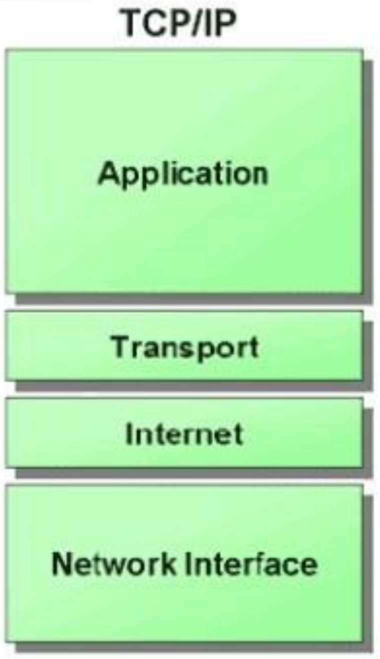
Firewalls

Firewalls

- Firewall
  - hardware/software
  - choke point between secured and unsecured network
  - filter incoming and outgoing traffic
  - prevent communications which are forbidden by the security policy
- What it can be used to do
  - Incoming: protect and insulate the applications, services and machines
    - Such as telnet, NetBIOS
  - Outgoing: limit or disable access from the internal network
    - Such as MSN, ssh, ftp, facebook, SC2, D3
  - NAT (Network Address Translation)

Firewalls – Capabilities

- Network Layer Firewalls
  - Operate at a low level of TCP/IP stack as IP-packet filters.
  - Filter attributes
    - Source/destination IP
    - Source/destination port
    - TTL
    - Protocols
    - …
- Application Layer Firewalls
  - Work on the application level of the TCP/IP stack.
  - Inspect all packets for improper content, a complex work!
- Application Firewalls
  - The access control implemented by applications.
  - TCP Wrapper (libwrap)



Firewalls – Rules

- Exclusive
  - Only block the traffic matching the rulesets
- Inclusive
  - Only allow the traffic matching the rulesets
  - Offer much better control of the incoming/outgoing traffic
  - Safer than exclusive one
    - (Y) reduce the risk of allowing unwanted traffic to pass
    - (N) increase the risk to block yourself with wrong configuration
- State
  - Stateful
    - Keep track of which connections are opened through the firewall
    - Be vulnerable to Denial of Service (DoS) attacks
  - Stateless

Firewalls – Packages

- FreeBSD
  - IPFILTER (known as IPF)
  - IPFIREWALL (known as IPFW) + Dummynet
  - *Packet Filter (known as PF)+ ALTQ*
    - migrated from OpenBSD
    - v4.5 (In FreeBSD 9.0)
    - http://www.openbsd.org/faq/pf/ v5.0
- Linux
  - ipchains
  - iptables

Packet Filter (PF)

- Functionality
  - Filtering packets
  - NAT
  - Load balance
  - QoS: (ALTQ: Alternate Queuing)
  - Failover (pfsync + carp)

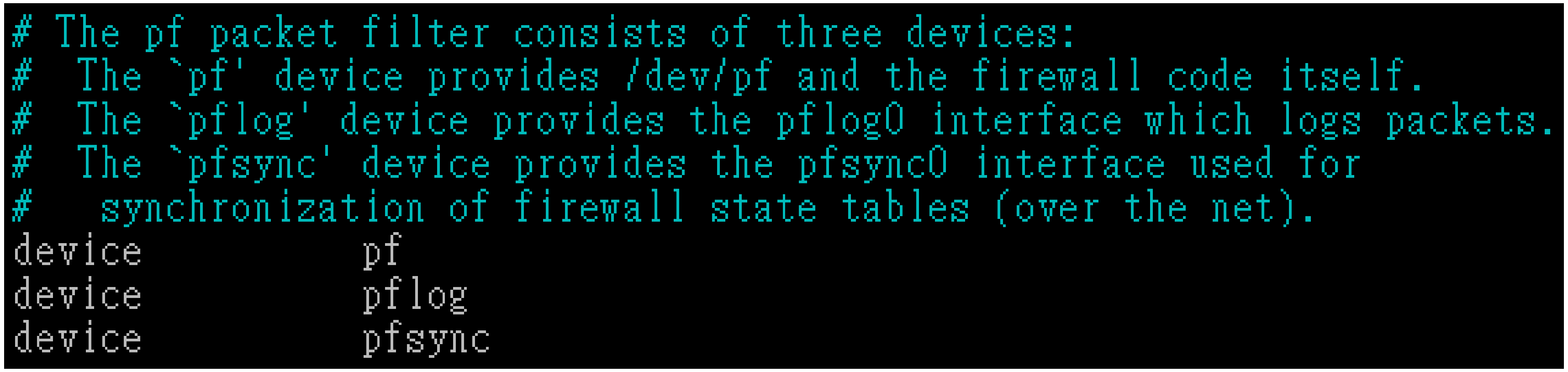
PF in FreeBSD – Enable pf*

- In /etc/rc.conf (kernel modules loaded automatically)

```
pf_enable="YES"
pflog_enable="YES"
pfsync_enable="YES"
```

- Kernel configurations

```
device    pf
device    pflog
device    pfsync
```



```
# The pf packet filter consists of three devices:
#  The `pf' device provides /dev/pf and the firewall code itself.
#  The `pflog' device provides the pflog0 interface which logs packets.
#  The `pfsync' device provides the pfsync0 interface used for
#   synchronization of firewall state tables (over the net).
device          pf
device          pflog
device          pfsync
```

PF in FreeBSD – Commands

- /etc/rc.d/pf
  - start / stop / restart / status / check / reload / resync
- pfctl
  - -e / -d
  - -F {nat | rules | state | info | Tables | all | …}
  - -v -s {nat | rules | state | info | all | Anchors | Tables | …}
  - -v -n -f /etc/pf.conf
  - -t <table> -T {add | delete| test} {ip …}
  - -t <table> -T {show | kill | flush | …}
  - -k {host | network} [-k {host | network}]
  - -a {anchor} …
    - Default anchor: -a '*'
    - Ex. -a 'ftp-proxy/*'

PF in FreeBSD – Config ordering

- ❑ Macros
  - user-defined variables, so they can be referenced and changed easily.
- ❑ Tables “table”
  - similar to macros, but efficient and more flexible for many addresses.
- ❑ Options “set”
  - tune the behavior of pf, default values are given.
- ❑ Normalization “scrub”
  - reassemble fragments and resolve or reduce traffic ambiguities.
- ❑ Queueing “altq”, “queue”
  - rule-based bandwidth control.
- ❑ Translation (NAT) “rdr”, “nat”, “binat”
  - specify how addresses are to be mapped or redirected to other addresses
  - First match rules
- ❑ Filtering “antispoof”, “block”, “pass”
  - rule-based blocking or passing packets
  - Last match rules

PF in FreeBSD – Lists

- Lists
  - Allow the specification of multiple similar criteria within a rule
    - multiple protocols, port numbers, addresses, etc.
  - defined by specifying items within { } brackets.
  - eg.
    - pass out on rl0 proto { tcp, udp } from { 192.168.0.1, 10.5.32.6 } to any
    - pass in on fxp0 proto tcp to port { 22 80 }
  - Pitfall
    - pass in on fxp0 from { 10.0.0.0/8, !10.1.2.3 }
    - You mean (It means)
      1. pass in on fxp0 from 10.0.0.0/8
      2. ~~block in on fxp0 from 10.1.2.3~~
      2. pass in on fxp0 from !10.1.2.3
    - Use table, instead.

PF in FreeBSD – Macros

❑ Macros

- user-defined variables that can hold IP addresses, port numbers, interface names, etc.
- reduce the complexity of a pf ruleset and also make maintaining a ruleset much easier.
- Naming: start with [a-zA-Z] and may contain [a-zA-Z0-9_]
- eg.
  - ext_if = "fxp0“
  - block in on $ext_if from any to any
- Macro of macros
  - host1 = "192.168.1.1“
  - host2 = "192.168.1.2“
  - all_hosts = "{" $host1 $host2 "}"

PF in FreeBSD – Tables (1)

- Tables
  - used to hold a group of IPv4 and/or IPv6 addresses
    - hostname, inteface name, and keyword *self*
  - Lookups against a table are very fast and consume less memory and processor time than lists
  - Two attributes
    - persist: keep the table in memory even when no rules refer to it
    - const: cannot be changed once the table is created
  - eg.
    - table <private> const { 10/8, 172.16/12, 192.168/16 }
    - table <badhosts> persist
    - block on fxp0 from { <private>, <badhosts> } to any
    - table <spam> persist file "/etc/spammers" file "/etc/openrelays"

PF in FreeBSD – Tables (2)

- Tables – Address Matching
  - An address lookup against a table will return the most narrowly matching entry
  - eg.
    - table <goodguys> { 172.16.0.0/16, !172.16.1.0/24, 172.16.1.100 }
    - block in on dc0
    - pass in on dc0 from <goodguys>
  - Result

172.16.50.5	passed
172.16.1.25	blocked
172.16.1.100	passed
10.1.4.55	blocked

PF in FreeBSD – Options

- Format
  - control pf's operation, and specified in pf.conf using "set"
    - Format: set option [sub-ops] value
- Options
  - *loginterface* – collect packets and gather byte count statistics
  - *ruleset-optimization* – ruleset optimizer
    - none, basic, profile
    - basic: remove dups, remove subs, combine into a table, re-order rules
  - *block-policy* – default behavior for blocked packets
    - drop, return
  - *skip on* {ifname} – interfaces for which packets should not be filtered.
    - eg. set skip on lo0
  - *timeout*, *limit*, *optimization*, *state-policy*, *hostid*, *require-order*, *fingerprints*, *debug*

PF in FreeBSD – Normalization

- Traffic Normalization
  - IP fragment reassembly
    - scrub in all
  - Default behavior
    - Fragments are buffered until they form a complete packet, and only the completed packet is passed on to the filter.
    - Advantage: filter rules have to deal only with complete packets, and ignore fragments.
    - Disadvantage: caching fragments is the additional memory cost
    - The full reassembly method is the only method that currently works with NAT.

PF in FreeBSD – Translation (1)

❑ Translation

- Modify either the source or destination address of the packets
- The translation engine
  1. modifies the specified address and/or port in the packet
  2. passes it to the packet filter for evaluation
- Filter rules filter based on the translated address and port number
- Packets passed directly if the *pass* modifier is given in the rule

PF in FreeBSD – Translation (2)

- Various types of translation
  - binat – bidirectional mapping between an external IP netblock and an internal IP netblock
    - binat on $ext_if from 10.1.2.150 to any -> 140.113.235.123
    - binat on $ext_if from 192.168.1.0/28 to any -> 140.113.24.0/28
  - nat – IP addresses are to be changes as the packet traverses the given interface
    - no nat on $ext_if from 192.168.123.234 to any
    - nat pass on $ext_if from 192.168.123.0/24 to any -> 140.113.235.21
  - rdr – redirect packets to another destination and possibly different port
    - no rdr on $int_if proto tcp from any to $server port 80
    - rdr on $int_if proto tcp from any to any port 80 -> 127.0.0.1 port 80

PF in FreeBSD – Translation (3)

- Evaluation
  - Evaluation order of translation rules depends on the type
    - *binat* rules first, and then either *rdr* rules for inbound packets or *nat* rules for outbound packets
  - Rules of the same type are evaluated in the order of appearing in the ruleset
  - The first matching rule decides what action is taken
  - If no rule matches the packet, it is passed to the filter unmodified

PF in FreeBSD – Packet Filtering (1)

- pf has the ability to *block* and *pass* packets based on
  - layer 3(ip, ip6) and layer 4(icmp, icmp6, tcp, udp) headers
- Each packet processed by the filter
  - The filter rules are evaluated in sequential order
  - The last matching rule decides what action is taken
  - If no rule matches the packet, the default action is to pass
- Format
  - {pass | block [drop | return]} [in | out] [log] [quick] [on ifname] … {hosts} …
  - The simplest to block everything by default: specify the first filter rule
    - block all

PF in FreeBSD – Packet Filtering (2)

- States
  - If the packet is *pass*ed, state is created unless the *no state* is specified
    - The first time a packet matches *pass*, a state entry is created
    - For subsequent packets, the filter checks whether each matches any state
    - For TCP, also check its sequence numbers
    - pf knows how to match ICMP replies to states
      - Port unreachable for UDP
      - ICMP echo reply for echo request
      - …
    - Stores in BST for efficiency

PF in FreeBSD – Packet Filtering (3)

- Parameters
  - *in* | *out* – apply to imcoming or outgoing packets
  - *log* - generate log messages to pflog (pflog0, /var/log/pflog)
    - Default: the packet that establishes the state is logged
  - *quick* – the rule is considered the last matching rule
  - *on ifname* – apply only on the particular interface
  - *inet* | *inet6* – apply only on this address family
  - *proto* {*tcp* | *udp* | *icmp* | *icmp6*} – apply only on this protocol

PF in FreeBSD – Packet Filtering (4)

- Parameters
  - *hosts* : { *from* <u>*host*</u> [*port* [*op*] <u>*#*</u>] *to* <u>*host*</u> [*port* [*op*] <u>*#*</u>] | *all* }
  - host:
    - host can be specified in CIDR notation, hostnames, interface names, table, or keywords *any*, *self*, …
    - Hostnames are translated to address(es) at ruleset load time.
    - When the address of an interface or hostname changes, the ruleset must be reloaded
    - When interface name is surrounded by (), the rule is automatically updated whenever the interface changes its address
  - port:
    - ops: unary(=, !=, <, <=, >, >=), and binary(:, ><, <>)
  - eg.
    - block in all
    - pass in proto tcp from any port < 1024 to self port 33333:44444

PF in FreeBSD – Packet Filtering (5)

- Parameters
  - *flags* {<u>*<a>*</u>/<u>*<b>*</u> | *any*} – only apply to TCP packets
    - Flags: (F)IN, (S)YN, (R)ST, (P)USH, (A)CK, (U)RG, (E)CE, C(W)R
    - Check flags listed in <b>, and see if the flags (not) in <a> is (not) set
    - eg.
      - flags S/S : check SYN is set, ignore others.
      - flags S/SA: check SYN is set and ACK is unset., ignore others
    - Default *flags S/SA* for TCP
  - *icmp-type <u>type</u> code <u>code</u>*
  - *icmp6-type <u>type</u> code <u>code</u>*
    - Apply to ICMP and ICMP6 packets
  - *label* – for per-rule statistics
  - {*tag* | *tagged*} <u>*string*</u>
    - tag by nat, rdr, or binat, and identify by filter rules.

PF in FreeBSD – Load Balance

- Load balance
  - For *nat* and *rdr* rules
  - eg.
    - rdr on $ext_if proto tcp from any to any port 80 \
      -> {10.1.2.155, 10.1.2.160, 10.1.2.161} round-robin

PF in FreeBSD – Security

- For security consideration
  - state modulation
    - Create a high quality random sequence number
    - Applying *modulate state* parameter to a TCP connection
  - syn proxy
    - pf itself completes the handshake
    - Applying *synproxy state* parameter to a TCP connection
      - Include modulate state

PF in FreeBSD – Stateful tracking

- Stateful tracking options
  - *keep state*, *modulate state*, and *synproxy state* support these options
    - keep state must be specidied explicitly to apply options to a rule
  - eg.
    - table <bad_hosts> persist
    - block quick from <bad_hosts>
    - pass in on $ext_if proto tcp to ($ext_if) port ssh keep state \
      (max-src-conn-rate 5/30, overload <bad_hosts> flush global)

PF in FreeBSD – Blocking spoofed

- Blocking spoofed traffic
  - *antispoof for ifname*
  - antispoof for lo0
    - block drop in on ! lo0 inet from 127.0.0.1/8 to any
    - block drop in on ! lo0 inet6 from ::1 to any
  - antispoof for wi0 inet (IP: 10.0.0.1, netmask 255.255.255.0)
    - block drop in on ! wi0 inet from 10.0.0.0/24 to any
    - block drop in inet from 10.0.0.1 to any
  - Pitfall:
    - Rules created by the *antispoof* interfere with packets sent over loopback interfaces to local addresses. One should pass these explicitly.
    - set skip on lo0

PF in FreeBSD – Anchors

- Besides the main ruleset, pf can load rulesets into anchor attachment points
  - An anchor is a container that can hold rules, address tables, and other anchors
  - The main ruleset is actually the default anchor
  - An anchor can reference another anchor attachment point using
    - nat-anchor
    - rdr-anchor
    - binat-anchor
    - anchor
    - load anchor <name> from <file>

PF in FreeBSD – Example

- Ex.

```
# macro definitions
extdev='fxp0'
server_ext='140.113.214.13'

# options
set limit { states 10000, frags 5000 }
set loginterface $extdev
set block-policy drop
set skip on lo0

# tables
table <badhosts> persist file "/etc/badhosts.list"

# filtering rules
block in  all
pass out all
antispoof for $extdev
block log in on $extdev proto tcp from any to any port {139, 445}
block log in on $extdev proto udp from any to any port {137, 138}
block on $extdev quick from <badhosts> to any
pass in on $extdev proto tcp from 140.113.0.0/16 to any port {139, 445}
pass in on $extdev proto udp from 140.113.0.0/16 to any port {137, 138}
```

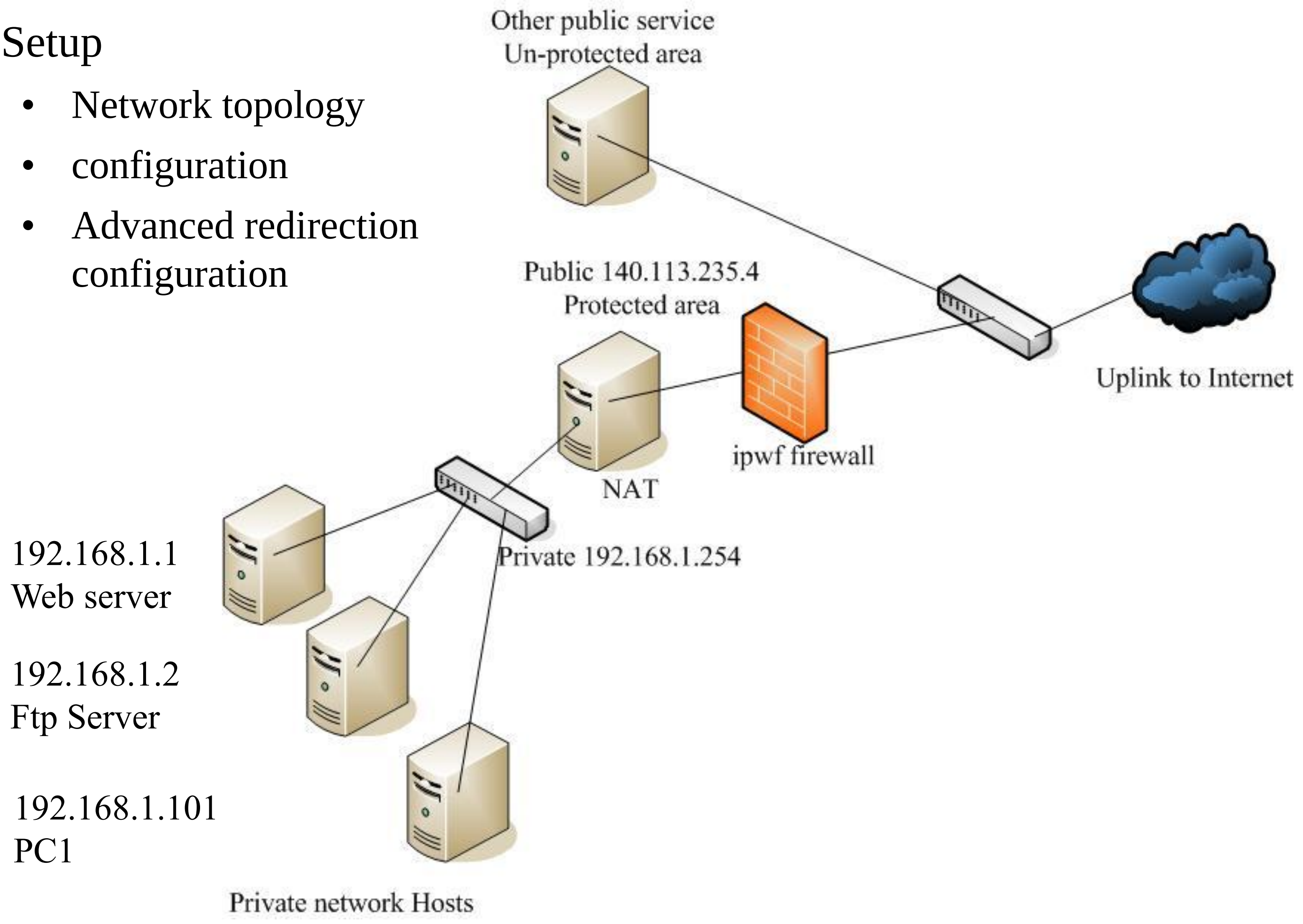
PF in FreeBSD – Debug by pflog

- Enable pflog in /etc/rc.conf (pflog.ko loaded automatically)
  - pflog_enable="YES"
    - Log to pflog0 interface
    - tcpdump –i pflog0
  - pflog_logfile="/var/log/pflog"
    - tcpdump -r /var/log/pflog

- Create firewall rules
  - Default configuration rules
    - pf_rules="/etc/pf.conf"
  - Sample files
    - /usr/share/examples/pf/*

NAT on FreeBSD (1)

- Setup
  - Network topology
  - configuration
  - Advanced redirection configuration



NAT on FreeBSD (2)

- In /etc/rc.conf

```
ifconfig_fxp0="inet 140.113.235.4"
ifconfig_fxp1="inet 192.168.1.254/24"
defaultrouter="140.113.235.254“
gateway_enable="YES"
```

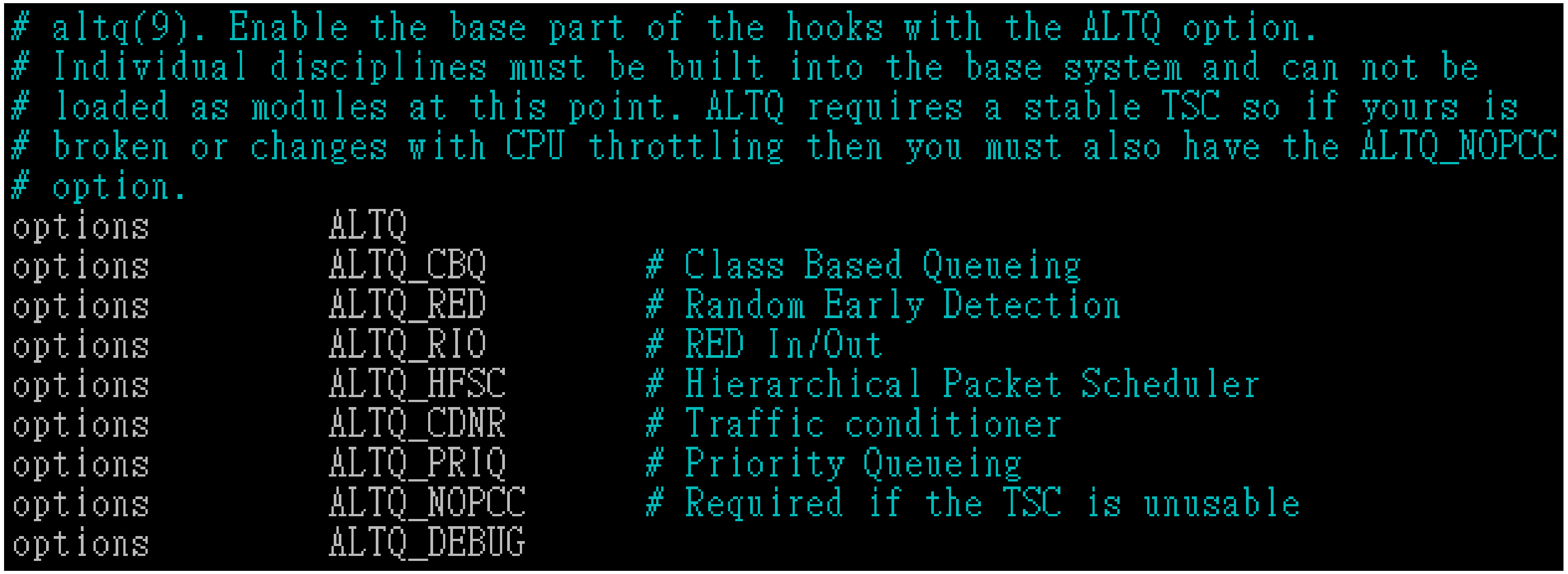
- In /etc/pf.conf
  - nat
  - rdr
  - binat

```
# macro definitions
extdev='fxp0‘
intranet='192.168.1.0/24‘
webserver=‘192.168.1.1’
ftpserver=‘192.168.1.2’
winxp=‘192.168.1.101’
server_int=‘192.168.1.88’
server_ext=‘140.113.235.13’

# nat rules
nat on $extdev inet from $intranet to any -> $extdev
rdr on $extdev inet proto tcp to port 80 -> $webserver port 80
rdr on $extdev inet proto tcp to port 443 -> $webserver port 443
rdr on $extdev inet proto tcp to port 21 -> $ftpserver port 21
rdr on $extdev inet proto tcp to port 3389 -> $winxp port 3389
binat on $extdev inet from $server_int to any -> $server_ext
```

ALTQ: Alternate Queue – (1)

- Rebuild Kernel is needed
  - http://www.freebsd.org/doc/handbook/firewalls-pf.html



```
# altq(9). Enable the base part of the hooks with the ALTQ option.
# Individual disciplines must be built into the base system and can not be
# loaded as modules at this point. ALTQ requires a stable TSC so if yours is
# broken or changes with CPU throttling then you must also have the ALTQ_NOPCC
# option.
options         ALTQ
options         ALTQ_CBQ        # Class Based Queueing
options         ALTQ_RED        # Random Early Detection
options         ALTQ_RIO        # RED In/Out
options         ALTQ_HFSC       # Hierarchical Packet Scheduler
options         ALTQ_CDNR       # Traffic conditioner
options         ALTQ_PRIQ       # Priority Queueing
options         ALTQ_NOPCC      # Required if the TSC is unusable
options         ALTQ_DEBUG
```

ALTQ: Alternate Queue – (2)

- altq on dc0 cbq bandwidth 5Mb queue {std, http}
- queue std bandwidth 10% cbq(default)
- queue http bandwidth 60% priority 2 cbq(borrow) {employee,developer}
- queue developers bandwidth 75% cbq(borrow)
- queue employees bandwidth 15%

- block return out on dc0 inet all queue std
- pass out on dc0 inet proto tcp from $developerhosts to any port 80 queue developers
- pass out on dc0 inet proto tcp from $employeehosts to any port 80 queue employees
- pass out on dc0 inet proto tcp from any to any port 22
- pass out on dc0 inet proto tcp from any to any port 25