Routing and IPv4

based on Chapter 8 of CompTIA Network+ Exam Guide, Mike Meyers

Routing

• How does a data packet get from its source network, to the destination's network?

• Individual networks are connected through the Internet
  - The Internet is a network of **routers**
  - also called a "network of networks"
Looking at Routes

- Routes can be discovered by:
  - traceroute, tracepath – Linux/MacOS programs
  - tracert – Windows program
  - open visual traceroute
    - open-source
cross-platform GUI program

- Some routes are surprising:
  - trace to "unam.mx" for example

Open Visual Traceroute

- Display:
  Map; list of routers; graph of latency times
### Creating a Route for a Packet

- Each router in the path chooses another router to send the packet to, based on its IP address
- No router “knows” the entire path
- This is “distributed knowledge”

*So how does each router decide what "next" router to forward the packet to?*

### Topics

- Home Routers and Backbone Routers
- Routing Tables
  - Dynamic Routing
    - Distance Vector
    - Link State
    - BGP
    - Hybrid
- Network Address Translation
- Working with Routers
Routers

- Routers:
  - Receive an incoming packet on a port
  - Inspect its IP address
  - Choose an outgoing port based on the network ID portion of the IP address
  - Forward the packet to that port

- IP addresses are layer 3 values – so routers are layer 3 devices

Home Routers

- Home routers are actually multi-function devices
  - Ethernet switch
    - layer-2 device
  - 802.11 Access Point
    - layer-2 device
  - two-port router
    - layer-3 device

- Routers operate on two (or more) different networks – the local one and the “Internet connection”

- This diagram shows a Linksys wireless router, implementing the Internet link and the local network as two VLANs (“Virtual LAN”)
  - The Access Point would be part of vlan0
**Backbone Routers**

- High-capacity routers handle multiple throughputs
- Example: Cisco XR12410 "core router"
  - 10 slots
  - 10 Gbps per slot
  - 200 Gbps total throughput
  - Many kinds of ports available to plug into slots
    - Ethernet, SONET, FDDI, etc.
  - $61,000 for a refurbished unit
  - *plus* port adapters

**Dimensions:**
- 37.5 inches high, 19 inches wide, 24 inches deep, 275 pounds

**Configuring a router**

- Web interfaces
  - Router has a built-in webserver
  - Home routers in particular
- Dedicated ports on the router itself
  - Requires physical access to the router
  - Generally on commercial routers
  - Cisco, et al provide their own configuration software and interfaces
- Network connection via SSH
  - Secure Shell – encrypted network connection between nodes
  - Allows “more secure” remote access to routers
The Routing Function

- Many data packets are addressed to destinations on other networks than the source
- Broadcasting an ARP “who-has” to the entire Internet is impractical
- Packets must be moved from the source’s network to the destination’s network
- Routers must know how to get from network to network
  - a routing animation:
    - montcs.bloom.edu/Networking/Simulations/Tomsho/router.swf
    - http://montcs.bloom.edu/Networking/Simulations/Tomsho/router.swf

Router Hops

- This transmission takes three hops from source router to destination router. Another route might take more, or fewer.
Routing Tables

- Router queues incoming packets
  - layer-2 headers are discarded

- Packet's destination IP address is compared to entries in the router's routing table

- Best-matching entry in routing table provides:
  - **Gateway**: IP address for next hop (next router)
  - **Interface**: which router port to forward packet to

A Basic Routing Table

<table>
<thead>
<tr>
<th>Destination</th>
<th>Subnet Mask</th>
<th>Gateway</th>
<th>Interface</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>148.137.59.0</td>
<td>255.255.255.0</td>
<td>148.137.59.1</td>
<td>eth0</td>
<td>2</td>
</tr>
<tr>
<td>192.168.122.0</td>
<td>255.255.255.192</td>
<td>*</td>
<td>eth1</td>
<td>1</td>
</tr>
<tr>
<td>0.0.0.0</td>
<td>0.0.0.0</td>
<td>*</td>
<td>eth0</td>
<td>2</td>
</tr>
<tr>
<td>default</td>
<td>0.0.0.0</td>
<td>148.137.59.1</td>
<td>eth0</td>
<td>2</td>
</tr>
</tbody>
</table>

- **Destination** – a network ID
  - all directly connected networks are included

- **Subnet mask** – description of entry’s size

- **Gateway** – IP address of the next-hop router

- **Interface** – the appropriate outgoing port

- **Metric** – "cost" in hops to use this route
Routing Tables and Network Nodes

- Routers and hosts all have routing tables

  - **Linux:**
    - “route”
    - or
    - “netstat –r”

  - **Windows:**
    - “route print”
    - or
    - “netstat –r”

Routing-Table Entries (Windows version)

- Where is it going?
- How much of the address is network ID?
- What gateway is it going to?
- Which interface leads to that gateway?
- How "expensive" is that link?
Routing-Table Entries – 1

The *most-specific* applicable entry will be used:

0.0.0.0, 0.0.0.0
Default route.
Matches anything, sends to the *local subnet gateway* via this node's NIC.

127.0.0.0, 255.0.0.0
Any address in the Loopback net goes to 127.0.0.1

<table>
<thead>
<tr>
<th>Network Destination</th>
<th>Netmask</th>
<th>Gateway</th>
<th>Interface</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0.0.0</td>
<td>0.0.0.0</td>
<td>148.137.59.1</td>
<td>148.137.59.42</td>
<td>20</td>
</tr>
<tr>
<td>127.0.0.0</td>
<td>255.0.0.0</td>
<td>127.0.0.1</td>
<td>127.0.0.1</td>
<td>1</td>
</tr>
<tr>
<td>148.137.59.0</td>
<td>255.255.255.0</td>
<td>148.137.59.42</td>
<td>148.137.59.42</td>
<td>20</td>
</tr>
<tr>
<td>148.137.59.42</td>
<td>255.255.255.255</td>
<td>127.0.0.1</td>
<td>127.0.0.1</td>
<td>1</td>
</tr>
<tr>
<td>148.137.59.42</td>
<td>255.255.255.255</td>
<td>148.137.59.42</td>
<td>148.137.59.42</td>
<td>20</td>
</tr>
<tr>
<td>224.0.0.0</td>
<td>240.0.0.0</td>
<td>148.137.59.42</td>
<td>148.137.59.42</td>
<td>20</td>
</tr>
<tr>
<td>255.255.255.255</td>
<td>255.255.255.255</td>
<td>148.137.59.42</td>
<td>148.137.59.42</td>
<td>1</td>
</tr>
<tr>
<td>Default Gateway:</td>
<td></td>
<td>148.137.59.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Routing-Table Entries – 2

148.137.59.0, 255.255.255.0
Local subnet.
This node can use ARP to send directly, so is its own "gateway".

148.137.59.42, 255.255.255.255
Node is sending to itself. Goes to Loopback (127.0.0.1)

<table>
<thead>
<tr>
<th>Network Destination</th>
<th>Netmask</th>
<th>Gateway</th>
<th>Interface</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0.0.0</td>
<td>0.0.0.0</td>
<td>148.137.59.1</td>
<td>148.137.59.42</td>
<td>20</td>
</tr>
<tr>
<td>127.0.0.0</td>
<td>255.0.0.0</td>
<td>127.0.0.1</td>
<td>127.0.0.1</td>
<td>1</td>
</tr>
<tr>
<td>148.137.59.0</td>
<td>255.255.255.0</td>
<td>148.137.59.42</td>
<td>148.137.59.42</td>
<td>20</td>
</tr>
<tr>
<td>148.137.59.42</td>
<td>255.255.255.255</td>
<td>127.0.0.1</td>
<td>127.0.0.1</td>
<td>1</td>
</tr>
<tr>
<td>148.137.59.42</td>
<td>255.255.255.255</td>
<td>148.137.59.42</td>
<td>148.137.59.42</td>
<td>20</td>
</tr>
<tr>
<td>224.0.0.0</td>
<td>240.0.0.0</td>
<td>148.137.59.42</td>
<td>148.137.59.42</td>
<td>20</td>
</tr>
<tr>
<td>255.255.255.255</td>
<td>255.255.255.255</td>
<td>148.137.59.42</td>
<td>148.137.59.42</td>
<td>1</td>
</tr>
<tr>
<td>Default Gateway:</td>
<td></td>
<td>148.137.59.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Linux Configured As A Router

- The "eth1" IP address is 172.16.0.1
- Any 172.16.0.0/19 traffic goes through NIC "eth1"
- Any 192.168.122.0/24 traffic goes through "eth0"
- All other traffic goes through "eth0" to another router, at 192.168.122.1

Routing-Table Entries – 3

148.137.255.255, 255.255.255.255
Broadcast to the BloomU network. Campus routers may accept or reject these.

224.0.0.0, 240.0.0.0
Multicast addresses. Handled on this machine.

255.255.255.255, 255.255.255.255
Global IP broadcast. Backbone routers reject these, nowadays.
example - a Cisco router’s routing table

<table>
<thead>
<tr>
<th>Address</th>
<th>Mask</th>
<th>Next Hop</th>
<th>Interface</th>
<th>Protocol</th>
<th>Age</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 0 0 0</td>
<td>0 0 0 0</td>
<td>80.124.1.1</td>
<td>2</td>
<td>Default</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>5 0 0 0</td>
<td>255 0 0 0</td>
<td>90.124.100.100</td>
<td>1</td>
<td>Static</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>73.2.3.0</td>
<td>255.255.255.252</td>
<td>80.124.10.240</td>
<td>2</td>
<td>Static</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>73.6.1.0</td>
<td>255.255.255.248</td>
<td>80.124.10.240</td>
<td>2</td>
<td>Static</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>73.7.1.0</td>
<td>255.255.255.248</td>
<td>80.124.10.240</td>
<td>2</td>
<td>Static</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>73.9.1.0</td>
<td>255.255.255.248</td>
<td>80.124.10.240</td>
<td>2</td>
<td>Static</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>73.83.93.0</td>
<td>255.255.255.252</td>
<td>80.124.10.240</td>
<td>2</td>
<td>Static</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>73.84.87.80</td>
<td>255.255.255.240</td>
<td>80.124.10.240</td>
<td>2</td>
<td>Static</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>73.88.31.0</td>
<td>255.255.255.192</td>
<td>80.124.10.240</td>
<td>2</td>
<td>Static</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>75.0.0.0</td>
<td>255 0 0 0</td>
<td>80.124.0.1</td>
<td>2</td>
<td>Static</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>80.124.0.0</td>
<td>255 252.0 0</td>
<td>0 0 0 0</td>
<td>2</td>
<td>Local</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>83.0.0.0</td>
<td>255 0 0 0</td>
<td>80.124.0.1</td>
<td>1</td>
<td>Static</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>90.0.0.0</td>
<td>255 0 0 0</td>
<td>90.124.1.1</td>
<td>1</td>
<td>Static</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>90.124.0.0</td>
<td>255 252.0 0</td>
<td>0 0 0 0</td>
<td>1</td>
<td>Local</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>93.4.2.0</td>
<td>255.255.255.248</td>
<td>80.124.10.240</td>
<td>2</td>
<td>Static</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>100.0.0.0</td>
<td>255 0 0 0</td>
<td>90.124.1.1</td>
<td>1</td>
<td>Static</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Routing Table

- Can’t contain all possible IP addresses
  - this would be nearly 4 billion entries!
## Longest prefix matching

<table>
<thead>
<tr>
<th>Prefix Match</th>
<th>Link Interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>11001000 00010111 00010</td>
<td>0</td>
</tr>
<tr>
<td>11001000 00010111 00011000</td>
<td>1</td>
</tr>
<tr>
<td>11001000 00010111 00011</td>
<td>2</td>
</tr>
<tr>
<td>otherwise</td>
<td>3</td>
</tr>
</tbody>
</table>

Examples

DestAddr: 11001000 00010111 00011010 10101010 Which interface?

DestAddr: 11001000 00010111 00011000 10101010 Which interface?