Routing & Forwarding

- Direct and Indirect Forwarding in Hosts and Routers
- Routing Tables
- Routing/Forwarding with Netmasks

Basics

☐ Forwarding:

- *Refers to the <u>effective transfer</u> of a packet, frame, etc.. downwards (normally implemented through a forwarding table)*

☐ Routing Algorithm:

- *Set of rules to decide <u>which route to choose</u> between a source and a destination (fills in the routing tables)*

☐ Routing Protocol:

- *Defines the <u>message exchange</u> phase to implement the routing algorithm*

Packet Forwarding

- IP uses the forwarding capabilities of underlying LAN technologies (Ethernet, 802.3, etc.)

- Direct Forwarding:
  - The destination is in the same (local) network as the source

- Indirect Forwarding:
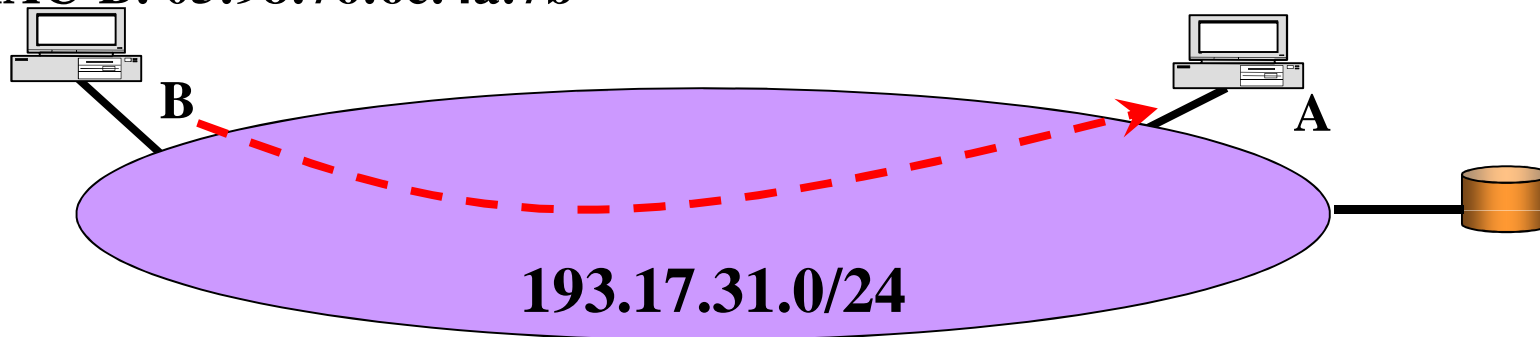 - The destination is somewhere else

Host Direct Forwarding

□ LAN coincides with IP subnet

IP-B: <u>193.17.31</u>.55/24
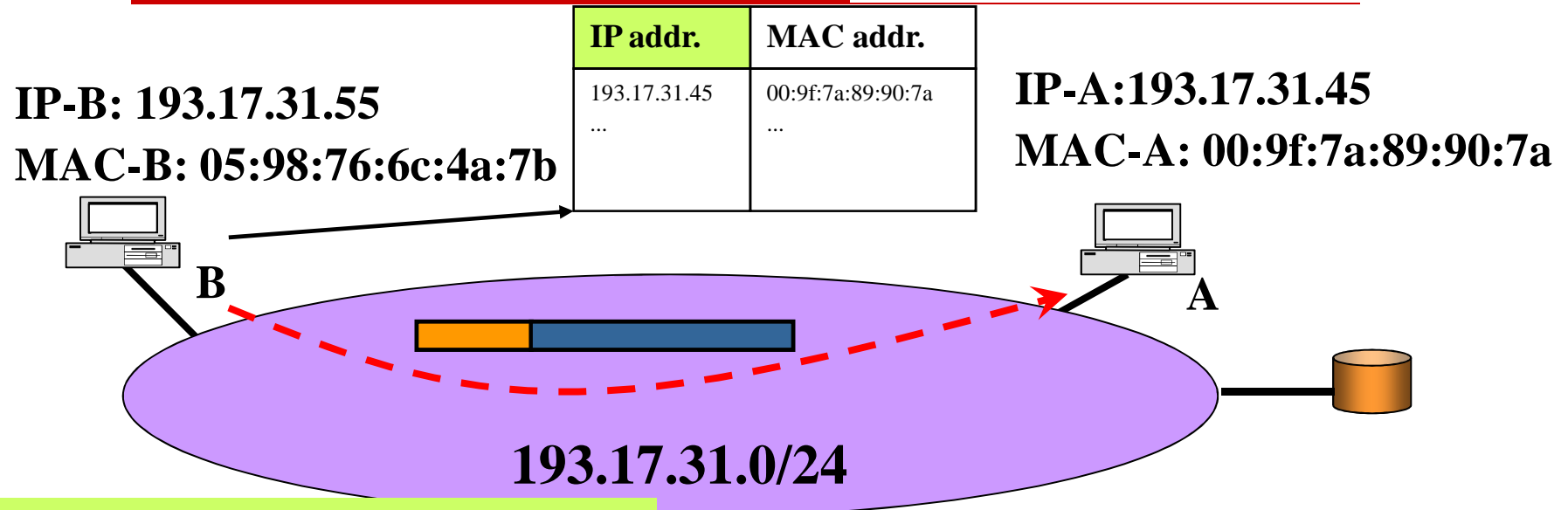
MAC-B: 05:98:76:6c:4a:7b

IP-A:<u>193.17.31</u>.45/24

MAC-A: 00:9f:7a:89:90:7a

B

A

193.17.31.0/24

1. Host B needs to send a IP packet to host A

2. B knows its own IP address (IP-B) and knows that A is on the same subnet (by comparing the NetIDs)

Host Direct Forwarding

IP addr.	MAC addr.
193.17.31.45 ...	00:9f:7a:89:90:7a ...

IP-B: 193.17.31.55
MAC-B: 05:98:76:6c:4a:7b

IP-A:193.17.31.45
MAC-A: 00:9f:7a:89:90:7a

B

A

193.17.31.0/24

3. B searches a table for the physical address corresponding to the IP destination address IP-A (ARP Table)

4. The IP layer of B passes down the packet to the lower layer (Ethernet …) which is responsible of the forwarding (destination MAC-A)
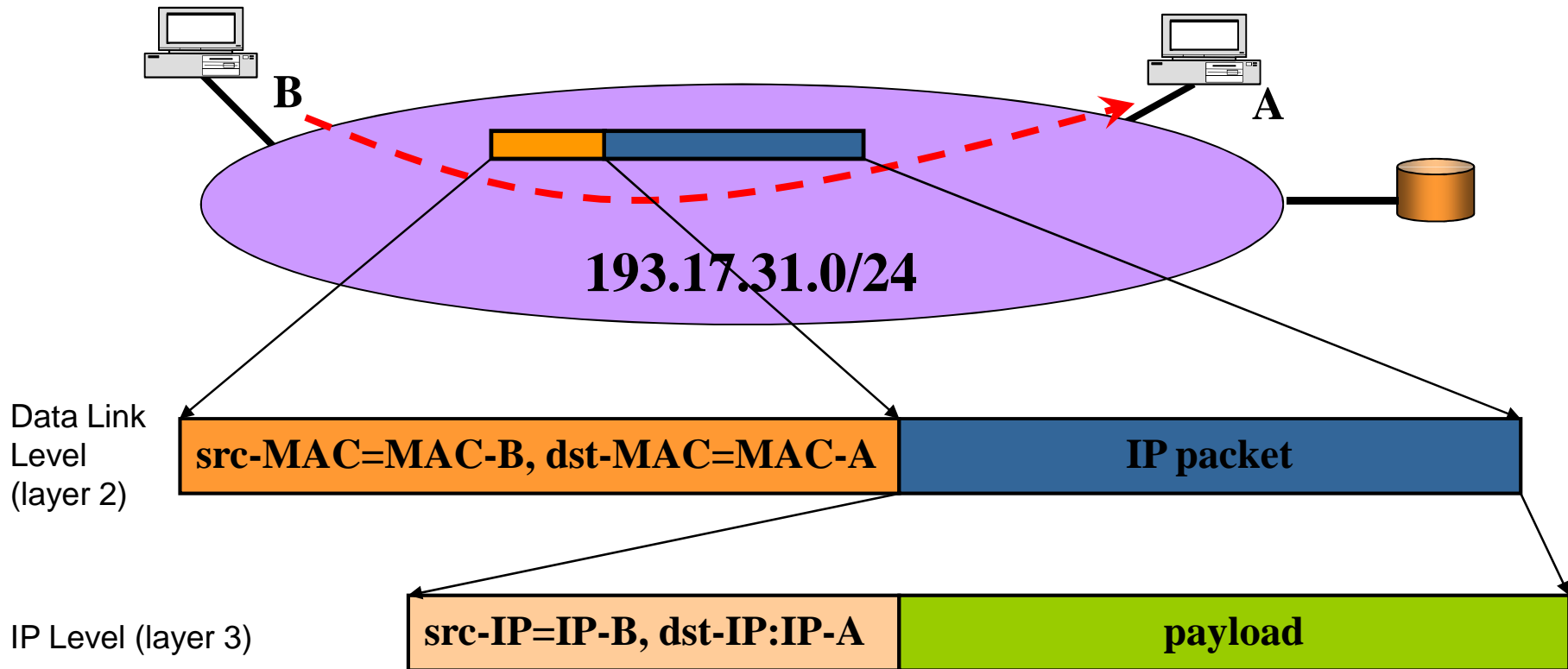
Host Direct Forwarding

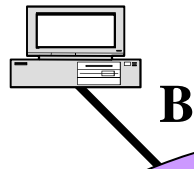IP-B: 193.17.31.55

MAC-B: 05:98:76:6c:4a:7b

IP-A:193.17.31.45
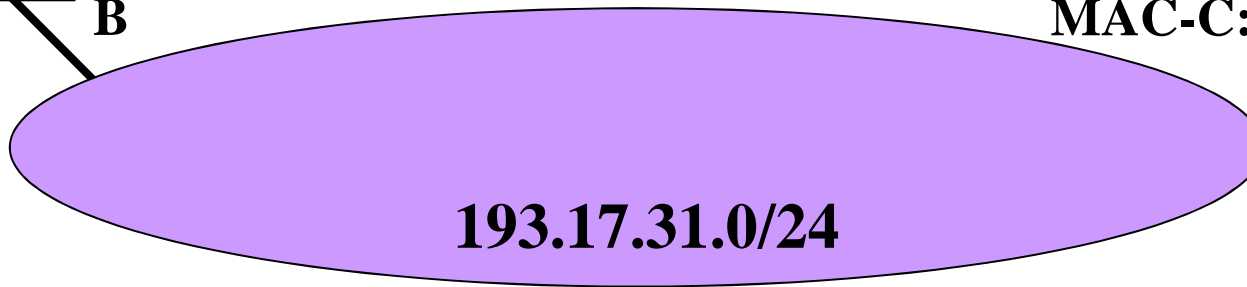
MAC-A: 00:9f:7a:89:90:7a

B

A

193.17.31.0/24

Data Link
Level
(layer 2)

src-MAC=MAC-B, dst-MAC=MAC-A

IP packet

IP Level (layer 3)

src-IP=IP-B, dst-IP:IP-A

payload

Host Indirect Forwarding

IP-B: <u>193.17.31</u>.55/24

MAC-B: 05:98:76:6c:4a:7b

B

IP-C: 193.17.31.254

MAC-C: 99:8b:6f:ac:58:7f

193.17.31.0/24
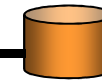
C

1. Host B needs to send a IP packet to destination *IP-D=131.17.23.4*

2. B knows its own IP address (IP-B) and knows that D is <u>NOT</u> on the same subnet (by comparing the NetIDs)
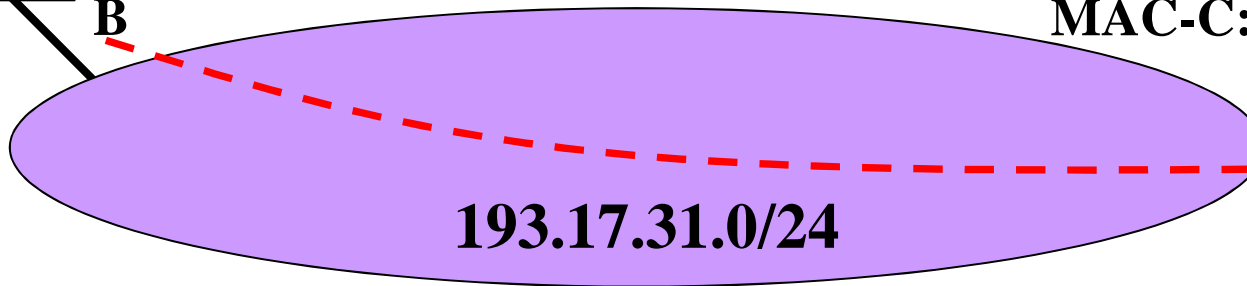
Host Indirect Forwarding

IP-B: 193.17.31.55

MAC-B: 05:98:76:6c:4a:7b

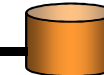IP-C: 193.17.31.254

MAC-C: 99:8b:6f:ac:58:7f

B

193.17.31.0/24

C

3. B needs to rely upon a router (usually just one default router is configured for a host)

4. B gathers the MAC address of the default router and passes downwards the packet
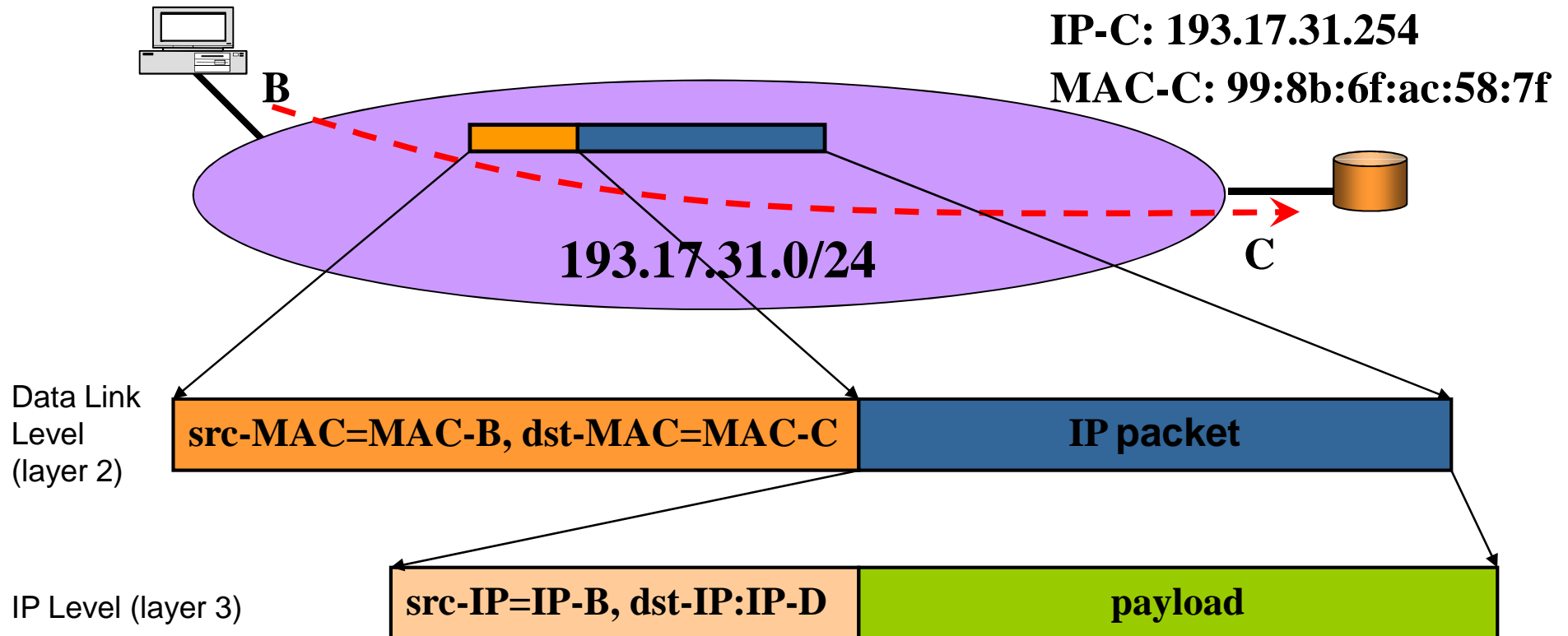
Host Indirect Forwarding

5. **The frame is built up and sent out the physical interface**

IP-B: 193.17.31.55

MAC-B: 05:98:76:6c:4a:7b

IP-C: 193.17.31.254

MAC-C: 99:8b:6f:ac:58:7f

B

C

193.17.31.0/24

Data Link Level (layer 2)

src-MAC=MAC-B, dst-MAC=MAC-C | **IP packet**

IP Level (layer 3)

src-IP=IP-B, dst-IP:IP-D | **payload**

Host Configuration

Default Router/ Gateway

Router Forwarding

- *Routers:* internetworking devices with multiple physical interfaces
- Also *routers* implement direct and indirect forwarding but:
    - Direct Forwarding: they can choose among many interfaces
    - Indirect Forwarding: is based on *routing tables*

Router Forwarding/Routing

- ☐ DESTINATION BASED: driven by the destination address

- ☐ NEXT HOP ROUTING: for each destination in the routing table, *only* the next relaying node is reported.

Router Forwarding

Net 131.175.0.0

A B

Net 131.30.0.0

131.175.1.254

131.175.1.253

131.30.78.4
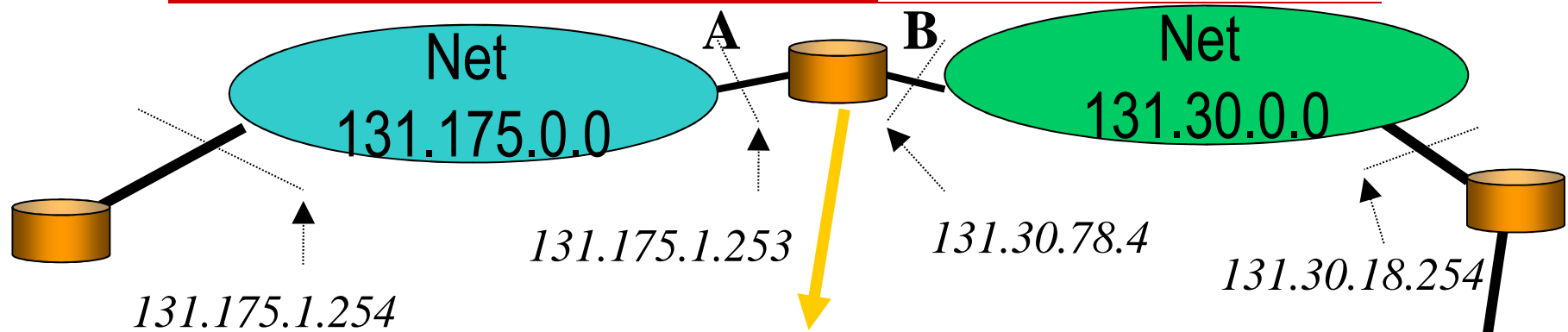
131.30.18.254

destination network	next-hop
194.34.23.0	131.175.1.254
194.34.34.0	131.175.1.254
140.56.0.0	131.30.18.254
141.56.0.0	131.30.18.254
131.175.0.0	interface A
131.30.0.0	interface B
…	…
default	131.30.18.254

Internet

Direct/Indirect Forwarding with Netmasks

- ☐ Given a packet, the router must realize if it is meant for a destination within the *directly connected* network(s)
- ☐ To perform this check, the router computes the bitwise *AND* between the interface address and the interface netmask, and between the destination address and the interface netmask
- ☐ If the two outcomes coincide, direct forwarding is performed on that interface

destination: (131.175.21.77) AND (255.255.255.0) = 131.175.21.0

Positive

crosscheck

Interface #N : (131.175.21.96) AND (255.255.255.0) = 131.175.21.0

Routing Tables & Netmasks

- ☐ If the crosscheck is *negative* for all the interfaces, <u>indirect</u> forwarding is performed

- ☐ The router must therefore refer to its routing table

- ☐ The very same crosscheck is performed for all the rows of the routing table using the corresponding netmask

- ☐ If the crosscheck is positive for multiple rows, the one with the highest number of 1s in its netmask is chosen (<u>*longest match*</u>)

Routing Tables & Netmasks

network	netmask	first hop
1 3 1 . 1 7 5 . 2 1 . 0	2 5 5 . 2 5 5 . 2 5 5 . 0	1 3 1 . 1 7 . 1 2 3 . 2 5 4
1 3 1 . 1 7 5 . 1 6 . 0	2 5 5 . 2 5 5 . 2 5 5 . 0	1 3 1 . 1 7 . 7 8 . 2 5 4
1 3 1 . 5 6 . 0 . 0	2 5 5 . 2 5 5 . 0 . 0	1 3 1 . 1 7 . 1 5 . 2 5 4
1 3 1 . 1 5 5 . 0 . 0	2 5 5 . 2 5 5 . 0 . 0	1 3 1 . 1 7 . 1 5 . 2 5 4
0 . 0 . 0 . 0	0 . 0 . 0 . 0	1 3 1 . 1 7 . 1 2 3 . 2 5 4

interface eth0

IP address	1 3 1 . 1 7 . 1 2 3 . 1
netmask	2 5 5 . 2 5 5 . 2 5 5 . 0

interface eth1

IP address	1 3 1 . 1 7 . 7 8 . 1
netmask	2 5 5 . 2 5 5 . 2 5 5 . 0

interface eth2

IP address	1 3 1 . 1 7 . 1 5 . 1 2
netmask	2 5 5 . 2 5 5 . 2 5 5 . 0

default router:

Crosscheck always positive but netmask lenght = 0

Routing Table: example 1

network	netmask	first hop
131.175.15.0	255.255.255.0	131.175.21.1
131.175.16.0	255.255.255.0	131.175.21.2
131.175.17.0	255.255.255.0	131.175.21.3
131.180.23.0	255.255.255.0	131.175.21.4
131.180.18.0	255.255.255.0	131.175.21.4
131.180.21.0	255.255.255.0	131.175.21.4
131.180.0.0	255.255.0.0	131.175.21.5
0.0.0.0	0.0.0.0	131.175.12.254

131.175.21.86

interface 1: 131.175.21.254, 255.255.255.0

interface 2: 131.175.12.254, 255.255.255.0

Routing Table: example 2

network	netmask	first hop		
131.175.15.0	255.255.255.0	131.175.21.1	**x**	
131.175.16.0	255.255.255.0	131.175.21.2	**OK**	**131.175.16.65**
131.175.17.0	255.255.255.0	131.175.21.3	**x**	
131.180.23.0	255.255.255.0	131.175.21.4	**x**	
131.180.18.0	255.255.255.0	131.175.21.4	**x**	
131.180.21.0	255.255.255.0	131.175.21.4	**x**	
131.180.0.0	255.255.0.0	131.175.21.5	**x**	
0.0.0.0	0.0.0.0	131.175.12.254	**OK**	

interface 1: 131.175.21.254, 255.255.255.0

interface 2: 131.175.12.254, 255.255.255.0

Routing Table: example 3

network	netmask	first hop		
131.175.15.0	255.255.255.0	131.175.21.1	x	
131.175.16.0	255.255.255.0	131.175.21.2	x	
131.175.17.0	255.255.255.0	131.175.21.3	x	
131.180.23.0	255.255.255.0	131.175.21.4	x	
131.180.18.0	255.255.255.0	131.175.21.4	x	
131.180.21.0	255.255.255.0	131.175.21.4	**OK**	⬅
131.180.0.0	255.255.0.0	131.175.21.5	**OK**	
0.0.0.0	0.0.0.0	131.175.12.254	**OK**	

131.180.21.78

interface 1: 131.175.21.254, 255.255.255.0

interface 2: 131.175.12.254, 255.255.255.0

Routing Table: example 4

network	netmask	first hop		
131.175.15.0	255.255.255.0	131.175.21.1	X	
131.175.16.0	255.255.255.0	131.175.21.2	X	
131.175.17.0	255.255.255.0	131.175.21.3	X	
131.180.23.0	255.255.255.0	131.175.21.4	X	
131.180.18.0	255.255.255.0	131.175.21.4	X	
131.180.21.0	255.255.255.0	131.175.21.4	X	
131.180.0.0	255.255.0.0	131.175.21.5	X	
0.0.0.0	0.0.0.0	131.175.12.254	**OK**	

200.45.21.84

interface 1: 131.175.21.254, 255.255.255.0

interface 2: 131.175.12.254, 255.255.255.0

Routing Table Format

Netmask	Destination	Next Hop	Flag	Reference Count	Use	Interface
255.0.0.0	124.0.0.0	145.6.7.23	UG	4	20	Eth1
....	....	....	....	....	....	....
....	....	....	....	....	....	....
....	....	....	....	....	....	....

- ☐ Flag:
  - ■ U: active router
  - ■ G: destination out of the subnet
  - ■ H: specific destination host

- ☐ Reference Count: number of flows using that route

- ☐ Use: number of packets to the destination

- ☐ Interface: exit interface name