

CSC465 – Computer Networks
Spring 2004

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These slides were produced almost entirely from material by Behrouz Forouzan for the text "TCP/IP Protocol Suite (2nd Edition)", McGraw Hill Publisher

Chapter 6

*Delivery and
Routing of
IP Packets*

Delivery and Routing

- Delivery: Physical forwarding of packets
- Routing: finding the route (next hop) for a datagram

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.

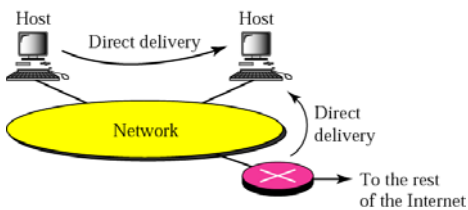
IP

- Connectionless
- Internetworking Protocol
- Packets may pass through multiple heterogeneous networks
- Not always the same networks
- Not all may offer connection services

6.2

DIRECT VERSUS INDIRECT DELIVERY

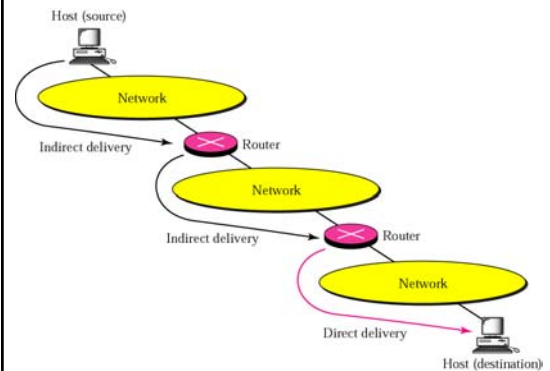
Direct delivery



Sender and receiver have same network ID

Sender uses destination IP to (dynamically) obtain physical address (ARP)

Indirect delivery



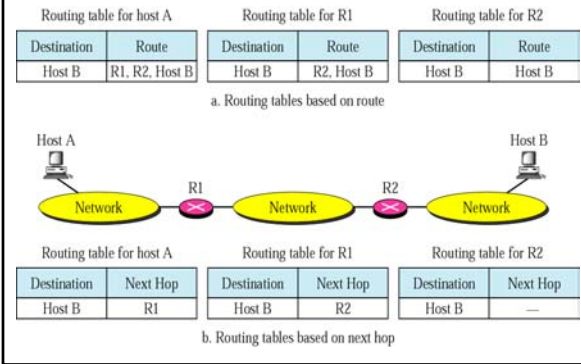
Indirect Delivery

- Sender uses the destination IP address and a routing table to find the IP address of the next router to which the packet should be delivered.
- The sender then uses the ARP protocol to find the physical address of the next router
- Direct delivery: mapping is between IP address of final destination and physical address of final destination

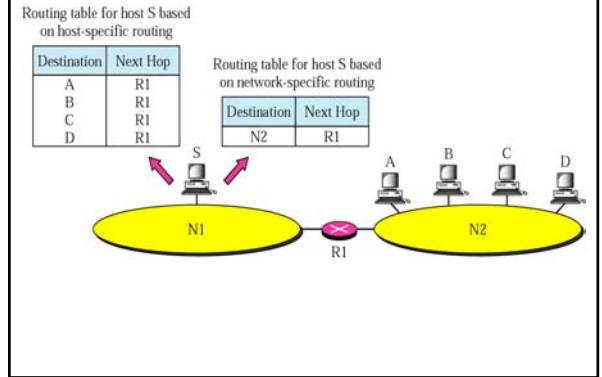
6.3

ROUTING METHODS

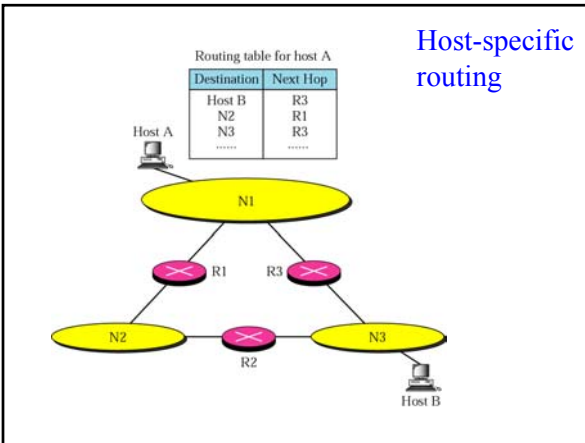
Next-hop routing



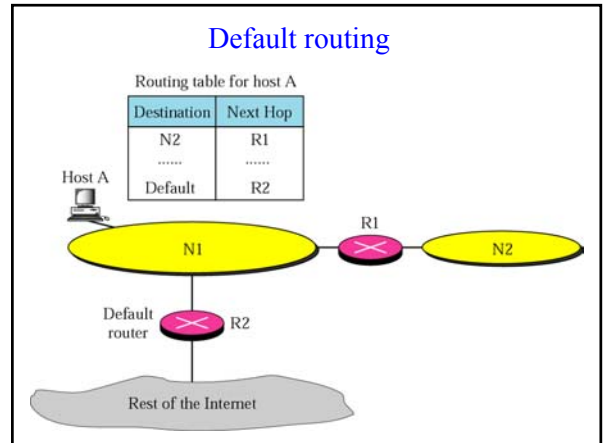
Network-specific routing



Host-specific routing



Default routing



W2K "Route Print" Example

Network Dest	Netmask	Gateway	Interface	Metric
0.0.0.0	0.0.0.0	192.168.0.1	192.168.0.3	1
127.0.0.0	255.0.0.0	127.0.0.1	127.0.0.1	1
192.168.0.0	255.255.255.0	192.168.0.3	192.168.0.3	1
192.168.0.3	255.255.255.255	127.0.0.1	127.0.0.1	1
192.168.0.255	255.255.255.255	192.168.0.3	192.168.0.3	1
224.0.0.0	224.0.0.0	192.168.0.3	192.168.0.3	1
255.255.255.255	255.255.255.255	192.168.0.3	192.168.0.3	1

Default Gateway: 192.168.0.1

Interface List

0x1 MS TCP Loopback interface
 0x1000003 00 72 3f 14 1f e8 NDIS 5.0 driver

Network Dest	Netmask	Gateway	Interface
0.0.0.0	Default	192.168.0.1	192.168.0.3
127.0.0.0	Loop	127.0.0.1	127.0.0.1
192.168.0.0	255.255.255.0	192.168.0.3	192.168.0.3
Local Network	Class C; no sub		
192.168.0.3	255.255.255.255	127.0.0.1	127.0.0.1
Local IP			
192.168.0.255	255.255.255.255	192.168.0.3	192.168.0.3
Direct Broadcast			
224.0.0.0	224.0.0.0	192.168.0.3	192.168.0.3
Multicast Addr			
255.255.255.255	255.255.255.255	192.168.0.3	192.168.0.3
Ltd Broadcast			

“Netmask” Column

- The subnet mask that is applied to the destination IP address when matching to the value in the network destination.
 - When netmask is written in binary, a "1" must match and a "0" need not match.
- For example, a 0.0.0.0 netmask is used for the default route, which means that none of the bits must match. For host routes, i.e., a route that matches an IP address, a 255.255.255.255 netmask is used.

“Gateway” Column

- The *gateway* address is the IP address that the local host uses to forward IP datagrams to other IP networks.
- This is either the IP address of a local network adapter or the IP address of an IP router (such as a default gateway router) on the local network segment.

“Interface” & “Metric” Columns

- The *interface* is the IP address that is configured on the local computer for the local network adapter that is used when an IP datagram is forwarded on the network.
- A *metric* indicates the cost of using a route, which is typically the number of hops to the IP destination.
 - Anything on the local subnet is one hop, and each router crossed after that is an additional hop.
 - If there are multiple routes to the same destination with different metrics, the route with the lowest metric is selected.

6.4

STATIC VERSUS DYNAMIC ROUTING

A **static routing table** contains information entered manually.
Appropriate for small internet.

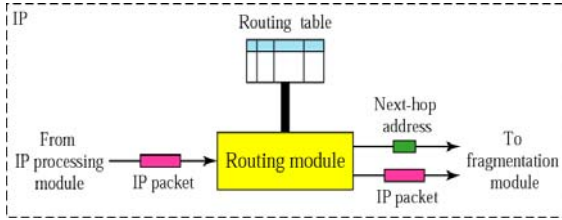
A **dynamic routing table** is updated periodically using one of the dynamic routing protocols such as RIP, OSPF, or BGP.

Changes such as shutdown of router or breaking of link causes dynamic routing protocols to update all of the tables in the routers (and eventually host) (*routing information protocol*)

6.5

ROUTING TABLE AND ROUTING MODULE

Routing module and routing table



Next hop: needed to find the physical address of the next router

Fragmentation module: needed to allow packet to traverse networks with small Maximum Transfer Units

Hierarchical Routing Strategy

Route search implementation:

1. Direct Delivery
2. Host-Specific Delivery
3. Network-specific Delivery
4. Default Delivery

Route table order based on hierarchy

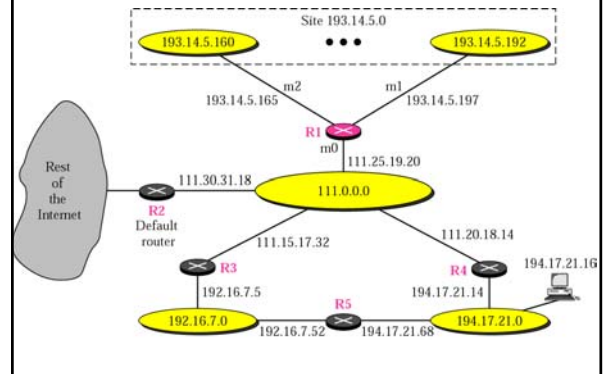
Routing Table

Mask	Destination address	Next-hop address	Flags	Reference count	Use	Interface
255.0.0.0	124.0.0.0	145.6.7.23	UG	4	20	m2
.....

Flags

- U The router is up and running (else drop).
- G Destination in another network (use next-hop)
- H Host-specific address (omission → *network*)
- D Added by redirection (msg from ICMP)
- M Modified by redirection (msg from ICMP)

Configuration for Routing Examples



Mask	Dest.	Next Hop	I.
255.0.0.0	111.0.0.0	--	m0
255.255.255.224	193.14.5.160	-	m2
255.255.255.224	193.14.5.192	-	m1
-----	-----	-----	-----
255.255.255.255	194.17.21.16	111.20.18.14	m0
-----	-----	-----	-----
255.255.255.0	192.16.7.0	111.15.17.32	m0
255.255.255.0	194.17.21.0	111.20.18.14	m0
-----	-----	-----	-----
0.0.0.0	0.0.0.0	111.30.31.18	m0

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

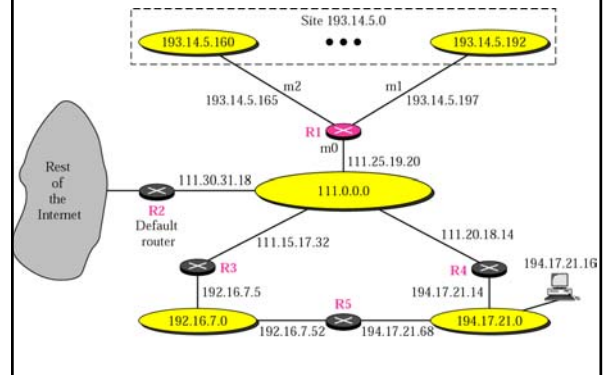
Host-specific

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**

Configuration for Routing Example (2)



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:

Mask	Dest.	Next Hop	I.
255.0.0.0	111.0.0.0	--	m0
255.255.255.224	193.14.5.160	-	m2
255.255.255.224	193.14.5.192	-	m1

255.255.255.255	194.17.21.16	111.20.18.14	m0

255.255.255.0	192.16.7.0	111.15.17.32	m0
255.255.255.0	194.17.21.0	111.20.18.14	m0

0.0.0.0	0.0.0.0	111.30.31.18	m0

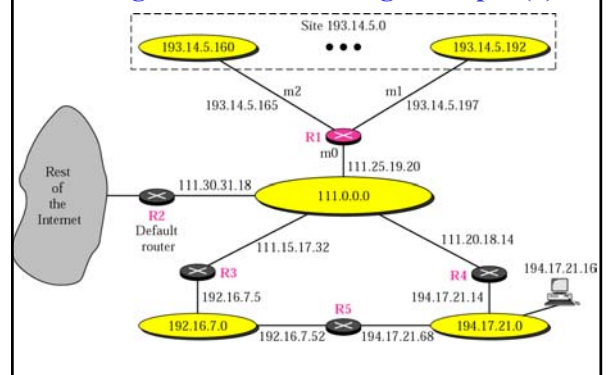
Solution

Direct delivery

193.14.5.176 & 255.0.0.0 → 193.0.0.0 no match

193.14.5.176 & 255.255.255.224 → 193.14.5.160 **match**

Configuration for Routing Example (3)



Mask	Dest.	Next Hop	I.
255.0.0.0	111.0.0.0	--	m0
255.255.255.224	193.14.5.160	-	m2
255.255.255.224	193.14.5.192	-	m1

255.255.255.255	194.17.21.16	111.20.18.14	m0

255.255.255.0	192.16.7.0	111.15.17.32	m0
255.255.255.0	194.17.21.0	111.20.18.14	m0

0.0.0.0	0.0.0.0	111.30.31.18	m0

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 → 200.0.0.0 no match
 200.34.12.34 & 255.255.255.224 → 200.34.12.32 no match
 200.34.12.34 & 255.255.255.224 → 200.34.12.32 no match

Host-specific

200.34.12.34 & 255.255.255.255 → 200.34.12.34 no match

Solution

Network-specific

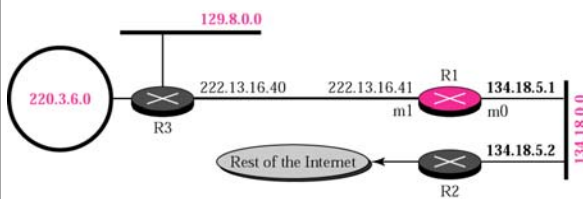
200.34.12.34 & 255.255.255.0 → 200.34.12.0 no match
 200.34.12.34 & 255.255.255.0 → 200.34.12.0 no match

Default

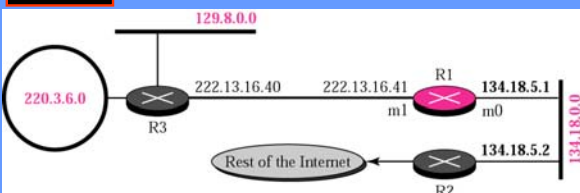
200.34.12.34 & 0.0.0.0 → 0.0.0.0 **match**

Example 4

Make the routing table for router R1



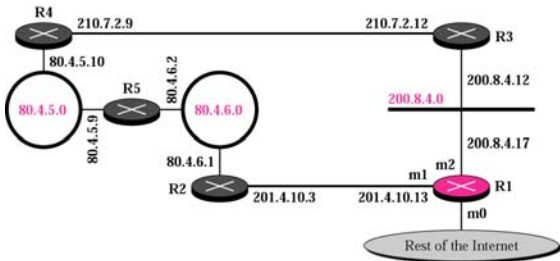
Solution



Mask	Destination	Next Hop	I.
255.255.0.0	134.18.0.0	--	m0
255.255.0.0	129.8.0.0	222.13.16.40	m1
255.255.255.0	220.3.6.0	222.13.16.40	m1
0.0.0.0	0.0.0.0	134.18.5.2	m0

Example 5

Make the routing table for router R1



Solution

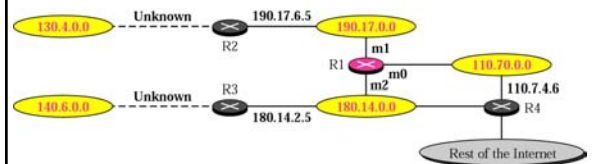
Mask	Destination	Next Hop	I.
255.255.255.0	200.8.4.0	----	m2
255.255.255.0	80.4.5.0	201.4.10.3 or 200.8.4.12	m1 or m2
255.255.255.0	80.4.6.0	201.4.10.3 or 200.4.8.12	m1 or m2
0.0.0.0	0.0.0.0	????????????	m0

Example 6

The routing table for router R1 is given below.
Draw its topology

Mask	Destination	Next Hop	I.
255.255.0.0	110.70.0.0	-	m0
255.255.0.0	180.14.0.0	-	m2
255.255.0.0	190.17.0.0	-	m1
255.255.0.0	130.4.0.0	190.17.6.5	m1
255.255.0.0	140.6.0.0	180.14.2.5	m2
0.0.0.0	0.0.0.0	110.70.4.6	m0

Example 6 (Solution)



6.6

CLASSLESS ADDRESSING: CIDR

ISSUES

Routing Table Size



Hierarchical Routing



Geographical Routing



Routing Table Search Algorithms



Note

In classful addressing, each address has self-contained information that facilitates routing table searching.

In classless addressing, there is no self-contained information in the destination address to facilitate routing table searching.