]       22451 pps   255 mbps     0 flows
45.11.[redacted]        20943 pps   254 mbps     0 flows
185.55.[redacted]       20298 pps   246 mbps     0 flows
5.134.[redacted]        20188 pps   236 mbps     0 flows
```

- With FastNetMon one can implement mitigations based on tresholds
  - Packets per second pps
  - Bandwidth per second Mbps

NAT64

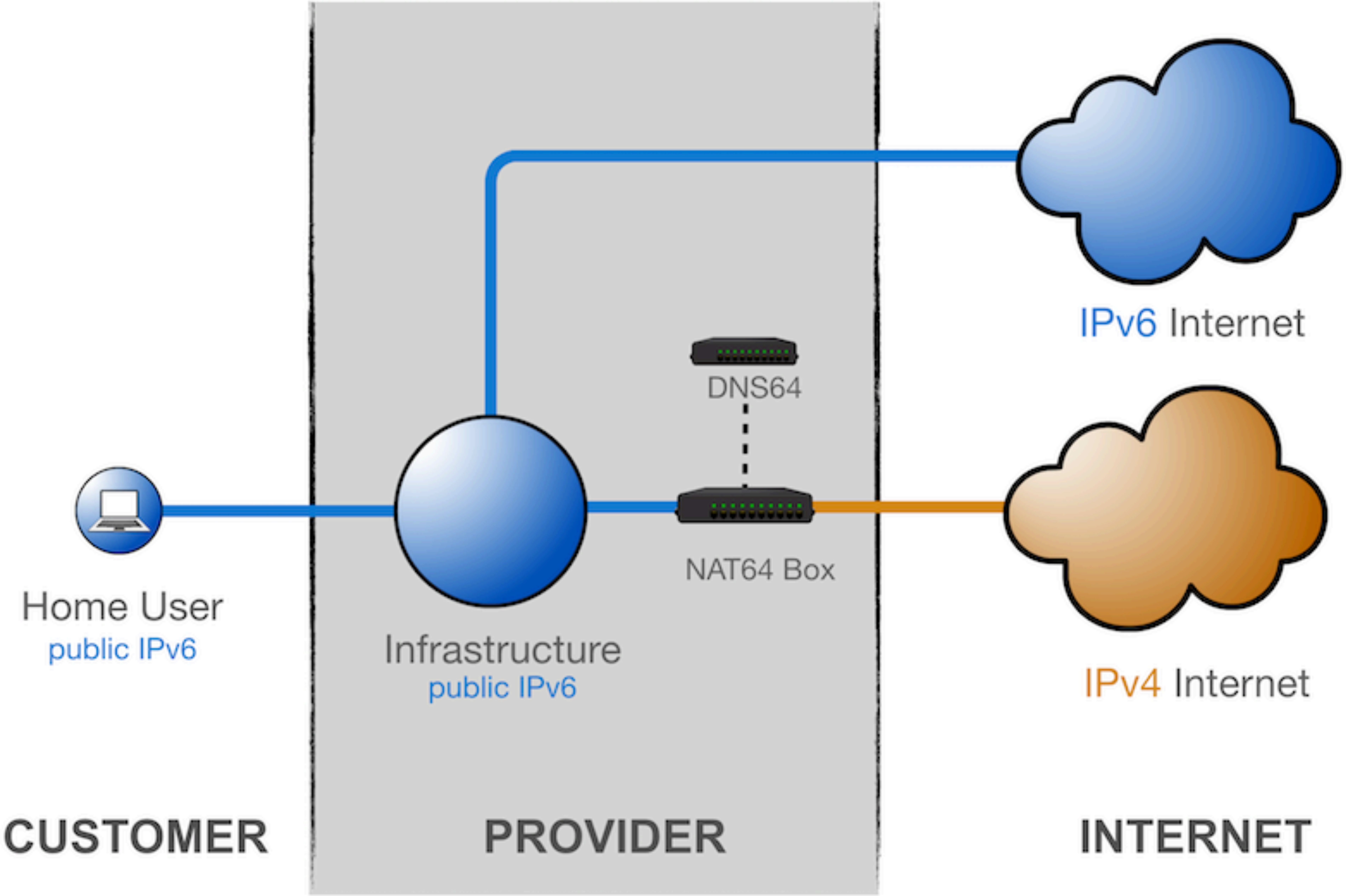
Exercise 6

NAT64

- Single-stack clients will only have IPv6

- Translator box will strip all headers and replace them with IPv4

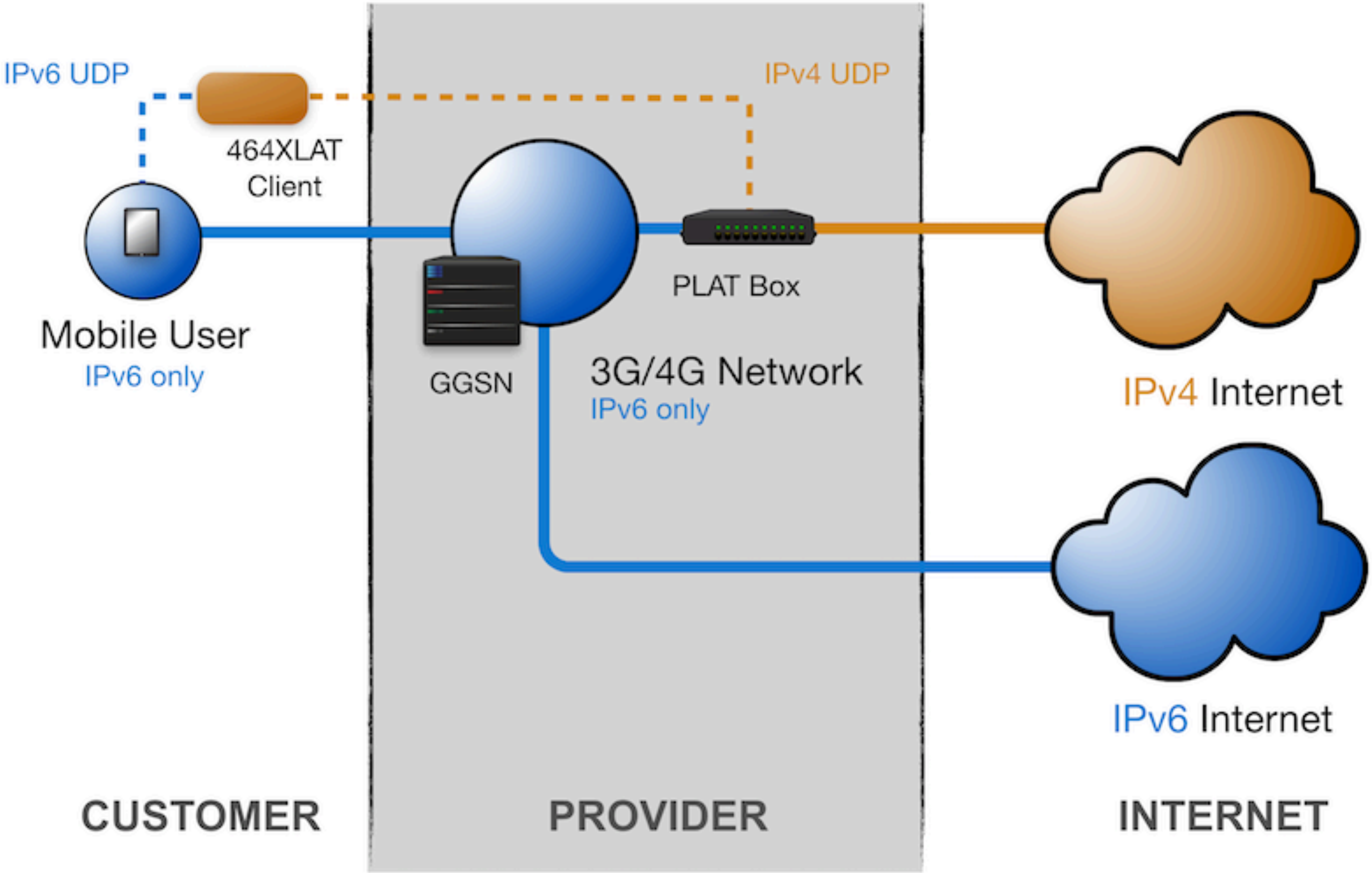
- Requires some DNS “magic”
  - Capture responses and replace A with AAAA
  - Response is crafted based on target IPv4 address
- Usually implies address sharing on IPv4


IPv6 Internet
DNS64
NAT64 Box
IPv4 Internet
Home User
public IPv6
Infrastructure
public IPv6
CUSTOMER
PROVIDER
INTERNET

464-XLAT

- Extension to NAT64 to access IPv4-only applications (like Skype or Whatsapp)

- Handset pretends there is an IPv4 address (CLAT) and sends IPv4 packets in UDP over IPv6


IPv6 UDP
IPv4 UDP
464XLAT
Client
Mobile User
IPv6 only
GGSN
PLAT Box
3G/4G Network
IPv6 only
IPv4 Internet
IPv6 Internet
CUSTOMER
PROVIDER
INTERNET

Exercise 6 - Goals

- Define the translating prefix
  - 64:ff9b::/96 is reserved by IETF
- Add NAT64 configuration to PF
- Remove IPv4 from the internal network
- Configure DNS64 on unbound

Exercise 6

- pf.conf

```
pass in quick on $int_if inet6 from any to 64:ff9b::/96 af-to inet from (egress:0) keep state
```

- unbound.conf

```
module-config: "dns64 validator iterator"
dns64-prefix: 64:FF9B::/96
```

- And it's done!

Questions?

Questions?

Last chance …

or questions@pftutorial.net

Web accessible resources

- OpenBSD website and documentation
  - https://www.openbsd.org/ The official OpenBSD website – to donate: https://www.openbsd.org/donations.html and please do donate, corporates may prefer https://www.openbsdfoundation.org/ - a Canadian non-profit
- The PF User Guide on the OpenBSD web site
- OpenBSD online man pages
- Note: You can convert the man page of pf.conf to PDF for reading in your favourite reader with the command:
  - man -T pdf pf.conf > pf.conf.pdf

Resources

Books / e-Books

- Michael W Lucas: *Absolute OpenBSD, 2nd ed.*
- Peter N. M. Hansteen: *The Book of PF, 3rd ed.*
- Elizabeth D. Zwicky, Simon Cooper, D. Brent Chapman *Building Internet Firewalls, 2nd ed.*

Blogs

- https://undeadly.org/ - The OpenBSD Journal news site
- https://bsdly.blogspot.com/ - Peter's rants^H^H^H^H^Hblog posts
- https://www.tedunangst.com/flak/ tedu@ on developments

The End!

Край

Y Diwedd

Fí

Finis

النهاية

Соңы

Վերջ

Liðugt

Ende

Finvezh

Кінець

Konec

Kraj

Ënn

Fund

پایان

Kpaj

Lõpp

Beigas

Vége

Son

An Críoch

הסוף

Fine

Endir

Sfârşit

Fin

Τέλος

Einde

Конец

Slut

Slutt

დასასრული

Pabaiga

Tmiem

Koniec

Fim

Amaia

Loppu

English
The End!

Bulgarian
Край
(Kraj)

Welsh
Y Diwedd

Arabic
النهاية
(An-Nahaya)

Catalan
Fí

Kazakh
Соңы

Armenian
Վերջ
(Verj)

Latin
Finis

Faroese
Liðugt

German
Ende

Breton
Finvezh

Ukrainian
Кінець
(Kinec))

Czech
Konec

Persian
پایان
(Payan)

Letzeburgisch(LUX)
Ënn

Albanian
Fund

Croatian
Kraj

Estonian
Lõpp

Latvian
Beigas

Hungarian
Vége

Turkish
Son

Serbian
Крај
(Kraj)

Irish
An Críoch

Hebrew
הסוף
(Ha-sof))

Italian
Fine

Icelandic
Endir

Romanian
Sfârşit

Greek
Τέλος
(Telos))

French
Fin

Dutch
Einde

Russian
Конец
(Konec))

Belorussian
Канец
(Kanec))

Swedish, Danish
Slut

Norwegian
Slutt

Georgian
დასასრული
(Dasasruli))

Lithuanian
Pabaiga

Maltese
Tmiem

Polish, Slovak
Koniec

Basque
Amaia

Finnish
Loppu

Portuguese
Fim