Chapter 6

Delivery and Routing of IP Packets
CONTENTS

- CONNECTION
- DELIVERY
- ROUTING METHODS
- STATIC AND DYNAMIC ROUTING
- ROUTING TABLE AND MODULE
- CLASSLESS ADDRESSING
6.1 CONNECTION-ORIENTED VERSUS CONNECTIONLESS SERVICES

In a connection-oriented situation, the network layer protocol first makes a connection.

In a connectionless situation, the network layer protocol treats each packet independently, with each packet having no relationship to any other packet.
DIRECT VERSUS INDIRECT DELIVERY

6.2

Direct delivery

At the Router

- Destination IP AND Mask = some adjacent Network Address
- Use ARP to map destination IP to destination physical address.
Indirect delivery

At the Router

- Destination IP AND Mask = none of the adjacent Network Addresses
- Use routing table to map IP_{dest} to IP of next router in the delivery route.
- Use ARP to map next router IP to its physical address.
6.3

ROUTING METHODS
Next-hop routing

a. Routing tables based on route

<table>
<thead>
<tr>
<th>Destination</th>
<th>Route</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host B</td>
<td>R1, R2, Host B</td>
</tr>
</tbody>
</table>

Routing table for host A

Routing table for R1

<table>
<thead>
<tr>
<th>Destination</th>
<th>Route</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host B</td>
<td>R2, Host B</td>
</tr>
</tbody>
</table>

Routing table for R2

b. Routing tables based on next hop

<table>
<thead>
<tr>
<th>Destination</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host B</td>
<td>R1</td>
</tr>
</tbody>
</table>

Routing table for host A

Routing table for R1

<table>
<thead>
<tr>
<th>Destination</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host B</td>
<td>R2</td>
</tr>
</tbody>
</table>

Routing table for R2

<table>
<thead>
<tr>
<th>Destination</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host B</td>
<td>—</td>
</tr>
</tbody>
</table>
# Network-specific routing

## Routing table for host S based on host-specific routing

<table>
<thead>
<tr>
<th>Destination</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>R1</td>
</tr>
<tr>
<td>B</td>
<td>R1</td>
</tr>
<tr>
<td>C</td>
<td>R1</td>
</tr>
<tr>
<td>D</td>
<td>R1</td>
</tr>
</tbody>
</table>

## Routing table for host S based on network-specific routing

<table>
<thead>
<tr>
<th>Destination</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>N2</td>
<td>R1</td>
</tr>
</tbody>
</table>

![Network diagram](image)
Host-specific routing

Routing table for host A

<table>
<thead>
<tr>
<th>Destination</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host B</td>
<td>R3</td>
</tr>
<tr>
<td>N2</td>
<td>R1</td>
</tr>
<tr>
<td>N3</td>
<td>R3</td>
</tr>
<tr>
<td>......</td>
<td>......</td>
</tr>
</tbody>
</table>
Default routing

Use 0.0.0.0 for the Default destination

Routing table for host A

<table>
<thead>
<tr>
<th>Destination</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>N2</td>
<td>R1</td>
</tr>
<tr>
<td>......</td>
<td>......</td>
</tr>
<tr>
<td>Default</td>
<td>R2</td>
</tr>
</tbody>
</table>
6.4 STATIC VERSUS DYNAMIC ROUTING

- **A static routing table** contains information entered manually.
  - Does not adapt to network changes
  - Used for small internetworks or for experimentation.
- **A dynamic routing table** is updated periodically using one of the dynamic routing protocols such as RIP, OSPF, or BGP.
6.5

ROUTING TABLE AND ROUTING MODULE

• Order of Routing
  1. Direct Delivery
  2. Host-Specific Routing
  3. Network-Specific Routing
  4. Default Routing

• Implemented inside:
  – the routing table (simplifies the routing module, we will use this approach in our discussion), or
  – the routing module itself.
Routing module as part of the IP Layer

Routing table

From IP processing module

IP packet

Routing module

Next-hop address

IP packet

To fragmentation module

IP
Routing Table

**Flags**

- **U** The router is up and running.
- **G** The destination is in another network.
- **H** Host-specific address.
- **D** Added by redirection.
- **M** Modified by redirection.

<table>
<thead>
<tr>
<th>Mask</th>
<th>Destination address</th>
<th>Next-hop address</th>
<th>Flags</th>
<th>Reference count</th>
<th>Use</th>
<th>Interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>255.0.0.0</td>
<td>124.0.0.0</td>
<td>145.6.7.23</td>
<td>UG</td>
<td>4</td>
<td>20</td>
<td>m2</td>
</tr>
<tr>
<td>0.0.0.0</td>
<td>0.0.0.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Finds Network or Subnetwork address**
- 255.255.255.255 for Host-Specific
- 0.0.0.0 for Default Routing
Routing Module

For each entry in Routing Table

Apply Mask to packet’s destination IP

Match with Destination field?

G Flag?

Next-IP = packet’s destination IP

Next-IP = Next-Hop field

Send Packet to Fragmentation module with the Next-IP address

STOP
Configuration for routing example

Site 193.14.5.0

193.14.5.160

193.14.5.165

m2

193.14.5.192

193.14.5.197

m1

R1
m0

111.30.31.18

Rest of the Internet

111.0.0.0

111.25.19.20

111.20.18.14

111.15.17.32

R2
Default router

192.16.7.0

R3

192.16.7.5

194.17.21.16

R4

194.17.21.14

R5

192.16.7.52

194.17.21.68

194.17.21.0
<table>
<thead>
<tr>
<th>Mask</th>
<th>Dest.</th>
<th>Next Hop</th>
<th>I.</th>
</tr>
</thead>
<tbody>
<tr>
<td>255.0.0.0</td>
<td>111.0.0.0</td>
<td>--</td>
<td>m0</td>
</tr>
<tr>
<td>255.255.255.224</td>
<td>193.14.5.160</td>
<td>-</td>
<td>m2</td>
</tr>
<tr>
<td>255.255.255.224</td>
<td>193.14.5.192</td>
<td>-</td>
<td>m1</td>
</tr>
<tr>
<td>255.255.255.255</td>
<td>194.17.21.16</td>
<td>111.20.18.14</td>
<td>m0</td>
</tr>
<tr>
<td>255.255.255.0</td>
<td>192.16.7.0</td>
<td>111.15.17.32</td>
<td>m0</td>
</tr>
<tr>
<td>255.255.255.0</td>
<td>194.17.21.0</td>
<td>111.20.18.14</td>
<td>m0</td>
</tr>
<tr>
<td>0.0.0.0</td>
<td>0.0.0.0</td>
<td>111.30.31.18</td>
<td>m0</td>
</tr>
</tbody>
</table>
Example 1

Router R1 receives 500 packets for destination 192.16.7.14; the algorithm applies the masks row by row to the destination address until a match (with the value in the second column) is found:
Solution

Direct delivery

192.16.7.14 & 255.0.0.0  ➞ 192.0.0.0  no match
192.16.7.14 & 255.255.255.224  ➞ 192.16.7.0  no match
192.16.7.14 & 255.255.255.224  ➞ 192.16.7.  no match

Host-specific

192.16.7.14 & 255.255.255.255  ➞ 192.16.7.14 no match

Network-specific

192.16.7.14 & 255.255.255.0  ➞ 192.16.7.0  match
Example 2

Router R1 receives 100 packets for destination 193.14.5.176; the algorithm applies the masks row by row to the destination address until a match is found:
Solution

Direct delivery

193.14.5.176 & 255.0.0.0  ➞ 193.0.0.0  no match

Example 3

Router R1 receives 20 packets for destination 200.34.12.34; the algorithm applies the masks row by row to the destination address until a match is found:
Solution

Direct delivery

200.34.12.34 & 255.0.0.0  \Rightarrow 200.0.0.0  
no match

200.34.12.34 & 255.255.255.224  \Rightarrow 200.34.12.32  
no match

200.34.12.34 & 255.255.255.224  \Rightarrow 200.34.12.32  
no match

Host-specific

200.34.12.34 & 255.255.255.255  \Rightarrow 200.34.12.34  
no match
Solution

Network-specific

200.34.12.34 & 255.255.255.0 ➔ 200.34.12.0 no match
200.34.12.34 & 255.255.255.0 ➔ 200.34.12.0 no match

Default

200.34.12.34 & 0.0.0.0 ➔ 0.0.0.0. match
Example 4

Make the routing table for router R1

- **Routing Table for R1**
  - Destination: 129.8.0.0
    - Next Hop: 222.13.16.40
  - Destination: 222.13.16.40
    - Next Hop: 222.13.16.41
  - Default Route: 134.18.5.0
    - Next Hop: 134.18.5.1

Diagrams show physical connections and network topology.
<table>
<thead>
<tr>
<th>Mask</th>
<th>Destination</th>
<th>Next Hop</th>
<th>I.</th>
</tr>
</thead>
<tbody>
<tr>
<td>255.255.0.0</td>
<td>134.18.0.0</td>
<td>--</td>
<td>m0</td>
</tr>
<tr>
<td>255.255.0.0</td>
<td>129.8.0.0</td>
<td>222.13.16.40</td>
<td>m1</td>
</tr>
<tr>
<td>255.255.255.0</td>
<td>220.3.6.0</td>
<td>222.13.16.40</td>
<td>m1</td>
</tr>
<tr>
<td>0.0.0.0</td>
<td>0.0.0.0</td>
<td>134.18.5.2</td>
<td>m0</td>
</tr>
</tbody>
</table>
Example 5

Make the routing table for router R1
## Solution

<table>
<thead>
<tr>
<th>Mask</th>
<th>Destination</th>
<th>Next Hop</th>
<th>1.</th>
</tr>
</thead>
<tbody>
<tr>
<td>255.255.255.0</td>
<td>200.8.4.0</td>
<td>----</td>
<td>m2</td>
</tr>
<tr>
<td>255.255.255.0</td>
<td>80.4.5.0</td>
<td>201.4.10.3</td>
<td>m1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>255.255.255.0</td>
<td>80.4.6.0</td>
<td>201.4.10.3</td>
<td>m1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.0.0.0</td>
<td>0.0.0.0</td>
<td>???????????</td>
<td>m0</td>
</tr>
</tbody>
</table>
Example 6
The routing table for router R1 is given below. Draw its topology

<table>
<thead>
<tr>
<th>Mask</th>
<th>Destination</th>
<th>Next Hop</th>
<th>I.</th>
</tr>
</thead>
<tbody>
<tr>
<td>255.255.0.0</td>
<td>110.70.0.0</td>
<td>-</td>
<td>m0</td>
</tr>
<tr>
<td>255.255.0.0</td>
<td>180.14.0.0</td>
<td>-</td>
<td>m2</td>
</tr>
<tr>
<td>255.255.0.0</td>
<td>190.17.0.0</td>
<td>-</td>
<td>m1</td>
</tr>
<tr>
<td>255.255.0.0</td>
<td>130.4.0.0</td>
<td>190.17.6.5</td>
<td>m1</td>
</tr>
<tr>
<td>255.255.0.0</td>
<td>140.6.0.0</td>
<td>180.14.2.5</td>
<td>m2</td>
</tr>
<tr>
<td>0.0.0.0</td>
<td>0.0.0.0</td>
<td>110.70.4.6</td>
<td>m0</td>
</tr>
</tbody>
</table>
Example 6
(Solution)
CLASSLESS ADDRESSING: CIDR
ISSUES

Routing Table Size

Hierarchical Routing

Geographical Routing

Routing Table Search Algorithms