Chapter 6: Network Layer

Introduction to Networks
Chapter 6

6.1 Network Layer Protocols
6.2 Routing
6.3 Routers
6.4 Configuring a Cisco Router
6.5 Summary
Chapter 6: Objectives

Students will be able to:

- Explain how network layer protocols and services support communications across data networks.
- Explain how routers enable end-to-end connectivity in a small to medium-sized business network.
- Determine the appropriate device to route traffic in a small to medium-sized business network.
- Configure a router with basic configurations.
Network Layer

OSI Model

<table>
<thead>
<tr>
<th>Host Layers</th>
<th>Data</th>
<th>Layer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Data</td>
<td>Application</td>
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<td></td>
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<td>Presentation</td>
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<td></td>
<td>Data Representation and Encryption</td>
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<td></td>
<td>Data</td>
<td>Session</td>
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<tr>
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<td>Transport</td>
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<td>End-to-End Connections and Reliability</td>
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<td>Packets</td>
<td>Network</td>
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<td></td>
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<td>Path Determination and IP (Logical Addressing)</td>
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<td>Frames</td>
<td>Data Link</td>
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<tr>
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<td>MAC and LLC (Physical addressing)</td>
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<tr>
<td></td>
<td>Bits</td>
<td>Physical</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Media, Signal, and Binary Transmission</td>
</tr>
</tbody>
</table>

6.0
Network Layer Protocols

Network Layer in Communication

Network layer protocols forward encapsulated Transport Layer PDUs between hosts.

1. Physical
2. Data Link
3. Network
4. Transport
5. Session
6. Presentation
7. Application

6.1.1
Network Layer in Communication

The Network Layer

End to End Transport processes

- Addressing end devices
- Encapsulation
- Routing
- De-encapsulating

Do animation on 6.1.1.1
Network Layer in Communication

Network Layer Protocols

Common Network Layer Protocols

- Internet Protocol version 4 (IPv4)
- Internet Protocol version 6 (IPv6)

Legacy Network Layer Protocols

- Novell Internetwork Packet Exchange (IPX)
- AppleTalk
- Connectionless Network Service (CLNS/DECNet)
Characteristics of the IP protocol

Characteristics of IP

- Connectionless - No connection is established before sending data packets.
- Best Effort (unreliable) - No overhead is used to guarantee packet delivery.
- Media Independent - Operates independently of the medium carrying the data.
Characteristics of the IP protocol

IP - Connectionless

Connectionless Communication

Letter → Post Box → Letter → House

A letter is sent.

The sender doesn't know:
- if the receiver is present
- if the letter arrived
- if the receiver can read the letter

The receiver doesn't know:
- when it is coming

Do buttons on 6.1.2.2
Characteristics of the IP protocol

IP – Best Effort Delivery

IP is often referred to as an unreliable or best-effort delivery protocol.

As an unreliable Network layer protocol, IP does not guarantee that all sent packets will be received.

Other protocols manage the process of tracking packets and ensuring their delivery.
Characteristics of the IP protocol

IP – Media Independent

IP packets can travel over different media.
IPv4 Packet
Encapsulating IP

Generating IP Packets

Transport Layer Encapsulation

Network Layer Encapsulation

In TCP/IP based networks, the Network layer PDU is the IP packet.

Do buttons on 6.1.2.5
IPv4 Packet

6.1.2.6 Activity - IP Characteristics

Activity – IP Characteristics
Read each IP Characteristic. Then click Connectionless, Best Effort, or Media Independent to indicate its delivery method.

IP Characteristic
Packet delivery is not guaranteed.

Delivery Method

Connectionless

Best Effort

Media Independent

Do activity on 6.1.2.6
### IPv4 Packet

**IPv4 Packet Header**

**Version, Differentiated Services (DS), Time-to-Live (TTL), Protocol, Source IP Address, Destination IP Address**

<table>
<thead>
<tr>
<th>Byte 1</th>
<th>Byte 2</th>
<th>Byte 3</th>
<th>Byte 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Version</strong></td>
<td><strong>IP Header Length</strong></td>
<td><strong>Differentiated Services</strong></td>
<td><strong>Total Length</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>DSCP</strong></td>
<td><strong>ECN</strong></td>
</tr>
<tr>
<td><strong>Identification</strong></td>
<td>Flag</td>
<td>Fragment Offset</td>
<td></td>
</tr>
<tr>
<td><strong>Time To Live</strong></td>
<td><strong>Protocol</strong></td>
<td><strong>Header Checksum</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Source IP Address</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Destination IP Address</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Options (optional)</strong></td>
<td></td>
<td><strong>Padding</strong></td>
<td></td>
</tr>
</tbody>
</table>
# IPv4 Packet

## IPv4 Header Fields

Internet Header Length (IHL), Total Length, Header Checksum, Identification, Flags, Fragment Offset

<table>
<thead>
<tr>
<th>Byte 1</th>
<th>Byte 2</th>
<th>Byte 3</th>
<th>Byte 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version</td>
<td>IP Header Length</td>
<td>Differentiated Services</td>
<td>Total Length</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DSCP</td>
<td>ECN</td>
</tr>
<tr>
<td>Identification</td>
<td>Flag</td>
<td>Fragment Offset</td>
<td></td>
</tr>
<tr>
<td>Time To Live</td>
<td>Protocol</td>
<td>Header Checksum</td>
<td></td>
</tr>
<tr>
<td>Source IP Address</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Destination IP Address</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Options (optional)</td>
<td>Padding</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
IPv4 Packet
Sample IPv4 Headers

Do buttons on 6.1.3.3
IPv4 Packet

6.1.3.4 Activities - IPv4 Header Fields

Do activities for both buttons on 6.1.3.4 In class
Network Layer in Communication

Limitations of IPv4

- IP Address depletion
- Internet routing table expansion
- Lack of end-to-end connectivity
Network Layer in Communication

Introducing IPv6

- Increased address space
- Improved packet handling
- Eliminates the need for NAT
- Integrated security

- 4 billion IPv4 addresses
  4,000,000,000

- 340 undecillion IPv6 addresses
  340,000,000,000,000,000,000,000,000,000,000,000,000,000
IPv6 Packet

Encapsulating IPv6

IPv4 and IPv6 Headers

IPv4 Header

- Version
- IHL
- Type of Service
- Total Length
- Identification
- Flags
- Fragment Offset
- Time to Live
- Protocol
- Header Checksum
- Source Address
- Destination Address
- Options
- Padding

IPv6 Header

- Version
- Traffic Class
- Flow Label
- Payload Length
- Next Header
- Hop Limit
- Source Address
- Destination Address

Legend
- Field names kept from IPv4 to IPv6
- Fields not kept in IPv6
- Name & position changed in IPv6
- New field in IPv6

Do buttons on 6.1.4.3
IPv6 Packet

IPv6 Packet Header

Version | Traffic Class | Flow Label
--------|--------------|-------------
Payload Length | Next Header | Hop Limit

Source IP Address

Destination IP Address

6.1.4.4
IPv6 Packet
Sample IPv6 Header
IPv4 Packet

6.1.4.6 Activity - IPv6 Header Fields

Do activity on 6.1.4.6
In class
# Routing

## Host Routing Tables

![Image of routing table output](image_url)

### Active Routes:

<table>
<thead>
<tr>
<th>Destination</th>
<th>Mask</th>
<th>Gateway Address</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0.0.0</td>
<td>0.0.0.0</td>
<td>127.0.0.1</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>1</td>
</tr>
<tr>
<td>127.0.0.1</td>
<td>255.0.0.0</td>
<td>127.0.0.1</td>
<td>1</td>
</tr>
<tr>
<td>169.254.0.0</td>
<td>255.255.0.0</td>
<td>127.0.0.1</td>
<td>1</td>
</tr>
<tr>
<td>192.168.0.0</td>
<td>255.255.255</td>
<td>127.0.0.1</td>
<td>1</td>
</tr>
<tr>
<td>192.168.128.0.0</td>
<td>255.255.255</td>
<td>127.0.0.1</td>
<td>1</td>
</tr>
<tr>
<td>192.168.192.0.0</td>
<td>255.255.255</td>
<td>127.0.0.1</td>
<td>1</td>
</tr>
<tr>
<td>192.168.255.255</td>
<td>255.255.255</td>
<td>127.0.0.1</td>
<td>1</td>
</tr>
</tbody>
</table>

### Default Gateway:

- 192.168.100.254

### Persistent Routes:

- None
Host Routing Tables

Host Packet Forwarding Decision

- **Itself** - This is a special IP address of 127.0.0.1 which is referred to as the loopback interface.
- **Local host** - This is a host on the same network as the sending host. The hosts share the same network address.
- **Remote host** - This is a host on a remote network. The hosts do not share the same network address.
Host Routing Tables

Default Gateway

Hosts must maintain their own, local, routing table to ensure that network layer packets are directed to the correct destination network. The local table of the host typically contains:

- Direct connection
- Local network route
- Local default route
Host Routing Tables

IPv4 Host Routing Table

C:\Users\PC1>netstat -r

<Output omitted>

IPv4 Route Table

<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>192.168.10.1</td>
<td>192.168.10.10</td>
<td>25</td>
</tr>
<tr>
<td>127.0.0.0</td>
<td>255.0.0.0</td>
<td>On-link</td>
<td>127.0.0.1</td>
<td>306</td>
</tr>
<tr>
<td>127.0.0.1</td>
<td>255.255.255.255</td>
<td>On-link</td>
<td>127.0.0.1</td>
<td>306</td>
</tr>
<tr>
<td>127.255.255.255</td>
<td>255.255.255.255</td>
<td>On-link</td>
<td>127.0.0.1</td>
<td>306</td>
</tr>
<tr>
<td>192.168.10.0</td>
<td>255.255.255.255</td>
<td>On-link</td>
<td>192.168.10.10</td>
<td>281</td>
</tr>
<tr>
<td>192.168.10.10</td>
<td>255.255.255.255</td>
<td>On-link</td>
<td>192.168.10.10</td>
<td>281</td>
</tr>
<tr>
<td>192.168.10.255</td>
<td>255.255.255.255</td>
<td>On-link</td>
<td>192.168.10.10</td>
<td>281</td>
</tr>
<tr>
<td>224.0.0.0</td>
<td>240.0.0.0</td>
<td>On-link</td>
<td>127.0.0.1</td>
<td>306</td>
</tr>
<tr>
<td>224.0.0.0</td>
<td>240.0.0.0</td>
<td>On-link</td>
<td>192.168.10.10</td>
<td>281</td>
</tr>
<tr>
<td>255.255.255.255</td>
<td>255.255.255.255</td>
<td>On-link</td>
<td>127.0.0.1</td>
<td>306</td>
</tr>
</tbody>
</table>

<Output omitted>
### IPv4 Host Routing Table

#### C:\Users\PC1> `netstat -r`

```
<Output omitted>
```

<table>
<thead>
<tr>
<th>Network</th>
<th>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>0.0.0.0</td>
<td>192.168.10.1</td>
<td>192.168.10.10</td>
<td>25</td>
</tr>
<tr>
<td>127.0.0.0</td>
<td>255.0.0.0</td>
<td>On-link</td>
<td>127.0.0.1</td>
<td>306</td>
<td></td>
</tr>
<tr>
<td>127.0.0.1</td>
<td>255.255.255.255</td>
<td>On-link</td>
<td>127.0.0.1</td>
<td>306</td>
<td></td>
</tr>
<tr>
<td>127.255.255.255</td>
<td>255.255.255.255</td>
<td>On-link</td>
<td>127.0.0.1</td>
<td>306</td>
<td></td>
</tr>
<tr>
<td>192.168.10.0</td>
<td>255.255.255.255</td>
<td>On-link</td>
<td>192.168.10.10</td>
<td>281</td>
<td></td>
</tr>
<tr>
<td>192.168.10.10</td>
<td>255.255.255.255</td>
<td>On-link</td>
<td>192.168.10.10</td>
<td>281</td>
<td></td>
</tr>
<tr>
<td>192.168.10.255</td>
<td>255.255.255.255</td>
<td>On-link</td>
<td>192.168.10.10</td>
<td>281</td>
<td></td>
</tr>
<tr>
<td>224.0.0.0</td>
<td>240.0.0.0</td>
<td>On-link</td>
<td>127.0.0.1</td>
<td>306</td>
<td></td>
</tr>
<tr>
<td>224.0.0.0</td>
<td>240.0.0.0</td>
<td>On-link</td>
<td>192.168.10.10</td>
<td>281</td>
<td></td>
</tr>
<tr>
<td>255.255.255.255</td>
<td>255.255.255.255</td>
<td>On-link</td>
<td>127.0.0.1</td>
<td>306</td>
<td></td>
</tr>
<tr>
<td>255.255.255.255</td>
<td>255.255.255.255</td>
<td>On-link</td>
<td>192.168.10.10</td>
<td>281</td>
<td></td>
</tr>
</tbody>
</table>
Host Routing Tables

Sample IPv4 Host Routing Table

6.2.1.5

Do buttons on 6.2.1.5
Host Routing Tables

Sample IPv6 Host Routing Table

```
C:\Users\PC1> netstat -r
<Output omitted>
IPv6 Route Table

<table>
<thead>
<tr>
<th>Active Routes:</th>
<th>If Metric</th>
<th>Network Destination</th>
<th>Gateway</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>16</td>
<td>58 ::/0</td>
<td>On-link</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>306 ::1/128</td>
<td>On-link</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>58 2001::/32</td>
<td>On-link</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>281 fe80::/64</td>
<td>On-link</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>306 fe80::/64</td>
<td>On-link</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>306 fe80::2c30:3071:e718:a926/128</td>
<td>On-link</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>281 fe80::b1ee:c4ae:a117:271f/128</td>
<td>On-link</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>306 ff00::/8</td>
<td>On-link</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>306 ff00::/8</td>
<td>On-link</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>281 ff00::/8</td>
<td>On-link</td>
</tr>
</tbody>
</table>

<Output omitted>
```
Host Routing Tables
6.2.1.7 Activity - Identify Elements of a Host Routing Table Entry

C:\Documents and Settings\cisco>netstat -r
Route Table
<Output omitted>

Active Routes:
Network Destination     Netmask     Gateway       Interface       Metric
0.0.0.0                  0.0.0.0     192.168.1.1   192.168.1.100  20
127.0.0.0                255.0.0.0   127.0.0.1     127.0.0.1     1
192.168.1.0              255.255.255.0 192.168.1.100  192.168.1.100  20
192.168.1.100            255.255.255.255 127.0.0.1     127.0.0.1     20

Interactive Activity – Identify Elements of a Host Routing Table Entry

A partial host routing table entry is shown. Each section of the entry is identified by a circled letter above it.

Select the correct routing table entry segment for each output statement by clicking the appropriate column.

1. The physical interface IP address used to send the packet to the gateway.
2. The route cost – lower numbers are best.
3. The reachable networks available.
4. The network address is found in this column.

Do activity on 6.2.1.7 in class
Router Routing Tables

Router Packet Forwarding Decision

R1 has three directly connected networks: 192.168.10.0/24, 192.168.11.0/24, and 209.165.200.224/30. R1 also has two remote networks that it can learn about from R2: 10.1.1.0/24 and 10.1.2.0/24.
Router Routing Tables
IPv4 Router Routing Table

R1#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
    D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
    N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
    E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
    i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
    * - candidate default, U - per-user static route, o - ODR
    P - periodic downloaded static route

Gateway of last resort is not set

    10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
        D  10.1.1.0/24 [90/2170112] via 209.165.200.226, 00:00:05, Serial0/0/0
        D  10.1.2.0/24 [90/2170112] via 209.165.200.226, 00:00:05, Serial0/0/0
    192.168.10.0/24 is variably subnetted, 2 subnets, 3 masks
        C  192.168.10.0/24 is directly connected, GigabitEthernet0/0
        L  192.168.10.1/32 is directly connected, GigabitEthernet0/0
    192.168.11.0/24 is variably subnetted, 2 subnets, 3 masks
        C  192.168.11.0/24 is directly connected, GigabitEthernet0/1
        L  192.168.11.1/32 is directly connected, GigabitEthernet0/1
        209.165.200.0/24 is variably subnetted, 2 subnets, 3 masks
        C  209.165.200.224/30 is directly connected, Serial0/0/0
        209.165.200.225/32 is directly connected, Serial0/0/0

6.2.2.2
Router Routing Tables

Directly Connected Routing Table Entries

Identifies how the network was learned by the router.

Identifies the destination network and how it is connected.

Identifies the interface on the router connected to the destination network.

192.168.10.0/24 is directly connected, GigabitEthernet0/0

192.168.10.1/32 is directly connected, GigabitEthernet0/0

64.100.0.1

6.2.2.3
Router Routing Tables

Remote Network Routing Table Entries

<table>
<thead>
<tr>
<th></th>
<th>192.168.10.0/24</th>
<th>192.168.11.0/24</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R1</td>
<td>R2</td>
</tr>
<tr>
<td>G0/0</td>
<td>209.165.200.226</td>
<td>209.165.200.225</td>
</tr>
<tr>
<td>G0/1</td>
<td>.225</td>
<td>.226</td>
</tr>
<tr>
<td>S0/0/0</td>
<td></td>
<td>.1</td>
</tr>
<tr>
<td>.1</td>
<td></td>
<td>.1</td>
</tr>
<tr>
<td>64.100.0.1</td>
<td></td>
<td>10.1.1.0/24</td>
</tr>
<tr>
<td></td>
<td>10.1.2.0/24</td>
<td>PC1</td>
</tr>
<tr>
<td></td>
<td>10.1.2.0/24</td>
<td>PC2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.2.2.4</td>
</tr>
</tbody>
</table>

### Table:

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>10.1.1.0/24</td>
<td>[90/2170112] via 209.165.200.226, 00:00:05, Serial0/0/0</td>
<td></td>
</tr>
</tbody>
</table>

### Identifications:

- **A**: Identifies how the network was learned by the router.
- **B**: Identifies the destination network.
- **C**: Identifies the administrative distance (trustworthiness) of the route source.
- **D**: Identifies the metric to reach the remote network.
- **E**: Identifies the next hop IP address to reach the remote network.
- **F**: Identifies the amount of elapsed time since the network was discovered.
- **G**: Identifies the outgoing interface on the router to reach the destination network.
Router Routing Tables

Next-Hop Address

R1#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
* - candidate default, U - per-user static route, o - ODR
P - periodic downloaded static route

Gateway of last resort is not set

10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
D 10.1.1.0/24 [90/2170112] via 209.165.200.226, 00:00:05, Serial0/0/0
D 10.1.2.0/24 [90/2170112] via 209.165.200.226, 00:00:05, Serial0/0/0
192.168.10.0/24 is variably subnetted, 2 subnets, 3 masks
C 192.168.10.0/24 is directly connected, GigabitEthernet0/0
L 192.168.10.1/32 is directly connected, GigabitEthernet0/0
192.168.11.0/24 is variably subnetted, 2 subnets, 3 masks
C 192.168.11.0/24 is directly connected, GigabitEthernet0/1
L 192.168.11.1/32 is directly connected, GigabitEthernet0/1
209.165.200.0/24 is variably subnetted, 2 subnets, 3 masks
C 209.165.200.0/24 is directly connected, Serial0/0/0
L 209.165.200.224/30 is directly connected, Serial0/0/0
R1#
Host Routing Tables
6.2.2.7 Activity - Identify Elements of a Router Routing Table Entry

1. The elapsed time since the network was discovered.
2. The administrative distance (source) and metric to reach the remote network.
3. How the network was learned by the router.
4. Shows the destination network.
5. The next hop IP address to reach the remote network.
6. The outgoing interface on the router to reach the destination network.

Do activity on 6.2.2.7 in class
Do modified on 6.2.2.8 in class
Routers

Anatomy of a Router
Anatomy of a Router

A Router is a Computer
Anatomy of a Router

Router CPU and OS

6.3.1.2
# Anatomy of a Router

## Router Memory

<table>
<thead>
<tr>
<th>Memory</th>
<th>Volatile / Non-Volatile</th>
<th>Stores</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAM</td>
<td>Volatile</td>
<td>• Running IOS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Running configuration file</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• IP routing and ARP tables</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Packet buffer</td>
</tr>
<tr>
<td>ROM</td>
<td>Non-Volatile</td>
<td>• Bootup instructions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Basic diagnostic software</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Limited IOS</td>
</tr>
<tr>
<td>NVRAM</td>
<td>Non-Volatile</td>
<td>• Startup configuration file</td>
</tr>
<tr>
<td>Flash</td>
<td>Non-Volatile</td>
<td>• IOS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Other system files</td>
</tr>
</tbody>
</table>
Anatomy of a Router
Inside a Router

Click on parts on 6.3.1.4 in class
Anatomy of a Router

Router Backplane

- Double-wide eHWIC slots
- Two 4 GB flash card slots
- eHWIC 0
- AUX port
- LAN interfaces
- Console RJ45
- USB Ports
- USB Type B
- 6.3.1.5
Anatomy of a Router

Connecting to a Router
Anatomy of a Router

LAN and WAN Interfaces

Serial interfaces

LAN interfaces

6.3.1.7
Anatomy of a Router

6.3.1.8 Activity - Identify Router Components

Do activity 6.3.1.8 in class
Anatomy of a Router

6.3.1.9 Lab - Exploring Router Physical Characteristics

6.3.1.10 Packet Tracer - Exploring Internetworking Devices

Do PT 6.3.1.9. and Lab 6.3.1.10
For homework
Router Boot-up
Cisco IOS
Router Boot-up

Bootset Files

- **FLASH**
  - IOS image
    - c1900-universalk9-mz.SPA.152-4.M1.bin
  - Other system related files

- **RAM**
  - Load IOS
    - Cisco IOS
  - Load startup-config
    - running-config

- **NVRAM**
  - startup-config

6.3.2.2
## Router Boot-up

### Router Bootup Process

<table>
<thead>
<tr>
<th>How a Router Boots Up</th>
<th>1. Perform the POST and load the bootstrap program</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROM</td>
<td>POST</td>
</tr>
<tr>
<td>ROM</td>
<td>Perform Post</td>
</tr>
<tr>
<td>Bootstrap</td>
<td>Load bootstrap</td>
</tr>
<tr>
<td>Flash</td>
<td>Cisco Internetwork Operating System</td>
</tr>
<tr>
<td>TFTP Server</td>
<td>Locate and load operating system</td>
</tr>
<tr>
<td>NVRAM</td>
<td>Configuration</td>
</tr>
<tr>
<td>TFTP Server</td>
<td>Locate and load configuration file or enter &quot;setup&quot; mode</td>
</tr>
<tr>
<td>Console</td>
<td></td>
</tr>
</tbody>
</table>

---

System Bootstrap, Version 15.0(1r)M15, RELEASE SOFTWARE (fc1)
Technical Support: http://www.cisco.com/techsupport

<output omitted>

6.3.2.3

Do buttons for 6.3.2.3 in class
Router Boot-up

Show Versions Output

Router# show version
Cisco IOS Software, C1900 Software (C1900-UNIVERSALK9-M), Version 15.2(4)M1, RELEASE SOFTWARE (fc1)
Technical Support: http://www.cisco.com/techsupport
Copyright (c) 1986-2012 by Cisco Systems, Inc.
Compiled Thu 26-Jul-12 19:34 by prod_rel_team

ROM: System Bootstrap, Version 15.0(1r)M15, RELEASE SOFTWARE (fc1)

Router uptime is 10 hours, 9 minutes
System returned to ROM by power-on
System image file is "flash0:c1900-universalk9-mz.SPA.152-4.M1.bin"
Last reload type: Normal Reload
Last reload reason: power-on

<Output omitted>

Cisco CISCO1941/K9 (revision 1.0) with 446464K/77824K bytes of memory.
Processor board ID FTX1636848Z
2 Gigabit Ethernet interfaces
2 Serial(sync/async) interfaces
1 terminal line
DRAM configuration is 64 bits wide with parity disabled.
255K bytes of non-volatile configuration memory.
250880K bytes of ATA System CompactFlash 0 (Read/Write)

<Output omitted>

Technology Package License Information for Module:'c1900'

<table>
<thead>
<tr>
<th>Technology</th>
<th>Technology-package</th>
<th>Technology-package</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Current</td>
<td>Type</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Next reboot</td>
</tr>
<tr>
<td>ipbase</td>
<td>ipbasek9</td>
<td>Permanent</td>
</tr>
<tr>
<td>security</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>data</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

Configuration register is 0x2142 (will be 0x2102 at next reload)

Router#
Router Boot-up
Video Demonstration - The Router Boot Process

Watch 6.3.2.5 in class
Route Boot-up
6.3.2.6 Activity - The Router Boot Process

Activity - The Router Boot Process
Drag each of the steps on the left to appropriate field in the table on the right to show the router boot process order.

- Load the IOS (operating system file for the router – loaded into RAM after Bootstrap finds the IOS file to be used)
- Perform POST (hardware check – performed by built-in ROM chip)
- Load the Configuration File from FLASH (NVRAM), a TFTP Server OR Go into Setup Mode (to create a Configuration file)
- Load Bootstrap (copied from ROM to RAM – locates the IOS)

The Router Boot Process
- Step 1
- Step 2
- Step 3
- Step 4

Do Activity 6.3.2.6 in class
Network Layer

Configuring a Cisco Router
Configure Initial Settings

Router Configuration Steps

Router> enable
Router# configure terminal
Enter configuration commands, one per line.
End with CNTL/Z.
Router(config)# hostname R1
R1(config)#

Router> enable secret class
R1(config)#
R1(config)# line console 0
R1(config-line)# password cisco
R1(config-line)# login
R1(config-line)# exit
R1(config)#
R1(config)# line vty 0 4
R1(config-line)# password cisco
R1(config-line)# login
R1(config-line)# exit
R1(config)# service password-encryption
R1(config)#

Router> en
Router# conf t
Enter configuration commands, one per line.
End with CNTL/Z.
Router(config)# ho R1
R2(config)#

Router(config)# banner motd #
Enter TEXT message. End with the character '#'.
**********************************************
WARNING: Unauthorized access is prohibited!
**********************************************
#
R1(config)#

Router# copy running-config startup-config
Destination filename [startup-config]?
Building configuration...
[OK]
R1#

Take advantage of short cuts, but know the full commands for the test

Do Buttons and especially the Activity button 5 for 6.4.1.1 in class
Router Boot-up
6.4.1.2 Packet Tracer - Configure Initial Router Settings

Do PT 6.4.1.2 for homework
Configure Interfaces

Configure LAN Interfaces

Do Buttons 6.4.2.1 in class
Especially practice on button 2

R1# conf t
Enter configuration commands, one per line. End with CNTL/Z.
R1(config)#
R1(config)# interface gigabitethernet 0/0
R1(config-if)# ip address 192.168.10.1 255.255.255.0
R1(config-if)# description Link to LAN-10
R1(config-if)# no shutdown
%LINK-5-CHANGED: Interface GigabitEthernet0/0, changed state to up
%LINEPROTO-5-UPDOWN: Line protocol on Interface GigabitEthernet0/0, changed state to up
R1(config-if)# exit
R1(config)#
R1(config)# int g0/1
R1(config-if)# ip add 192.168.11.1 255.255.255.0
R1(config-if)# des Link to LAN-11
R1(config-if)# no shut
%LINK-5-CHANGED: Interface GigabitEthernet0/1, changed state to up
%LINEPROTO-5-UPDOWN: Line protocol on Interface GigabitEthernet0/1, changed state to up
R1(config-if)# exit
R1(config)#
Configure Interfaces

Verify Interface Configuration

```
R1# show ip interface brief
Interface                      IP-Address      OK? Method Status                Protocol
GigabitEthernet0/0             192.168.10.1    YES manual up                    up
GigabitEthernet0/1             192.168.11.1    YES manual up                    up
Serial0/0/0                    209.165.200.225 YES manual up                    up
Serial0/0/1                    unassigned      YES NVRAM  administratively down  down
Vlan1                          unassigned      YES NVRAM  administratively down  down
R1#
R1# ping 209.165.200.226

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 209.165.200.226, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/9 ms
R1#
```

Do Buttons 6.4.2.2 in class
Configuring a Cisco Router

Configuring the Default Gateway

An IP address can be automatically assigned to this network card by a DHCP server. If your network does not have a DHCP server, ask your network administrator for an address, and then type it in the space below.

Adapter:

- [ ] Obtain an IP address from a DHCP server
- [x] Specify an IP address

IP Address: 192.168.2.2
Subnet Mask: 255.255.255.0
Default Gateway: 192.168.2.1
Configuring the Default Gateway

Default Gateway on a Host

Do Buttons 6.4.3.1 in class
Configuring the Default Gateway

Default Gateway on a Switch

If the default gateway were not configured on S1, response packets from S1 would not be able to reach the administrator at 192.168.11.10. The administrator would not be able to manage the device remotely.

Do Buttons 6.4.3.2 in class
Do practice activity on button 2
Router Boot-up
6.4.3.3 Packet Tracer - Connect a Router to a LAN
6.4.3.4 Packet Tracer - Troubleshooting Default Gateway Issues

Homework: Packet Tracer 6.4.3.3
Opt: Packet Tracer 6.4.3.4
Opt: Practice 6.4.3.5 in Packet Tracer
Network Layer

Summary

In this chapter, you learned:

- The network layer, or OSI Layer 3, provides services to allow end devices to exchange data across the network.

- The network layer uses four basic processes: IP addressing for end devices, encapsulation, routing, and de-encapsulation.

- The Internet is largely based on IPv4, which is still the most widely-used network layer protocol.

- An IPv4 packet contains the IP header and the payload.

- The IPv6 simplified header offers several advantages over IPv4, including better routing efficiency, simplified extension headers, and capability for per-flow processing.
Network Layer

Summary

In this chapter, you learned:

- In addition to hierarchical addressing, the network layer is also responsible for routing.
- Hosts require a local routing table to ensure that packets are directed to the correct destination network.
- The local default route is the route to the default gateway.
- The default gateway is the IP address of a router interface connected to the local network.
- When a router, such as the default gateway, receives a packet, it examines the destination IP address to determine the destination network.
Network Layer

Summary

In this chapter, you learned:

- The routing table of a router stores information about directly-connected routes and remote routes to IP networks. If the router has an entry in its routing table for the destination network, the router forwards the packet. If no routing entry exists, the router may forward the packet to its own default route, if one is configured, or it will drop the packet.

- Routing table entries can be configured manually on each router to provide static routing or the routers may communicate route information dynamically between each other using a routing protocol.

- In order for routers to be reachable, the router interface must be configured.

6.5.1.1 – 6.5.1.3