

Failover and Route Redundancy for IP Based Networks

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The Goal

- Provide redundant connectivity using IPv4 network connections
- Requirements
 - Multiple connections
 - Router with multiple WAN ports
 - Consumer style hardware does not support this
- Purpose
 - Full redundancy vs. command and control backup
 - Inbound or outbound

Applications

- QTH access to outside world
 - ISP failover to Starlink
 - ISP failover to Starlink, then cellphone network
- Remote site
 - Microwave link and VPN backup
 - VPN only site with multiple ISPs

Note that these make outbound connections

Failover vs. Load Balancing

- **Failover** uses one connection at a time
 - Selected using specified order
 - Link State Routing
 - Outbound is easier than symmetric or inbound
- **Load Balancing** uses all the connections on a per packet or per connection basis
 - Link aggregation or bonding for point-to-point
 - Usually includes failover

Connection Selections

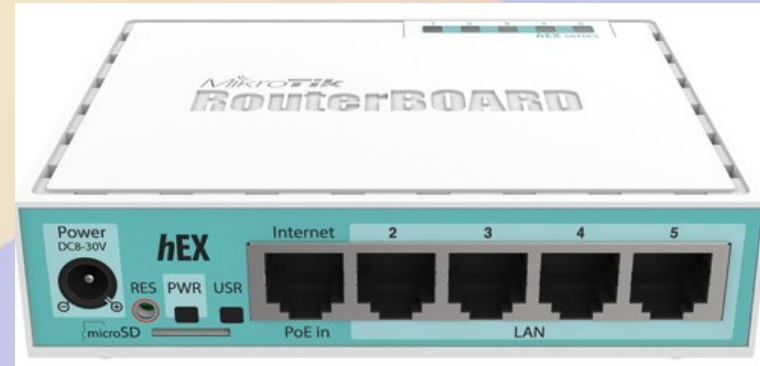
- Terrestrial microwave links
- Commercial ISPs (fiber, copper, wireless)
- Starlink (attractive metered pricing)
- Cellphone data networks
- Other data networks (CellWave, LoRa, ...)
 - Anything with an ethernet or fiber interface

Router Hardware

- Any Unix/Linux box with multiple ethernet cards
 - Routing in software via the linux kernel
 - Wrapper programs like **Sonicwall** and **pfSense** do this
- Mikrotik Routerboard
 - Any port can serve any function
 - Hardware switching fabric for wire speed routing
 - Linux kernel tuned for routing
 - Inexpensive and wide range of capabilities
 - WinBox GUI simplifies configuration
- Cisco, Juniper, Arista, ...

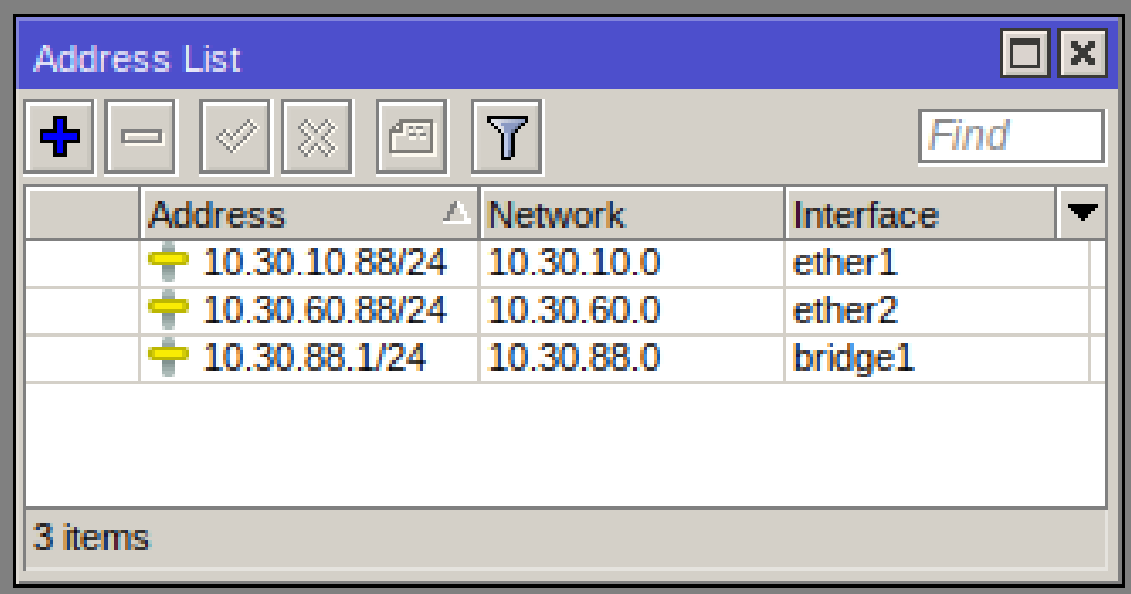
Mikrotik Hardware

- Very capable
- Wide range of speeds
- Same user interface
- Inexpensive



Route Distance Failover Scenario

- Two WAN addresses
 - 10.30.10.88/24,
GW=10.30.10.1
 - 10.30.60.88/24,
GW=10.30.60.1
- Local network
 - 10.30.88.1/24



The screenshot shows a window titled "Address List" with a blue header bar. Below the header is a toolbar with icons for adding (+), removing (-), checking (✓), unchecking (✗), saving (floppy disk), and filtering (funnel). To the right of the toolbar is a search box labeled "Find". Below the toolbar is a table with four columns: "Address", "Network", and "Interface". The "Address" column has a small upward arrow icon, and the "Interface" column has a small downward arrow icon. The table contains three rows of data, each with a yellow plus icon in the first column. At the bottom of the window, a status bar indicates "3 items".

	Address ▲	Network	Interface ▼
+	10.30.10.88/24	10.30.10.0	ether1
+	10.30.60.88/24	10.30.60.0	ether2
+	10.30.88.1/24	10.30.88.0	bridge1

3 items

Distance Failover Default Routes

The image displays two side-by-side network configuration windows for static default routes. Both windows have a title bar indicating the destination address: "Route <0.0.0.0/0>->10.30.10.1>" on the left and "Route <0.0.0.0/0>->10.30.60.1>" on the right.

Left Window (Destination: 10.30.10.1):

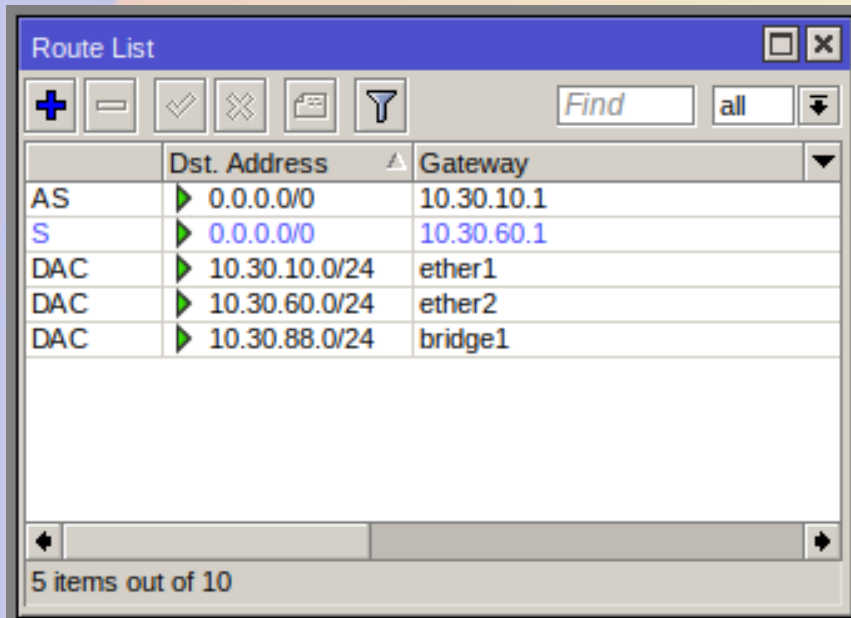
- General Tab:**
 - Dst. Address: 0.0.0.0/0
 - Gateway: 10.30.10.1
 - Immediate Gateway: [10.30.10.1%ether1](#)
 - Local Address: (empty)
 - Check Gateway: (dropdown menu)
 - ☐ Suppress Hw Offload
 - Distance: 1** (highlighted with a red box)
 - Scope: 30
 - Target Scope: 10
 - VRF Interface: (dropdown menu)
 - Routing Table: main
 - Pref. Source: (dropdown menu)
 - ☐ Blackhole
- Buttons:** OK, Cancel, Apply, Disable, Comment, Copy, Remove
- Status Bar:** enabled, active, static, Hw Offload, ECMP, inactive

Right Window (Destination: 10.30.60.1):

- General Tab:**
 - Dst. Address: 0.0.0.0/0
 - Gateway: 10.30.60.1
 - Immediate Gateway: [10.30.60.1%ether2](#)
 - Local Address: (empty)
 - Check Gateway: (dropdown menu)
 - ☐ Suppress Hw Offload
 - Distance: 2** (highlighted with a red box)
 - Scope: 30
 - Target Scope: 10
 - VRF Interface: (dropdown menu)
 - Routing Table: main
 - Pref. Source: (dropdown menu)
 - ☐ Blackhole
- Buttons:** OK, Cancel, Apply, Disable, Comment, Copy, Remove
- Status Bar:** enabled, static, Hw Offloaded, ECMP, inactive

Route Failover

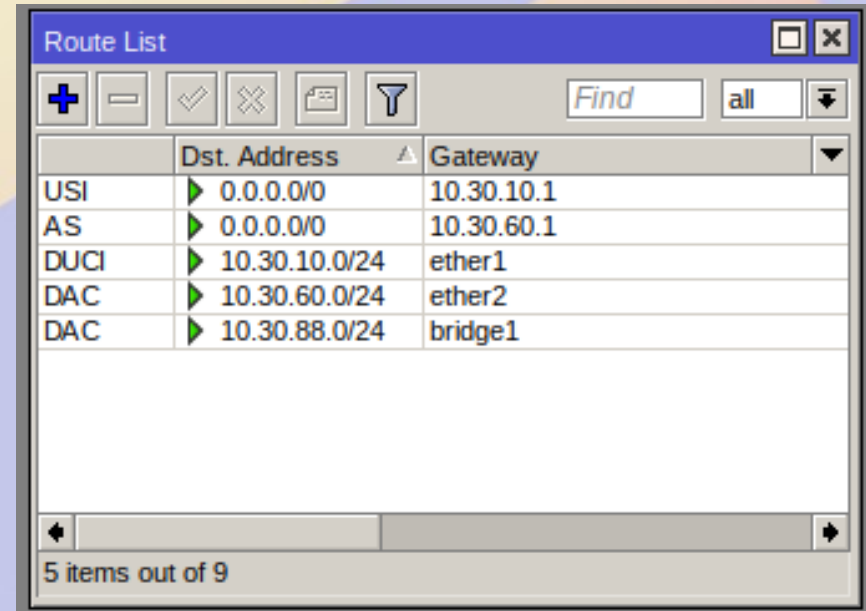
- Both active
 - AS=Active Static
 - blue means not selected
- Failed primary
 - USI=Unreachable, Static, Inactive



The screenshot shows a 'Route List' window with a toolbar containing icons for adding, removing, checking, unchecking, saving, and filtering. A search bar contains the text 'Find' and 'all'. The table below lists routes with columns for status, destination address, and gateway. The first two rows are highlighted in blue, indicating they are not selected. The status 'AS' is shown in blue for the first row, and 'S' for the second row. The status 'DAC' is shown in black for the last three rows. The status 'AS' is shown in black for the first row, and 'S' for the second row. The status 'DAC' is shown in black for the last three rows. The status 'AS' is shown in black for the first row, and 'S' for the second row. The status 'DAC' is shown in black for the last three rows.

	Dst. Address	Gateway
AS	0.0.0.0/0	10.30.10.1
S	0.0.0.0/0	10.30.60.1
DAC	10.30.10.0/24	ether1
DAC	10.30.60.0/24	ether2
DAC	10.30.88.0/24	bridge1

5 items out of 10



The screenshot shows a 'Route List' window with a toolbar containing icons for adding, removing, checking, unchecking, saving, and filtering. A search bar contains the text 'Find' and 'all'. The table below lists routes with columns for status, destination address, and gateway. The first row is highlighted in blue, indicating it is not selected. The status 'USI' is shown in blue for the first row, and 'AS' for the second row. The status 'DAC' is shown in black for the last three rows. The status 'USI' is shown in blue for the first row, and 'AS' for the second row. The status 'DAC' is shown in black for the last three rows. The status 'USI' is shown in blue for the first row, and 'AS' for the second row. The status 'DAC' is shown in black for the last three rows.

	Dst. Address	Gateway
USI	0.0.0.0/0	10.30.10.1
AS	0.0.0.0/0	10.30.60.1
DUCI	10.30.10.0/24	ether1
DAC	10.30.60.0/24	ether2
DAC	10.30.88.0/24	bridge1

5 items out of 9

Route Distance Pros and Cons

- **Pros**

- Easy to configure
- Works with >2 links
- Senses failure from link
- Fails over/back fast
- Works with default route
- Works for static route

- **Cons**

- Requires link to fail
- Cannot sense downstream failures
 - Wireless link local radio OK but remote radio failed
 - Failure after next device
 - Failure at ISP

Failure on Wireless Links

- Wireless links are bridged
 - Wireless link works like a wire
 - Link check only to local radio
- Set **check-gateway=ping**
- When pings fail, route is deactivated

Route <0.0.0.0->10.30.10.1>

General Status MPLS

Dst. Address: 0.0.0.0/0

Gateway: 10.30.10.1

Immediate Gateway: 10.30.10.1%ether1

Local Address:

Check Gateway: ping

☐ Suppress Hw Offload

Distance: 1

Scope: 30

Target Scope: 10

VRF Interface:

Routing Table: main

Pref. Source:

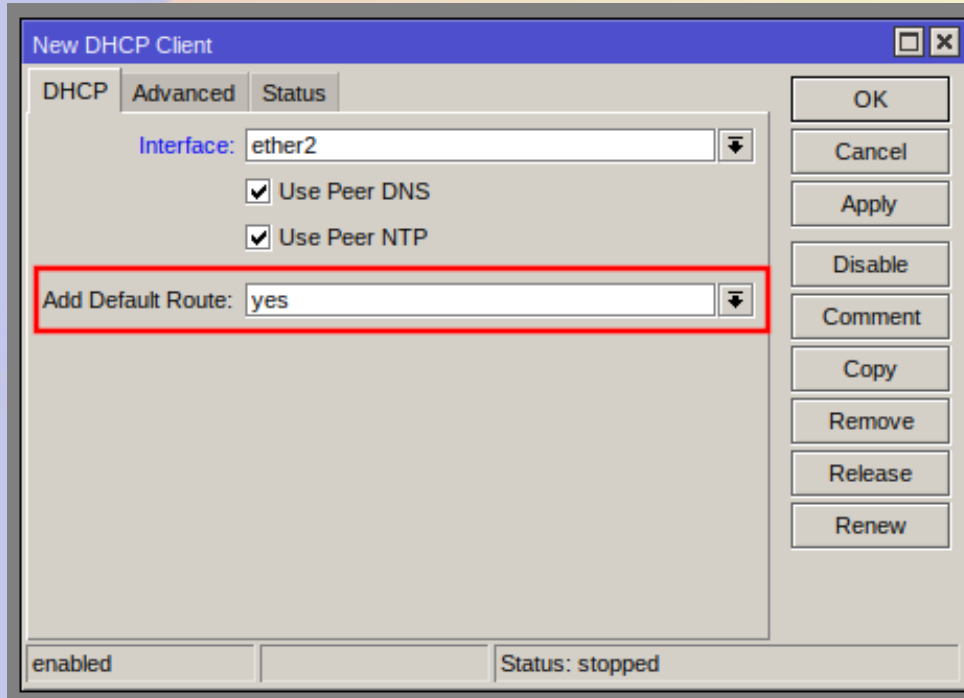
☐ Blackhole

OK Cancel Apply Disable Comment Copy Remove

enabled active static Hw Offlo... ECMP inactive

Interfaces with DHCP

- Set default distance when adding interface



The image shows the 'New DHCP Client' dialog box with the 'DHCP' tab selected. The 'Interface' is set to 'ether2'. The 'Add Default Route' dropdown is highlighted with a red box and set to 'yes'. The status at the bottom is 'enabled' and 'Status: stopped'.

New DHCP Client

DHCP Advanced Status

Interface: ether2

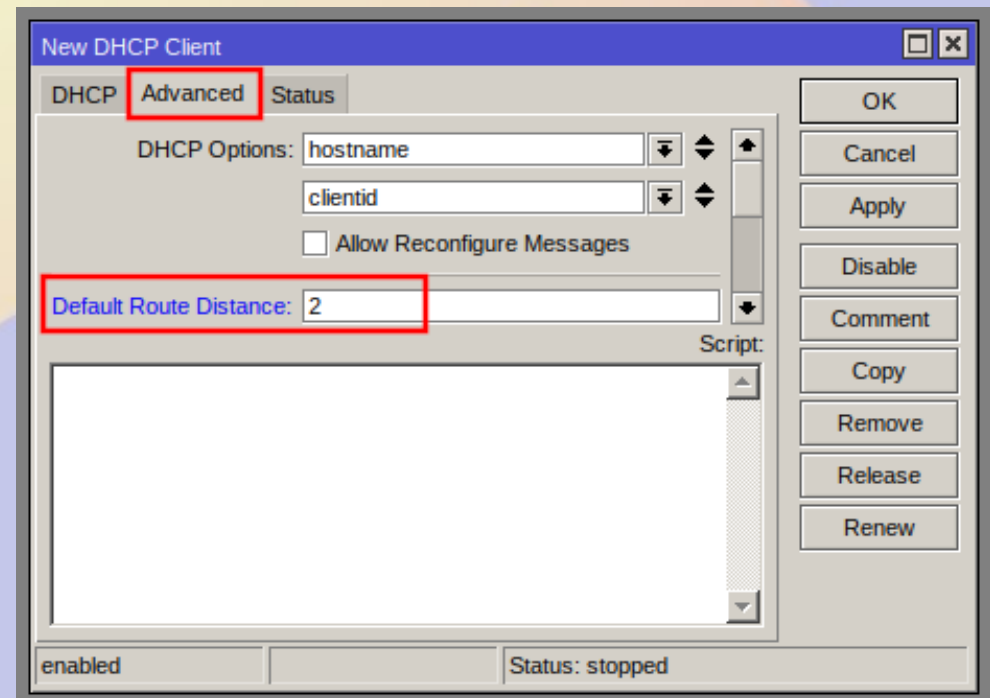
☒ Use Peer DNS

☒ Use Peer NTP

Add Default Route: yes

OK Cancel Apply Disable Comment Copy Remove Release Renew

enabled Status: stopped



The image shows the 'New DHCP Client' dialog box with the 'Advanced' tab selected. The 'Default Route Distance' is set to '2' and is highlighted with a red box. The status at the bottom is 'enabled' and 'Status: stopped'.

New DHCP Client

DHCP Advanced Status

DHCP Options: hostname clientid

☐ Allow Reconfigure Messages

Default Route Distance: 2

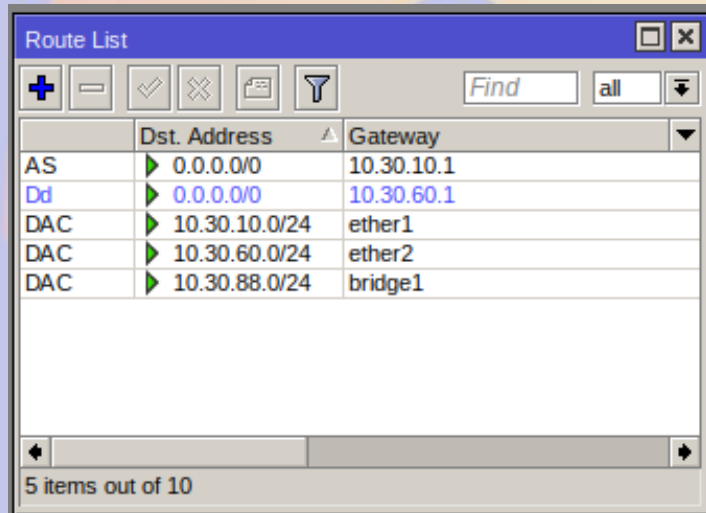
Script:

OK Cancel Apply Disable Comment Copy Remove Release Renew

enabled Status: stopped

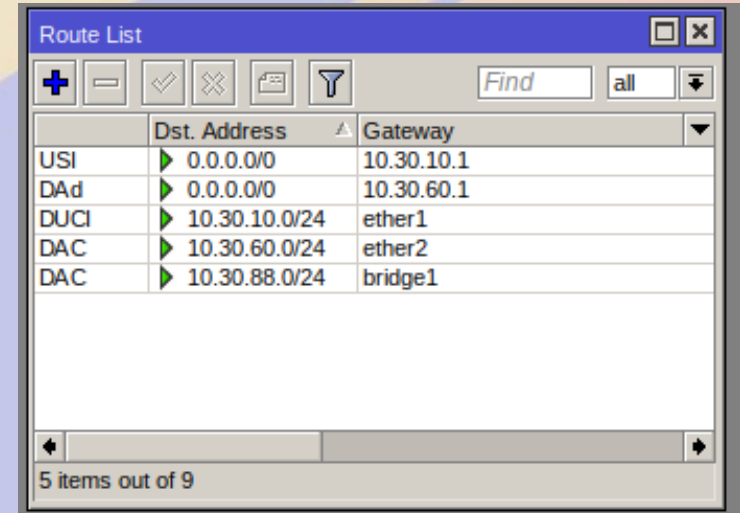
Failover with DHCP

- Primary active
 - Dd=Dynamic,DHCP
 - blue means not selected
- Failed primary
 - Dad=Dynamic,Active,DHCP



The 'Route List' window displays a table of routes. The first two rows are highlighted in blue, indicating they are not selected. The first row is 'AS' with destination '0.0.0.0/0' and gateway '10.30.10.1'. The second row is 'Dd' with destination '0.0.0.0/0' and gateway '10.30.60.1'. The remaining three rows are 'DAC' with destinations '10.30.10.0/24', '10.30.60.0/24', and '10.30.88.0/24', all with gateways 'ether1', 'ether2', and 'bridge1' respectively. The status bar at the bottom indicates '5 items out of 10'.

	Dst. Address	Gateway
AS	0.0.0.0/0	10.30.10.1
Dd	0.0.0.0/0	10.30.60.1
DAC	10.30.10.0/24	ether1
DAC	10.30.60.0/24	ether2
DAC	10.30.88.0/24	bridge1



The 'Route List' window displays a table of routes. The first two rows are highlighted in blue, indicating they are not selected. The first row is 'USI' with destination '0.0.0.0/0' and gateway '10.30.10.1'. The second row is 'DAd' with destination '0.0.0.0/0' and gateway '10.30.60.1'. The remaining three rows are 'DUCI' with destination '10.30.10.0/24' and gateway 'ether1', and two 'DAC' rows with destinations '10.30.60.0/24' and '10.30.88.0/24' and gateways 'ether2' and 'bridge1' respectively. The status bar at the bottom indicates '5 items out of 9'.

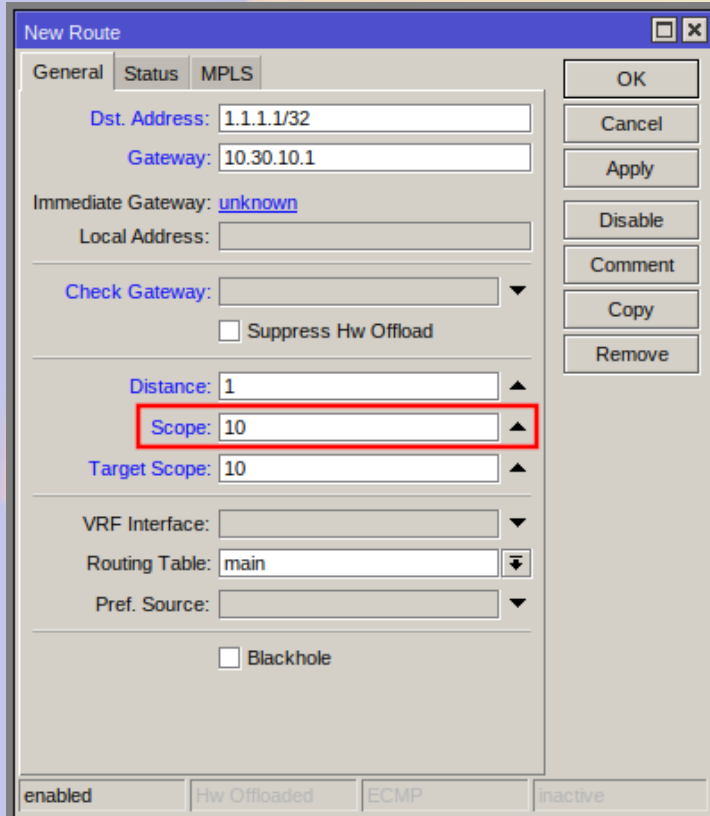
	Dst. Address	Gateway
USI	0.0.0.0/0	10.30.10.1
DAd	0.0.0.0/0	10.30.60.1
DUCI	10.30.10.0/24	ether1
DAC	10.30.60.0/24	ether2
DAC	10.30.88.0/24	bridge1

Recursive Routing

- Select a reliable remote target (e.g. 1.1.1.1)
 - This address will not be available if primary route fails
- Set a route to this address with **scope=10**
- Add a default route using
 - target address as gateway
 - **target scope** > scope of remote target (11>10)

Recursive setting

- Gateway route
- Recursive default route



The 'New Route' dialog box is shown with the 'General' tab selected. The 'Dst. Address' is '1.1.1.1/32' and the 'Gateway' is '10.30.10.1'. The 'Scope' is set to '10' and is highlighted with a red box. The 'Target Scope' is also '10'. The 'Distance' is '1'. The 'Check Gateway' dropdown is set to 'ping'. The 'Suppress Hw Offload' checkbox is unchecked. The 'VRF Interface' is empty, 'Routing Table' is 'main', and 'Pref. Source' is empty. The 'Blackhole' checkbox is unchecked. The 'OK', 'Cancel', 'Apply', 'Disable', 'Comment', 'Copy', and 'Remove' buttons are on the right. The status bar at the bottom shows 'enabled', 'Hw Offloaded', 'ECMP', and 'inactive'.

New Route

General Status MPLS

Dst. Address: 1.1.1.1/32

Gateway: 10.30.10.1

Immediate Gateway: unknown

Local Address:

Check Gateway: ping

☐ Suppress Hw Offload

Distance: 1

Scope: 10

Target Scope: 10

VRF Interface:

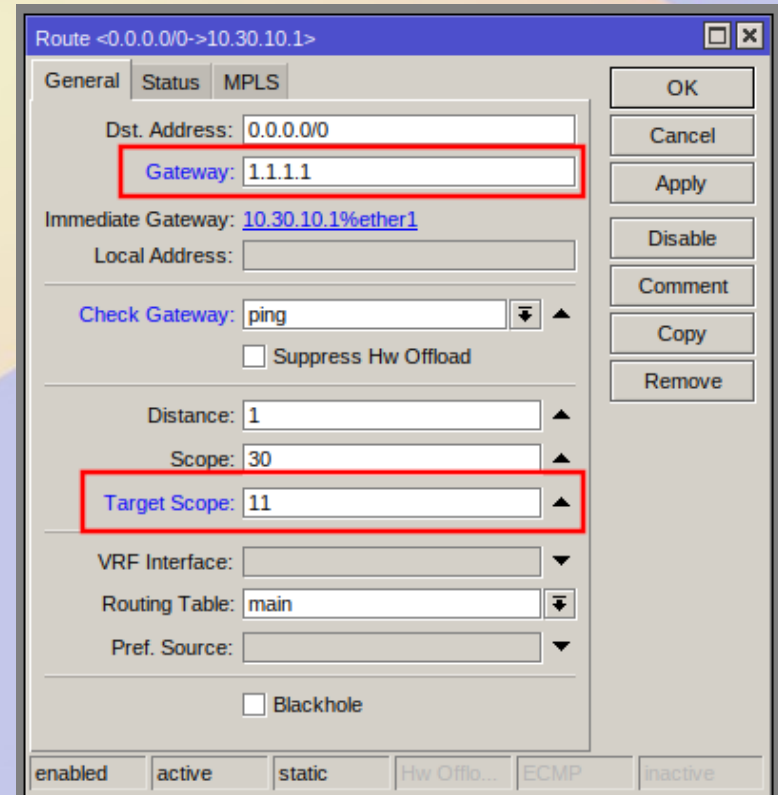
Routing Table: main

Pref. Source:

☐ Blackhole

OK Cancel Apply Disable Comment Copy Remove

enabled Hw Offloaded ECMP inactive



The 'Route' dialog box is shown with the 'General' tab selected. The 'Dst. Address' is '0.0.0.0/0' and the 'Gateway' is '1.1.1.1', both highlighted with red boxes. The 'Immediate Gateway' is '10.30.10.1%ether1'. The 'Scope' is '30' and the 'Target Scope' is '11', both highlighted with red boxes. The 'Distance' is '1'. The 'Check Gateway' dropdown is set to 'ping'. The 'Suppress Hw Offload' checkbox is unchecked. The 'VRF Interface' is empty, 'Routing Table' is 'main', and 'Pref. Source' is empty. The 'Blackhole' checkbox is unchecked. The 'OK', 'Cancel', 'Apply', 'Disable', 'Comment', 'Copy', and 'Remove' buttons are on the right. The status bar at the bottom shows 'enabled', 'active', 'static', 'Hw Offlo...', 'ECMP', and 'inactive'.

Route <0.0.0.0/0->10.30.10.1>

General Status MPLS

Dst. Address: 0.0.0.0/0

Gateway: 1.1.1.1

Immediate Gateway: 10.30.10.1%ether1

Local Address:

Check Gateway: ping

☐ Suppress Hw Offload

Distance: 1

Scope: 30

Target Scope: 11

VRF Interface:

Routing Table: main

Pref. Source:

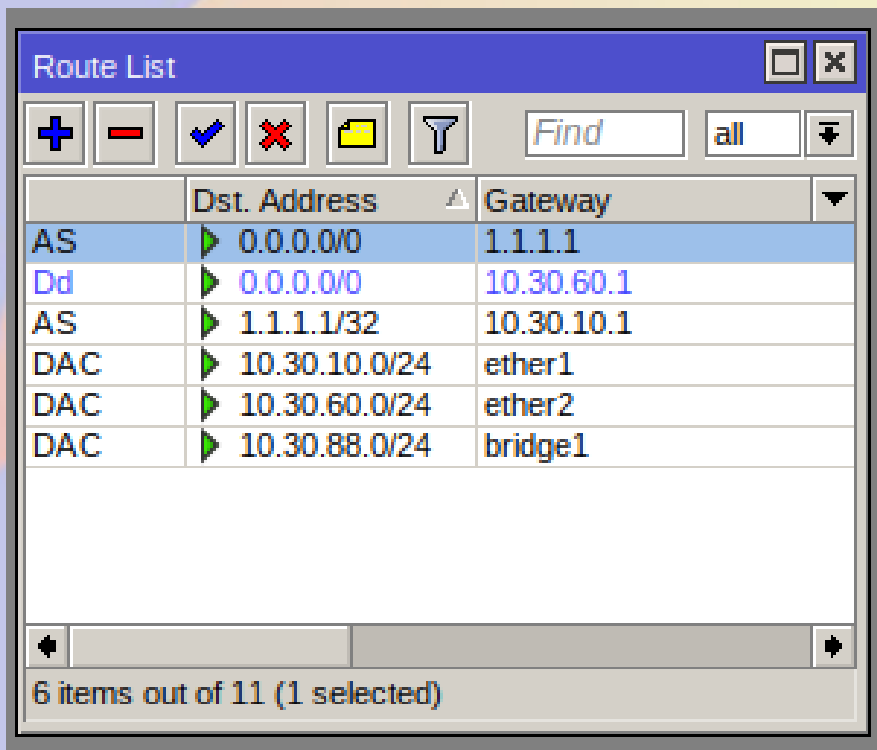
☐ Blackhole

OK Cancel Apply Disable Comment Copy Remove

enabled active static Hw Offlo... ECMP inactive

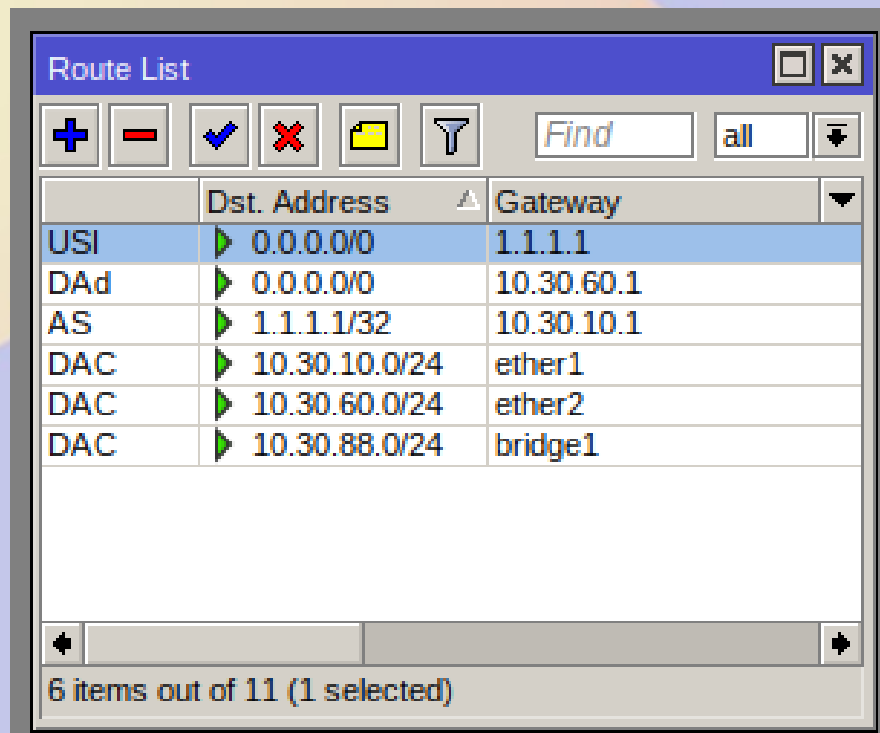
Recursive Routing in Action

- 1.1.1.1 reachable
- 1.1.1.1 unreachable



Route List window showing routing table. The table has columns for Source, Dst. Address, and Gateway. The first row is selected (AS, 0.0.0.0/0, 1.1.1.1). The second row is Dd, 0.0.0.0/0, 10.30.60.1. The third row is AS, 1.1.1.1/32, 10.30.10.1. The fourth row is DAC, 10.30.10.0/24, ether1. The fifth row is DAC, 10.30.60.0/24, ether2. The sixth row is DAC, 10.30.88.0/24, bridge1. The status bar shows 6 items out of 11 (1 selected).

	Dst. Address	Gateway
AS	0.0.0.0/0	1.1.1.1
Dd	0.0.0.0/0	10.30.60.1
AS	1.1.1.1/32	10.30.10.1
DAC	10.30.10.0/24	ether1
DAC	10.30.60.0/24	ether2
DAC	10.30.88.0/24	bridge1

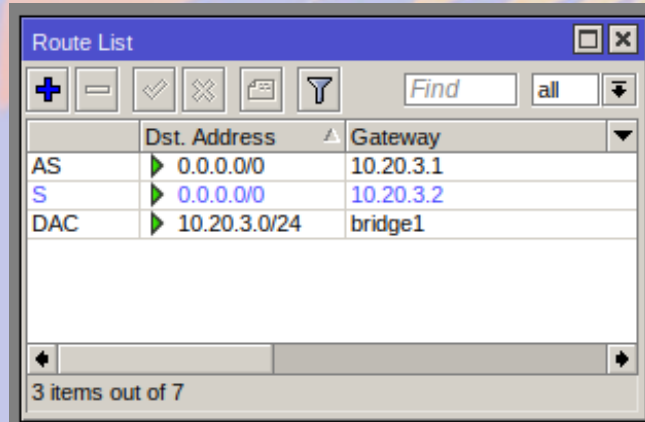


Route List window showing routing table. The table has columns for Source, Dst. Address, and Gateway. The first row is selected (USI, 0.0.0.0/0, 1.1.1.1). The second row is DAd, 0.0.0.0/0, 10.30.60.1. The third row is AS, 1.1.1.1/32, 10.30.10.1. The fourth row is DAC, 10.30.10.0/24, ether1. The fifth row is DAC, 10.30.60.0/24, ether2. The sixth row is DAC, 10.30.88.0/24, bridge1. The status bar shows 6 items out of 11 (1 selected).

	Dst. Address	Gateway
USI	0.0.0.0/0	1.1.1.1
DAd	0.0.0.0/0	10.30.60.1
AS	1.1.1.1/32	10.30.10.1
DAC	10.30.10.0/24	ether1
DAC	10.30.60.0/24	ether2
DAC	10.30.88.0/24	bridge1

Link radio Default Gateway failover

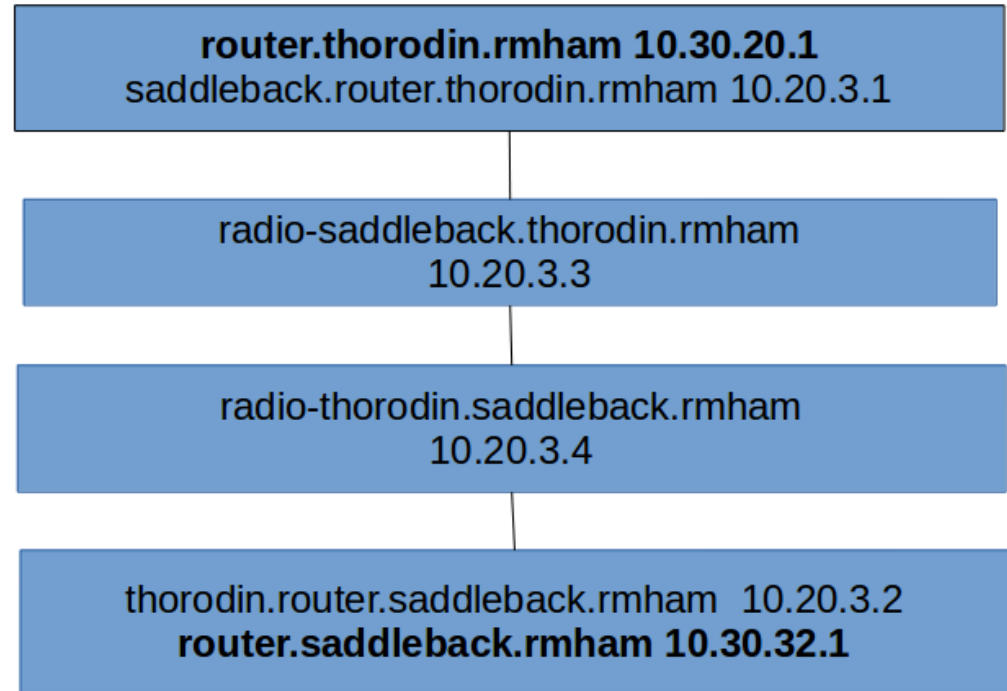
- Router link IP is **10.20.3.1** and **10.20.3.2**
- Radio IP is **10.20.3.3** and **10.20.3.4**



The screenshot shows a 'Route List' window with a toolbar containing icons for adding, removing, and filtering routes. The table below displays the current route list:

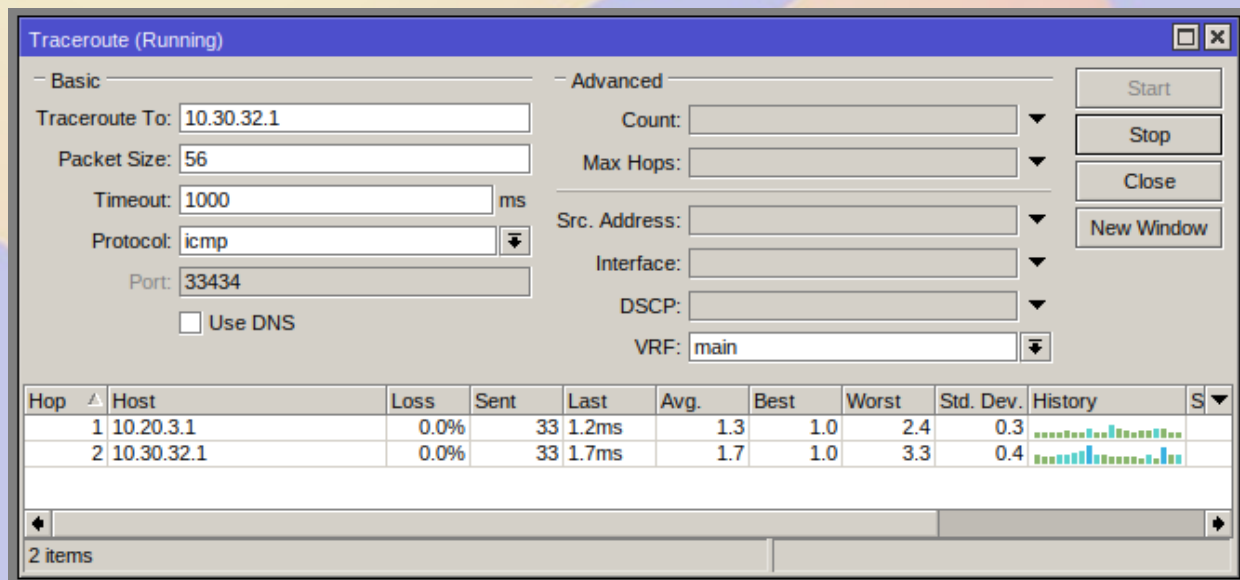
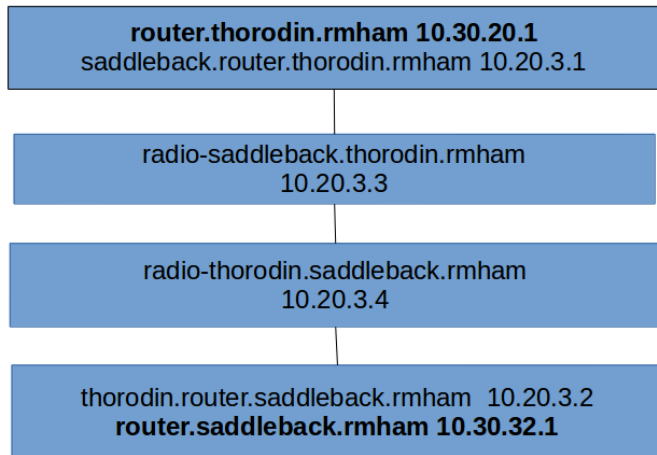
	Dst. Address	Gateway
AS	0.0.0.0/0	10.20.3.1
S	0.0.0.0/0	10.20.3.2
DAC	10.20.3.0/24	bridge1

At the bottom of the window, it indicates '3 items out of 7'.



Traceroute from 10.20.3.4 to 10.30.32.1

- With only a default route, packets go to the default gateway, so they traverse RF link twice



When the RF link fails

- Default gateway **10.20.3.1** becomes unreachable from link radio **10.20.3.4**
- Therefore **10.20.3.4** is unreachable even when directly connected to **10.30.32.1**
 - Laptop IP is (say) **10.30.32.200**, default gateway **10.30.32.1**
 - **10.30.32.1** knows to send packets to **10.20.3.4**, but **10.20.3.4** tries to reply via **10.20.3.1**
 - Unless secondary default gateway is set to directly attached secondary interface **10.20.3.2**
 - Or you use a Layer 2 protocol like ROMON

Inbound Failover

- How do I know what IP to connect to
 - Where does this subnet connect to my network?
- DNS based failover
 - Publish both IP addresses with DNS
 - Connecting programs try other IP if first is unavailable
 - Does not work with NAT
 - When primary is up, request on secondary replies via primary

Network Wide Failover with OSPF

- **Open Shortest Path First**
 - Each link has an associated distance (weight)
 - Each router publishes routes it knows to neighbors
 - Dijkstra's algorithm find shortest open path
 - Each router only needs to know whom to send to next
- **Link State Routing**
 - Preferred route to each subnet (lowest weight/distance)
 - All routers know about all subnets (scales to 1000s)

OSPF Routes

(RMHAM Squaw Pass Site)

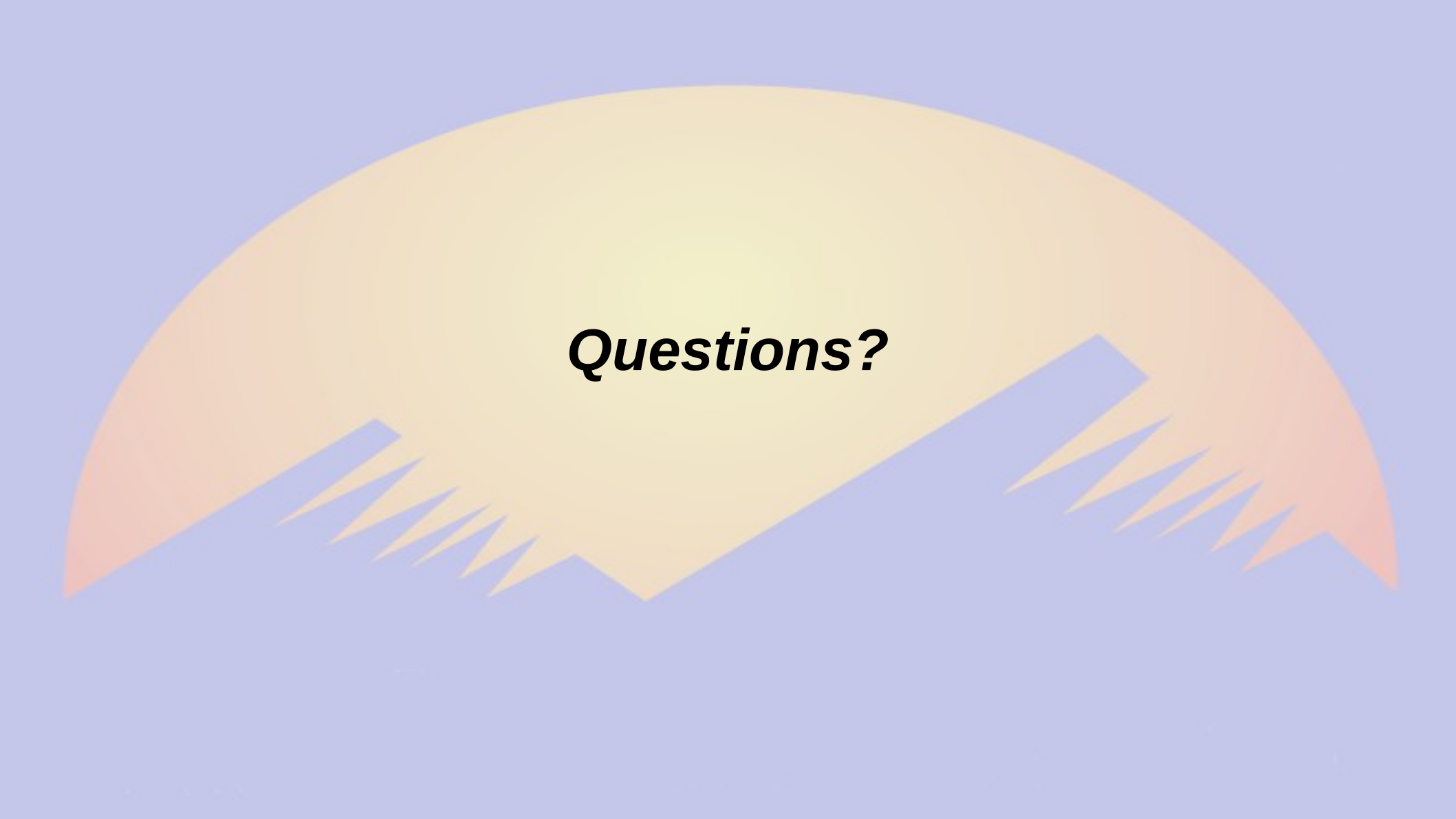
- Default route set both as static and OSPF
 - Fails to RF when ISP is down
- Other subnets discovered from neighbors
 - Devilshead
 - Saddleback

	Do	Dst. Address	Gateway	Distance	Routing Table	Pre
	▶	0.0.0.0/0	10.20.13.2%ether1-Saddleback	110	main	
AS	▶	0.0.0.0/0	165.140.184.225	1	main	
DAo	▶	10.0.0.0/8	10.20.13.2%ether1-Saddleback	110	main	
DAo	▶	10.0.0.0/24	10.20.5.2%sf1-DEVILSHEAD	110	main	
DAo	▶	10.0.2.0/24	10.20.5.2%sf1-DEVILSHEAD	110	main	
DAo	▶	10.0.3.0/24	10.20.5.2%sf1-DEVILSHEAD	110	main	
DAo	▶	10.0.9.0/24	10.20.5.2%sf1-DEVILSHEAD	110	main	
DAo	▶	10.0.10.0/24	10.20.5.2%sf1-DEVILSHEAD	110	main	
DAo	▶	10.0.11.0/24	10.20.5.2%sf1-DEVILSHEAD	110	main	
DAo	▶	10.0.12.0/24	10.20.5.2%sf1-DEVILSHEAD	110	main	
DAo	▶	10.0.15.0/24	10.20.5.2%sf1-DEVILSHEAD	110	main	
DAo	▶	10.0.100.0/24	10.20.5.2%sf1-DEVILSHEAD	110	main	
DAo	▶	10.1.1.0/24	10.20.5.2%sf1-DEVILSHEAD	110	main	
DAo	▶	10.1.2.0/24	10.20.5.2%sf1-DEVILSHEAD	110	main	
DAo	▶	10.5.1.0/24	10.20.5.2%sf1-DEVILSHEAD	110	main	
DAo	▶	10.5.2.0/24	10.20.5.2%sf1-DEVILSHEAD	110	main	
DAo	▶	10.5.3.0/24	10.20.5.2%sf1-DEVILSHEAD	110	main	
DAo	▶	10.5.4.0/24	10.20.5.2%sf1-DEVILSHEAD	110	main	
DAo	▶	10.5.5.0/24	10.20.5.2%sf1-DEVILSHEAD	110	main	
DAo	▶	10.5.6.0/29	10.20.5.2%sf1-DEVILSHEAD	110	main	
DAo	▶	10.5.13.0/24	10.20.5.2%sf1-DEVILSHEAD	110	main	
DAo	▶	10.6.0.1/32	10.20.13.2%ether1-Saddleback	110	main	
DAo	▶	10.9.239.0/24	10.20.5.2%sf1-DEVILSHEAD	110	main	
DAo	▶	10.11.3.0/24	10.20.13.2%ether1-Saddleback	110	main	
DAo	▶	10.11.4.0/23	10.20.13.2%ether1-Saddleback	110	main	
DAo	▶	10.11.6.0/23	10.20.13.2%ether1-Saddleback	110	main	
DAo	▶	10.11.11.0/24	10.20.13.2%ether1-Saddleback	110	main	
DAo	▶	10.11.12.0/24	10.20.13.2%ether1-Saddleback	110	main	
DAo	▶	10.11.13.0/24	10.20.13.2%ether1-Saddleback	110	main	
DAo	▶	10.11.14.0/24	10.20.13.2%ether1-Saddleback	110	main	
DAo	▶	10.11.15.0/24	10.20.13.2%ether1-Saddleback	110	main	
DAo	▶	10.11.16.0/24	10.20.13.2%ether1-Saddleback	110	main	
DAo	▶	10.11.17.0/24	10.20.13.2%ether1-Saddleback	110	main	
DAo	▶	10.11.19.0/24	10.20.5.2%sf1-DEVILSHEAD	110	main	
DAo	▶	10.11.21.0/24	10.20.13.2%ether1-Saddleback	110	main	
DAo	▶	10.11.22.0/24	10.20.13.2%ether1-Saddleback	110	main	
DAo	▶	10.11.23.0/24	10.20.13.2%ether1-Saddleback	110	main	
DAo	▶	10.11.24.0/24	10.20.13.2%ether1-Saddleback	110	main	
DAo	▶	10.11.27.0/24	10.20.13.2%ether1-Saddleback	110	main	
DAo	▶	10.11.32.0/24	10.20.13.2%ether1-Saddleback	110	main	
DAo	▶	10.11.32.70/32	10.20.13.2%ether1-Saddleback	110	main	

450 items out of 470

OSPF on the RMHAM network

- Alternate RF paths with failover to VPN
- Multi-homed VPN only sites
- Multiple outlets to commercial internet
- Fast (<5 seconds to fail over)



Questions?