Failover Firewalls with OpenBSD and CARP

Jason Dixon
DixonGroup Consulting

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Introduction

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- Should be both a guardian and a guide
- Often a single point of failure
- Failover Firewalls are as vital as HA Application clusters
- Chicks dig redundancy
History of OpenBSD

- A leading secure UNIX-like operating system
- Emphasize code robustness and security
- Open licensing is crucial
- OpenBSD Packet Filter (PF) born out of IPFilter license change
PFSYNC Protocol

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- Other firewalls will update their own state tables
- Synchronized state == graceful failover
Before CARP

- OpenBSD lacked failover mechanism
- Virtual Router Redundancy Protocol (VRRP) assigns virtual gateway between physical routers
- Operates at OSI Layers 2 and 3
- Master/Backup relationship
- VRRP encumbered by Cisco patent
- Common Address Redundancy Protocol (IP Protocol 112)
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- Addressed the need for a patent-free failover mechanism
- Virtual MAC and IP addresses
- Supports IPv4 and IPv6
- Also provides load-balancing, preemption, and crypto hashed announcements
Basic CARP Failover
Basic CARP Example

- Single CARP virtual host on each gateway
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- Virtual host ID (vhid)
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- Control frequency of CARP advertisements (advskew)
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- Control frequency of CARP advertisements (advskew)
- Authenticate your advertisements (pass foo)
- Attach CARP device to interface (carpdev)
Basic CARP Example (cont'd)

- Auto-recovery (net.inet.carp.preempt)
Basic CARP Example (cont'd)

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- Secure pfsync interface OR peer address (syncpeer) + IPSec
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- Filter and translate on the physical interface
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- Auto-recovery (net.inet.carp.preempt)
- Secure pfsync interface OR peer address (syncpeer) + IPSec
- Filter and translate on the physical interface
- Must allow PFSYNC and CARP protocols
Basic Filtering - pf.conf

# Macros
ext_if="fxp1"
int_if="fxp0"
pfsync_if="xl0"

# Options
set skip on { lo $int_if }

# Normalization
scrub in

# Translation
nat on $ext_if from $int_if:network \
    to any -> (carp0)

# cont'd ...
# Basic Filtering - pf.conf

# Filtering
block in
pass out keep state
pass quick on { $ext_if $int_if } \ 
proto carp keep state
pass quick on $pfsync_if proto pfsync
pass in on $ext_if inet proto icmp \ 
icmp-type echoreq keep state
pass in on $ext_if inet proto tcp \ 
port ssh flags S/SA keep state
pass out on $ext_if all keep state
server1# ifconfig carp0 vhid 1 pass foo \
> carpdev fxp1 192.168.0.20 255.255.255.0
Basic Setup – server1

server1# ifconfig carp0 vhid 1 pass foo \ > carpdev fxp1 192.168.0.20 255.255.255.0

server1# ifconfig carp1 vhid 1 pass bar \ > carpdev fxp0 10.0.0.1 255.255.255.0
Basic Setup – server1

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server1# ifconfig carp0 vhid 1 pass foo \ > carpdev fxp1 192.168.0.20 255.255.255.0

server1# ifconfig carp1 vhid 1 pass bar \ > carpdev fxp0 10.0.0.1 255.255.255.0

server1# ifconfig pfsync0 syncdev xl0
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server1# sysctl -w net.inet.carp.preempt=1
net.inet.carp.preempt 0 -> 1
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server1# ifconfig carp0 vhid 1 pass foo \ 
> carpdev fxp1 192.168.0.20 255.255.255.0

server1# ifconfig carp1 vhid 1 pass bar \ 
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server1# ifconfig pfsync0 syncdev xl0

server1# sysctl -w net.inet.carp.preempt=1
net.inet.carp.preempt 0 -> 1

server1# sysctl -w net.inet.ip.forwarding=1
net.inet.ip.forwarding 0 -> 1
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```bash
server1# ifconfig carp0 vhid 1 pass foo \ > carpdev fxp1 192.168.0.20 255.255.255.0
server1# ifconfig carp1 vhid 1 pass bar \ > carpdev fxp0 10.0.0.1 255.255.255.0
server1# ifconfig pfsync0 syncdev xl0
server1# sysctl -w net.inet.carp.preempt=1
    net.inet.carp.preempt 0 -> 1
server1# sysctl -w net.inet.ip.forwarding=1
    net.inet.ip.forwarding 0 -> 1
server1# pfctl -nf /etc/pf.conf
```
Basic Setup – server1

server1# ifconfig carp0 vhid 1 pass foo \\
> carpdev fxp1 192.168.0.20 255.255.255.0

server1# ifconfig carp1 vhid 1 pass bar \\
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server1# sysctl -w net.inet.carp.preempt=1
net.inet.carp.preempt 0 -> 1

server1# sysctl -w net.inet.ip.forwarding=1
net.inet.ip.forwarding 0 -> 1

server1# pfctl -nf /etc/pf.conf

server1# pfctl -f /etc/pf.conf
Basic Setup – server2

```bash
server2# ifconfig carp0 vhid 1 pass foo \
> advskew 100 carpdev fxp1 \
> 192.168.0.20 255.255.255.0
```
Basic Setup – server2

server2# ifconfig carp0 vhid 1 pass foo \
> advskew 100 carpdev fxp1 \
> 192.168.0.20 255.255.255.0

server2# ifconfig carp1 vhid 1 pass bar \
> advskew 100 carpdev fxp0 \
> 10.0.0.1 255.255.255.0
server2# ifconfig carp0 vhid 1 pass foo \ 
> advskew 100 carpdev fxp1 \ 
> 192.168.0.20 255.255.255.0

server2# ifconfig carp1 vhid 1 pass bar \ 
> advskew 100 carpdev fxp0 \ 
> 10.0.0.1 255.255.255.0

server2# ifconfig pfsync0 syncdev xl0
Basic Setup – server2

server2# ifconfig carp0 vhid 1 pass foo 
> advskew 100 carpdev fxp1 
> 192.168.0.20 255.255.255.0

server2# ifconfig carp1 vhid 1 pass bar 
> advskew 100 carpdev fxp0 
> 10.0.0.1 255.255.255.0

server2# ifconfig pfsync0 syncdev xl0

server2# sysctl -w net.inet.carp.preempt=1
net.inet.carp.preempt 0 -> 1
server2# ifconfig carp0 vhid 1 pass foo \
> advskew 100 carpdev fxp1 \
> 192.168.0.20 255.255.255.0

server2# ifconfig carp1 vhid 1 pass bar \
> advskew 100 carpdev fxp0 \
> 10.0.0.1 255.255.255.0

server2# ifconfig pfsync0 syncdev xl0

server2# sysctl -w net.inet.carp.preempt=1
net.inet.carp.preempt 0 -> 1

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Basic Setup – server2

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server2# ifconfig carp0 vhid 1 pass foo 
   > advskew 100 carpdev fxp1 
   > 192.168.0.20 255.255.255.0

server2# ifconfig carp1 vhid 1 pass bar 
   > advskew 100 carpdev fxp0 
   > 10.0.0.1 255.255.255.0

server2# ifconfig pfsync0 syncdev xl0

server2# sysctl -w net.inet.carp.preempt=1
net.inet.carp.preempt 0 -> 1

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```
server2# ifconfig carp0 vhid 1 pass foo \ > advskew 100 carpdev fxp1 \ > 192.168.0.20 255.255.255.0

server2# ifconfig carp1 vhid 1 pass bar \ > advskew 100 carpdev fxp0 \ > 10.0.0.1 255.255.255.0

server2# ifconfig pfsync0 syncdev xl0

server2# sysctl -w net.inet.carp.preempt=1
net.inet.carp.preempt 0 -> 1

server2# sysctl -w net.inet.ip.forwarding=1
net.inet.ip.forwarding 0 -> 1

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server2# pfctl -f /etc/pf.conf
Demonstration
Basic Example - Troubleshooting

- **Tools:**
  -Tcpdump, ifconfig, arp, pfctl, vmstat, pftop

- **Items to check:**
  -CARP, PFSYNC announcements
  -Interface state (MASTER, BACKUP, INIT)
  -LAN client settings (CARP gateway)

- **Application tests:**
  -Ping
  -Large file transfer (scp/sftp)
  -Multimedia over NFS

- **Failover mechanisms:**
  -Down CARP interface
  -Unplug ethernet cable
  -Power down CARP member
Advanced Failover with Load-Balancing
Advanced Example

- Multiple CARP virtual hosts on each gateway
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- Each CARP member will serve as MASTER for one CARP interface, and BACKUP as the other
Advanced Example

- Multiple CARP virtual hosts on each gateway
- Virtual host ID (vhid) must be unique for each CARP interface on each segment
- Each CARP member will serve as MASTER for one CARP interface, and BACKUP as the other
- Load-balance at the packet level (net.inet.carp.arpbalance)
Advanced Filtering - pf.conf

# Macros
ext_if="fxp1"
int_if="fxp0"
pfsync_if="x10"
http_ext="192.168.0.20"
http_int="10.0.0.50"
smtp_ext="192.168.0.30"
smtp_int="10.0.0.60"

# Options
set skip on { lo $int_if }

# Normalization
scrub in

# Translation
binat on $ext_if from any to $smtp_ext \ 
   -> $smtp_int
rdr on $ext_if from any to $http_ext \ 
    port http -> $http_int source-hash

# cont'd ...
# ... cont'd

# Filters
block in
pass quick on { $ext_if $int_if } \ 
    proto carp keep state
pass quick on $pfsync_if proto pfsync
pass in on $ext_if inet proto icmp \ 
    icmp-type echoreq keep state
pass in on $ext_if inet proto tcp \ 
    from any to ($ext_if) port ssh \ 
    flags S/SA keep state
pass in on $ext_if inet proto tcp \ 
    from any to $smtp_int port smtp \ 
    flags S/SA keep state
pass in on $ext_if inet proto tcp \ 
    from any to $http_int port http \ 
    flags S/SA keep state
pass out on $ext_if keep state

# EOF
server1# ifconfig carp0 vhid 1 pass foo carpdev fxp1 \
> 192.168.0.20 255.255.255.0

server1# ifconfig carp0 vhid 1 pass foo carpdev fxp1 \
> alias 192.168.0.30 255.255.255.0

server1# ifconfig carp1 vhid 2 pass foo carpdev fxp1 \
> advskew 100 192.168.0.20 255.255.255.0

server1# ifconfig carp1 vhid 2 pass foo carpdev fxp1 \
> advskew 100 alias 192.168.0.30 255.255.255.0

server1# ifconfig carp2 vhid 1 pass bar carpdev fxp0 \
> 10.0.0.1 255.255.255.0

server1# ifconfig carp3 vhid 2 pass bar carpdev fxp0 \
> advskew 100 10.0.0.1 255.255.255.0

server1# sysctl -w net.inet.carp.arpbalance=1
net.inet.carp.arpbalance: 0 -> 1
server2# ifconfig carp0 vhid 1 pass foo carpdev fxp1 \ > advskew 100 192.168.0.20 255.255.255.0

server2# ifconfig carp0 vhid 1 pass foo carpdev fxp1 \ > advskew 100 alias 192.168.0.30 255.255.255.0

server2# ifconfig carp1 vhid 2 pass foo carpdev fxp1 \ > 192.168.0.20 255.255.255.0

server2# ifconfig carp1 vhid 2 pass foo carpdev fxp1 \ > alias 192.168.0.30 255.255.255.0

server2# ifconfig carp2 vhid 1 pass bar carpdev fxp0 \ > advskew 100 10.0.0.1 255.255.255.0

server2# ifconfig carp3 vhid 2 pass bar carpdev fxp0 \ > 10.0.0.1 255.255.255.0

server2# sysctl -w net.inet.carp.arpbalance=1
net.inet.carp.arpbalance: 0 -> 1
Brief Intermission
sasynccd

- IPSec SA synchronization daemon
sasyncd

- IPSec SA synchronization daemon
- Tracks state changes on a CARP interface
sasynccd

- IPSec SA synchronization daemon
- Tracks state changes on a CARP interface
- Messages encrypted using AES key
sasynccd

- IPSec SA synchronization daemon
- Tracks state changes on a CARP interface
- Messages encrypted using AES key
- /etc/sasynccd.conf
sasyncd

- IPSec SA synchronization daemon
- Tracks state changes on a CARP interface
- Messages encrypted using AES key
- /etc/sasyncd.conf
- Shared IPSec keys for CARP hosts
IPSes Failover Setup – CARP hosts

server1# cat /etc/hostname.carp0
vhid 1 pass foo carpdev fxp1 192.168.0.20 255.255.255.0
!ipsecadm flush
!ipsecadm flow -addr 10.0.0.0/24 10.10.10.0/24 \
    -src 192.168.0.20 -dst 192.168.0.23 \
    -proto esp -out -require
!ipsecadm flow -addr 10.10.10.0/24 10.0.0.0/24 \
    -src 192.168.0.20 -dst 192.168.0.23 \
    -proto esp -in -require
!sasyncd

server1# cat /etc/sasyncd.conf
carp interface carp0
peer 10.255.255.22
sharedkey /etc/sasyncd.key
Summary

- HA Firewall & VPN solution
- Commodity hardware
- Available for all BSDs and Linux (uCARP)
- Competes with (or exceeds) functionality of commercial offerings
References

- OpenBSD -- http://www.openbsd.org/
- PF -- http://www.benzedrine.cx/pf.html
- VRRP RFC 3768 -- http://www.faqs.org/rfcs/rfc3768.html
- OpenBSD FAQ -- http://www.openbsd.org/faq/index.html
- Userland CARP -- http://www.ucarp.org/
Stateful Failover