

Routing & Forwarding

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

Basics

□ Forwarding:

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

□ Routing Algorithm:

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

□ Routing Protocol:

- Defines the message exchange phase to implement the routing algorithm
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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
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Host Direct Forwarding

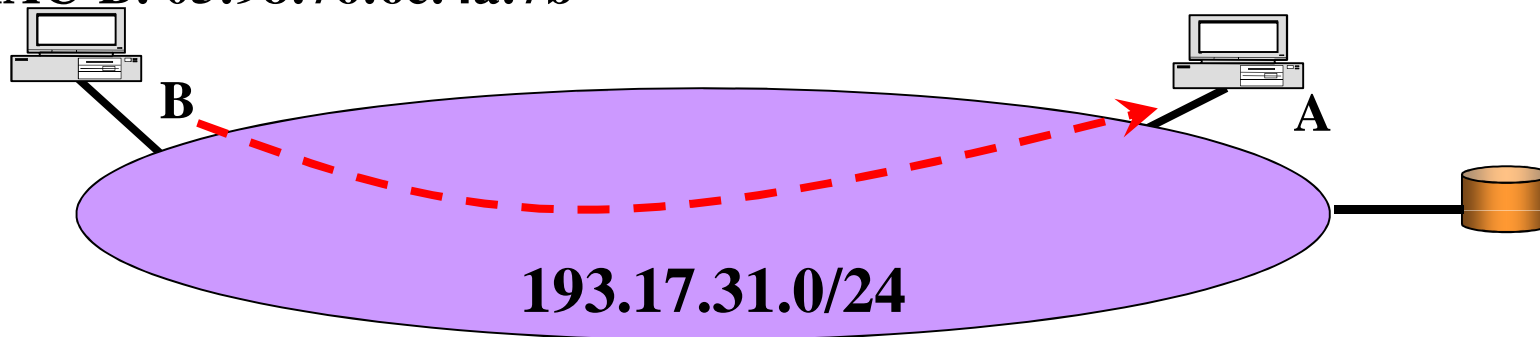
- LAN coincides with IP subnet

IP-B: 193.17.31.55/24

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

IP-A: 193.17.31.45/24

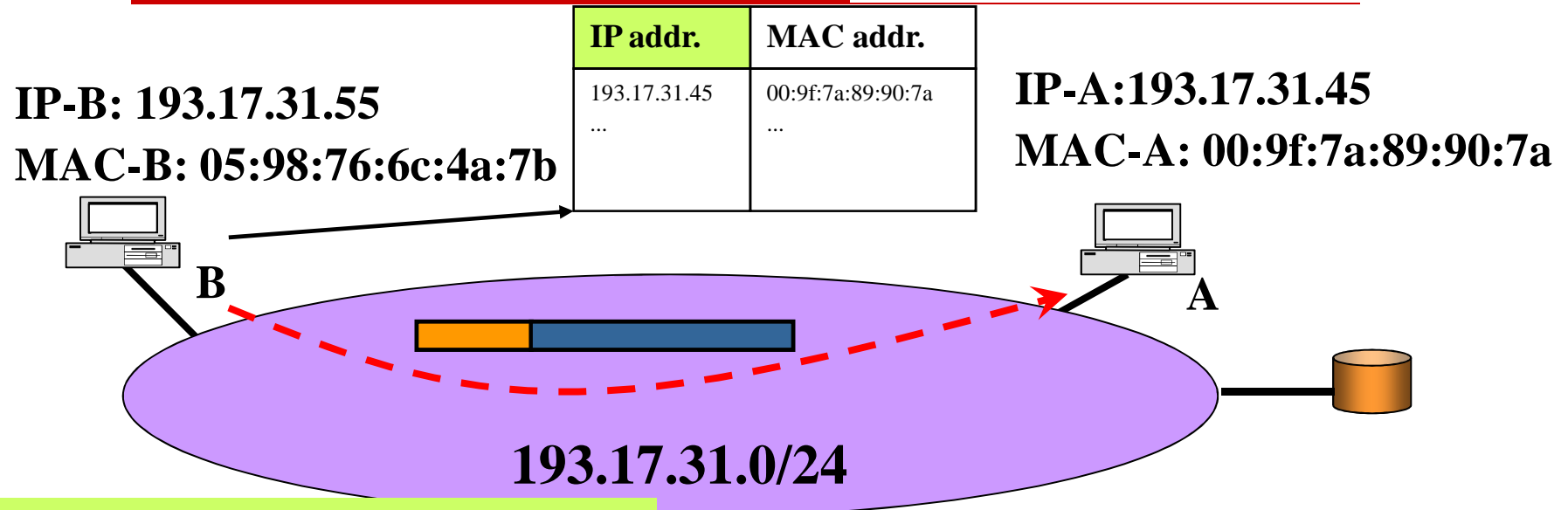
MAC-A: 00:9f:7a:89:90:7a



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



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)

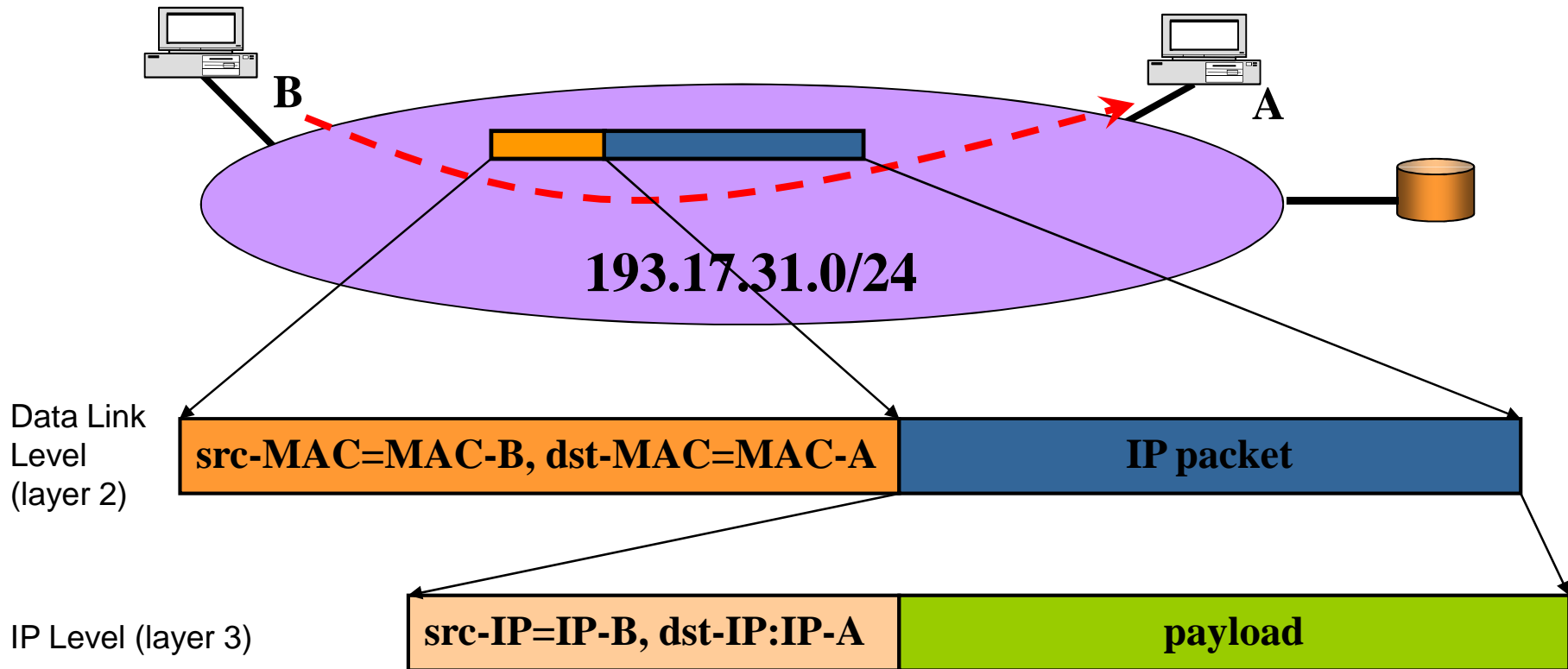
Host Direct Forwarding

IP-B: 193.17.31.55

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

IP-A: 193.17.31.45

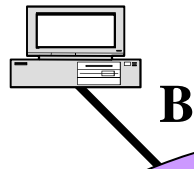
MAC-A: 00:9f:7a:89:90:7a



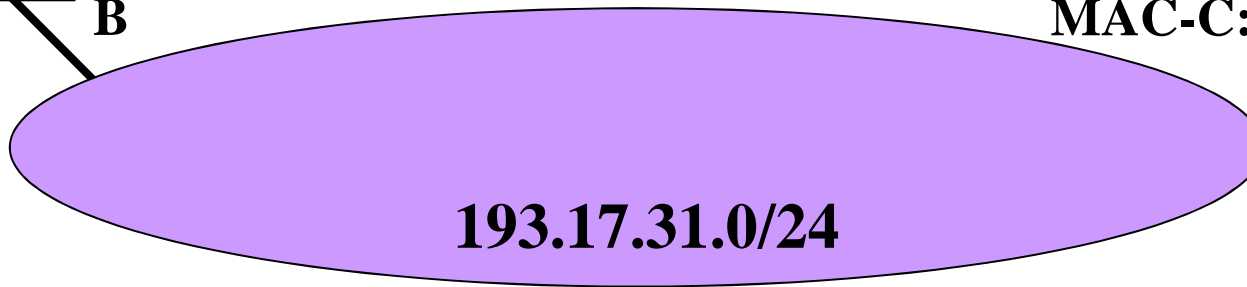
Host Indirect Forwarding

IP-B: 193.17.31.55/24

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



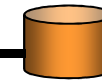
B



193.17.31.0/24

IP-C: 193.17.31.254

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



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 NOT on the same subnet (by comparing the NetIDs)

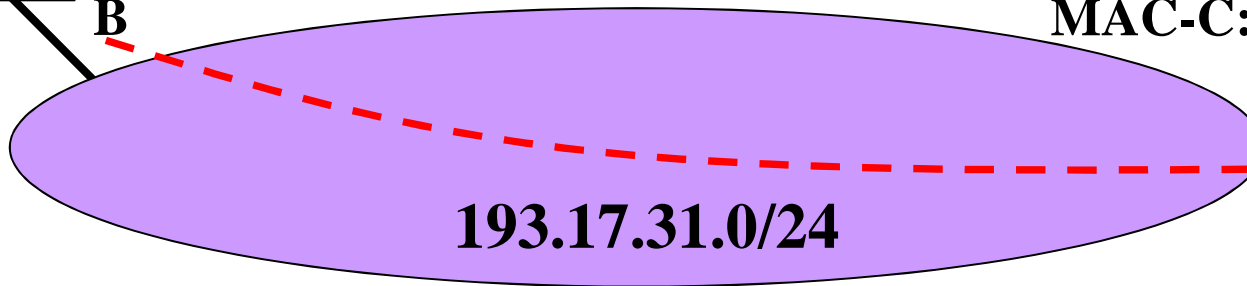
Host Indirect Forwarding

IP-B: 193.17.31.55

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

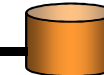


B



IP-C: 193.17.31.254

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



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

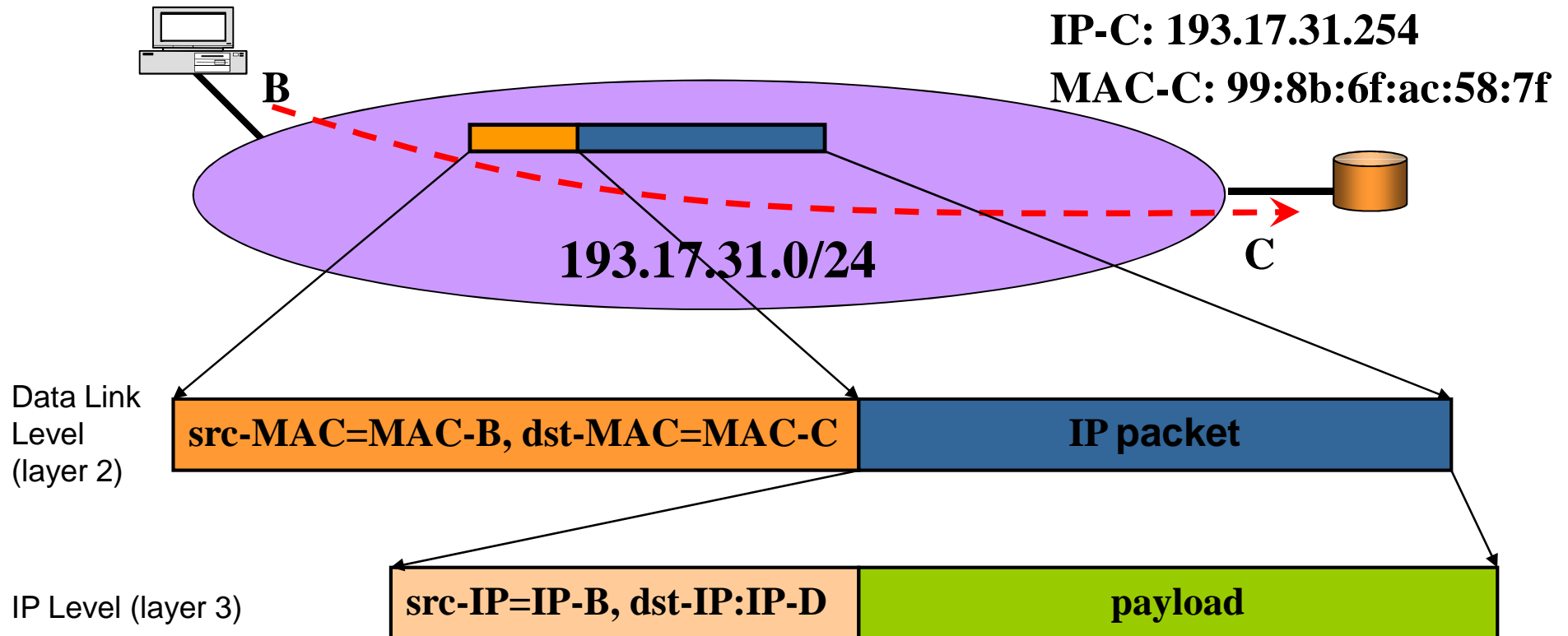
5. The frame is built up and sent out the physical interface

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



Host Configuration

The image displays three overlapping Windows dialog boxes from the 'Rete' (Network) control panel. The background window, 'Rete', shows a list of installed network components, including 'TCP/IP -> PCMCIA Fast Ethernet Card'. The middle window, 'Proprietà - TCP/IP', is on the 'Gateway' tab and shows the 'Specifica l'indirizzo IP' option selected, with the IP address '131.175.21.175' and Subnet Mask '255.255.255.0'. The foreground window, also 'Proprietà - TCP/IP', is on the 'Gateway' tab and shows the 'Nuovo gateway' field with a red dashed circle around it, and a list of installed gateways containing '131.175.21.254', also circled in red. A red dashed arrow points from the text 'Default Router/Gateway' to the circled gateway address.

**Default Router/
Gateway**

Rete

Configurazione | Identificazione | Controllo di accesso

I seguenti componenti di rete sono installati:

- Protocollo compatibile IPX/SPX -> Dispositivo di Accesso remoto
- Protocollo compatibile IPX/SPX -> PCMCIA Fast Ethernet Card
- TCP/IP -> Dispositivo di Accesso remoto
- TCP/IP -> PCMCIA Fast Ethernet Card
- Condivisione file e stampanti per reti Microsoft

Accesso primario:
Accesso a Windows

Condivisione di file e stampanti...

Descrizione
Il protocollo TCP/IP può essere utilizzato per condividerli Internet e ad altre WAN.

OK

Proprietà - TCP/IP

Binding | Avanzate | NetBIOS | Configurazione DNS

Gateway | Configurazione WINS | Indirizzo IP

Un indirizzo IP può essere assegnato automaticamente al computer. Se la rete non assegna automaticamente gli indirizzi IP, richiedere l'indirizzo IP all'amministratore della rete, quindi digitare l'indirizzo nello spazio sottostante.

Ottieni automaticamente un indirizzo IP

Specifica l'indirizzo IP:

Indirizzo IP: 131.175.21.175

Subnet Mask: 255.255.255.0

OK Anr

Proprietà - TCP/IP

Binding | Avanzate | NetBIOS | Configurazione DNS

Gateway | Configurazione WINS | Indirizzo IP

Il gateway predefinito sarà il primo nell'elenco dei gateway installati. L'ordine dei gateway nell'elenco sarà l'ordine secondo il quale questi verranno utilizzati.

Nuovo gateway:
. . . Aggiungi

Gateway installati

131.175.21.254 Rimuovi

OK Annulla

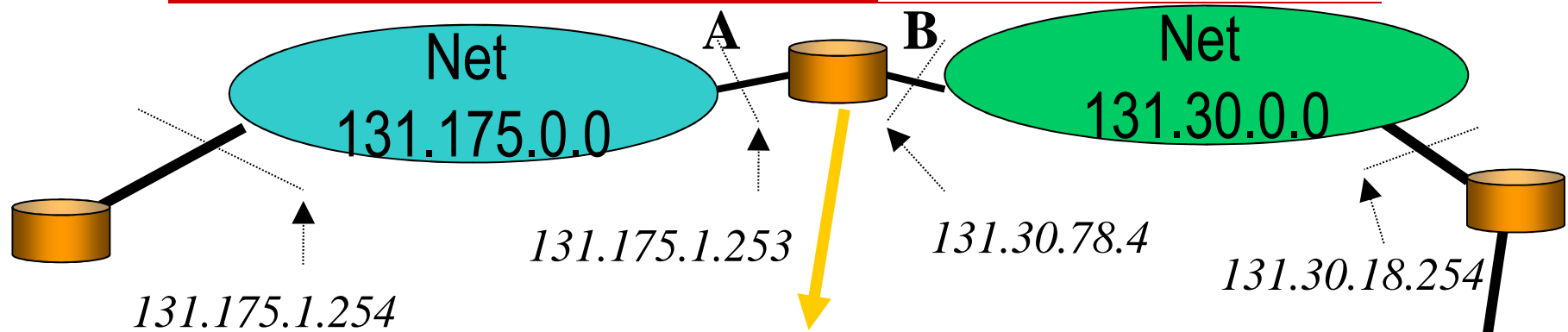
Router Forwarding

- *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*
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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



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

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, indirect 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 (*longest match*)
-

Routing Tables & Netmasks

network	netmask	first hop
131.175.21.0	255.255.255.0	131.17.123.254
131.175.16.0	255.255.255.0	131.17.78.254
131.56.0.0	255.255.0.0	131.17.15.254
131.155.0.0	255.255.0.0	131.17.15.254
0.0.0.0	0.0.0.0	131.17.123.254

interface eth0

IP address	131.17.123.1
netmask	255.255.255.0

interface eth1

IP address	131.17.78.1
netmask	255.255.255.0

interface eth2

IP address	131.17.15.12
netmask	255.255.255.0

default router:

**Crosscheck always
positive but netmask
length = 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
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

X

OK

X

X

X

X

X

OK

131.175.16.65



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
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

131.180.21.78

X

X

X

X

X

OK

OK

OK



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
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