CS321: Computer Networks

Network Layer:
Switching and IP addressing

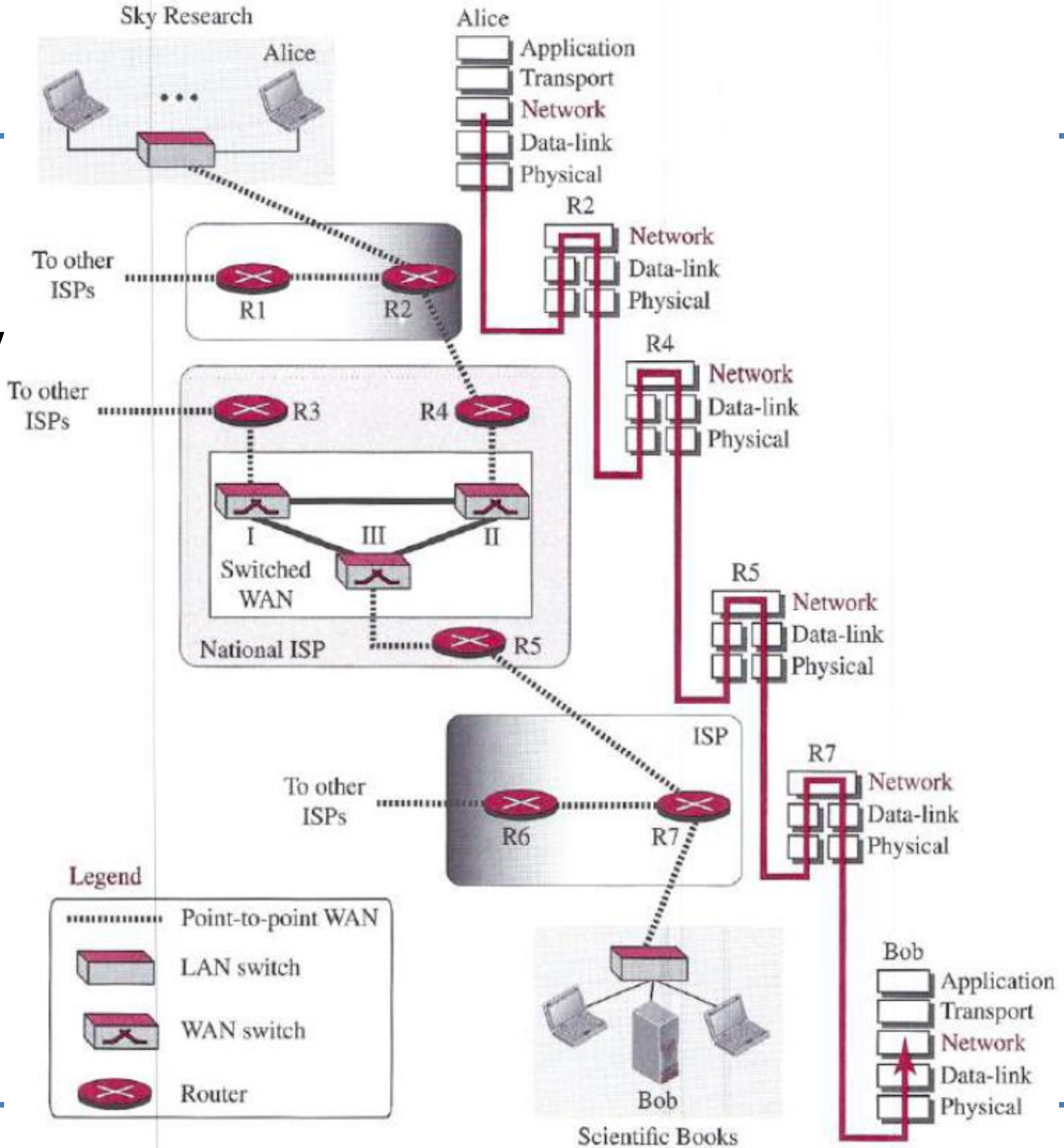
Dr. Manas Khatua
Assistant Professor
Dept. of CSE
IIT Jodhpur
E-mail: manaskhatua@iitj.ac.in

Introduction

Network Layer is responsible for the end-to-end delivery of packets.

Services

1. Packetizing
2. Addressing
3. Routing
4. Forwarding

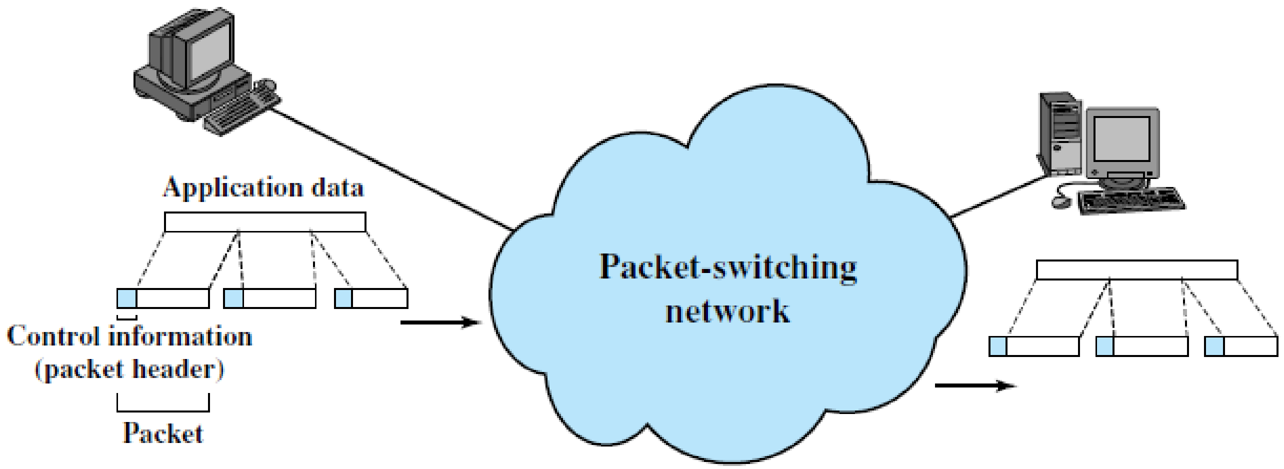


Network Service Models

- Services provided by Network Layer
  - Guaranteed delivery
  - Guaranteed delivery with bounded delay
  - In-order packet delivery
  - Guaranteed minimum bandwidth
  - Guaranteed maximum jitter
  - Security Service
  - Congestion Indication

Network Architecture	Service Model	Bandwidth Guarantee	No-Loss Guarantee	Ordering	Timing	Congestion Indication
Internet	Best Effort	None	None	Any order possible	Not maintained	None
ATM	CBR	Guaranteed constant rate	Yes	In order	Maintained	Congestion will not occur
ATM	ABR	Guaranteed minimum	None	In order	Not maintained	Congestion indication provided

Packet Switching



- Advantages of Packet Switching over Circuit Switching
  - Higher line efficiency, because a single node-to-node link can be dynamically shared by many packets over time
  - Two end stations of different data rates can exchange packets
  - Under heavy traffic condition, circuit switching refuses connection, but packet allows with higher delay
  - Priorities can be applied

Packet Switching Technique

- Datagram Approach
  - each packet is treated independently, with no reference to packets that have gone before
  - Connectionless

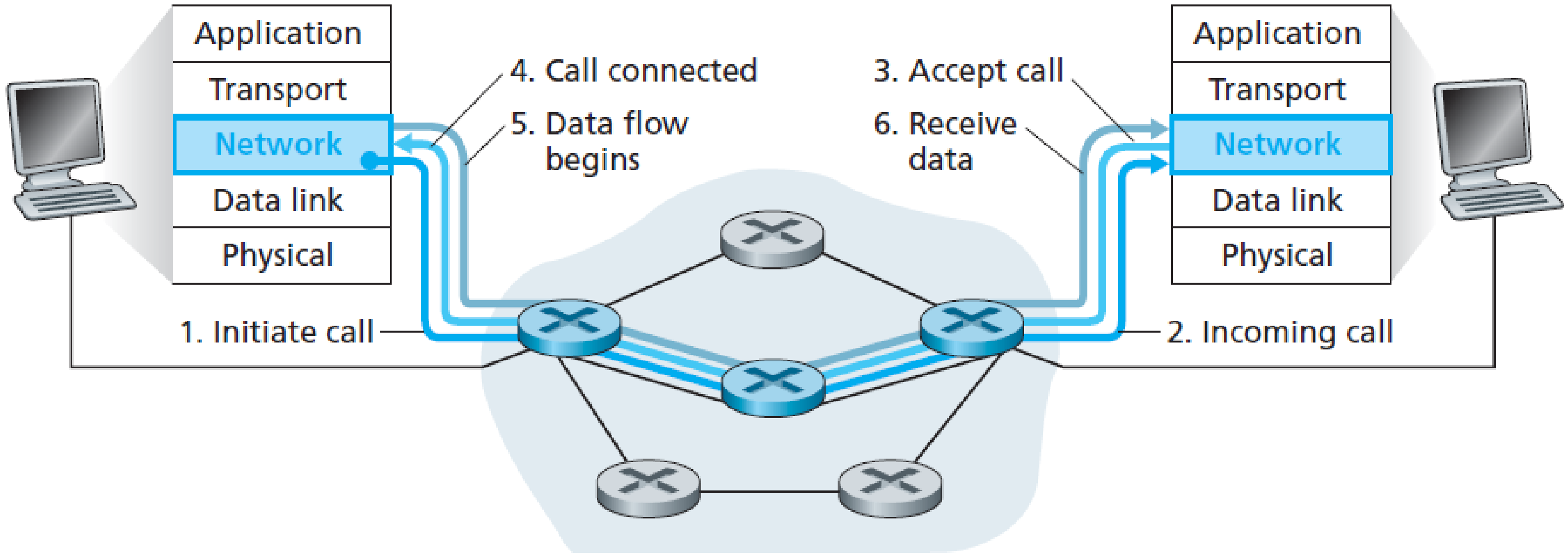
- Virtual Circuit Approach
  - a pre-planned route is established before any packets are sent.
  - Once the route is established, all the packets between a pair of communicating parties follow this same route through the network
  - Connection-oriented

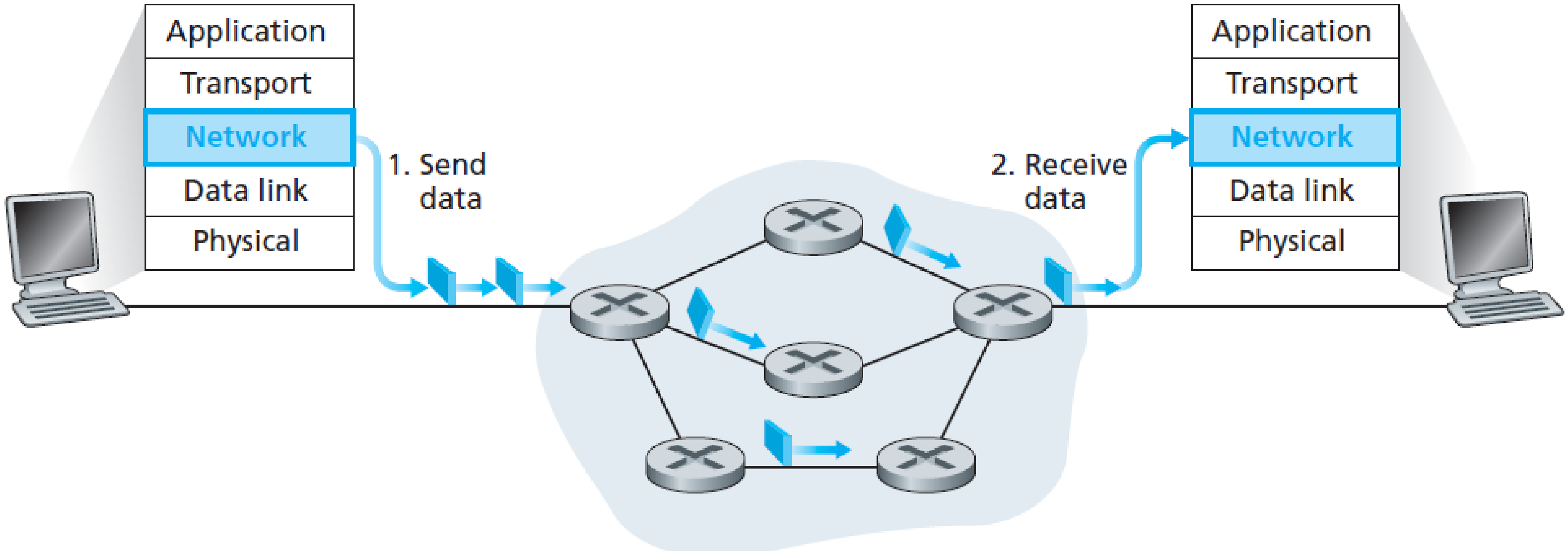
- VC setup in Network layer v/s Connection setup in Transport layer

  - Connection setup at the transport layer involves only the two end systems, and
  - routers within the network are completely oblivious to it.

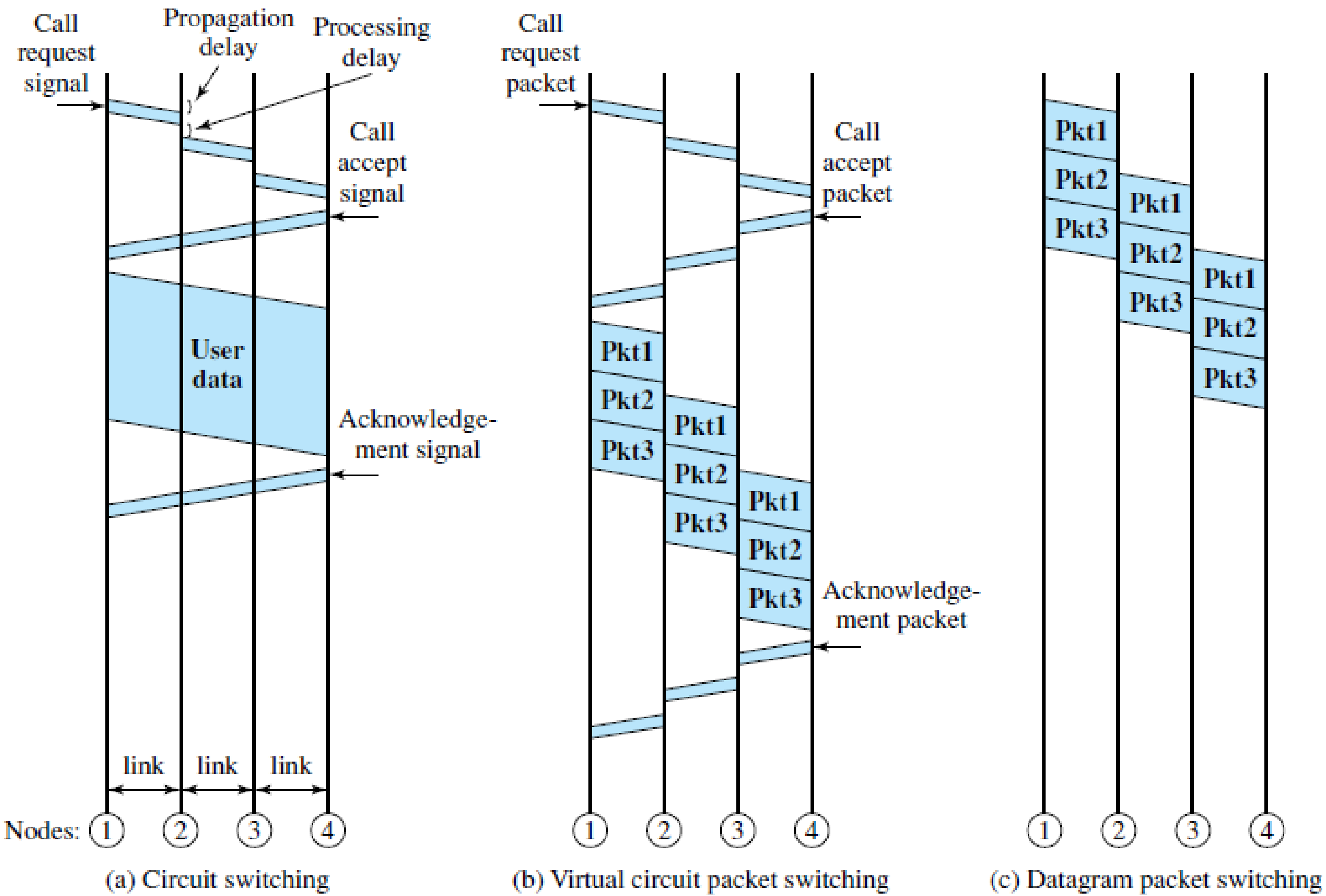
  - All routers along the path between the two end systems are involved in VC setup, and
  - each router is fully aware of all the VCs passing through it.

Virtual Circuit & Datagram Approaches





Comparison



Call request signal
Propagation delay
Processing delay
Call accept signal
User data
Acknowledge-ment signal
link
link
link
Nodes: 1 2 3 4
(a) Circuit switching
Call request packet
Call accept packet
Pkt1
Pkt2
Pkt3
Acknowledge-ment packet
1 2 3 4
(b) Virtual circuit packet switching
Pkt1
Pkt2
Pkt3
1 2 3 4
(c) Datagram packet switching

Comparison

Circuit Switching	Datagram Packet Switching	Virtual Circuit Packet Switching
Dedicated transmission path	No dedicated path	No dedicated path
Continuous transmission of data	Transmission of packets	Transmission of packets
Fast enough for interactive	Fast enough for interactive	Fast enough for interactive
Messages are not stored	Packets may be stored until delivered	Packets stored until delivered
The path is established for entire conversation	Route established for each packet	Route established for entire conversation
Call setup delay; negligible transmission delay	Packet transmission delay	Call setup delay; packet transmission delay
Busy signal if called party busy	Sender may be notified if packet not delivered	Sender notified of connection denial
Overload may block call setup; no delay for established calls	Overload increases packet delay	Overload may block call setup; increases packet delay
Electromechanical or computerized switching nodes	Small switching nodes	Small switching nodes
User responsible for message loss protection	Network may be responsible for individual packets	Network may be responsible for packet sequences
Usually no speed or code conversion	Speed and code conversion	Speed and code conversion
Fixed bandwidth	Dynamic use of bandwidth	Dynamic use of bandwidth
No overhead bits after call setup	Overhead bits in each packet	Overhead bits in each packet

Which one is better?

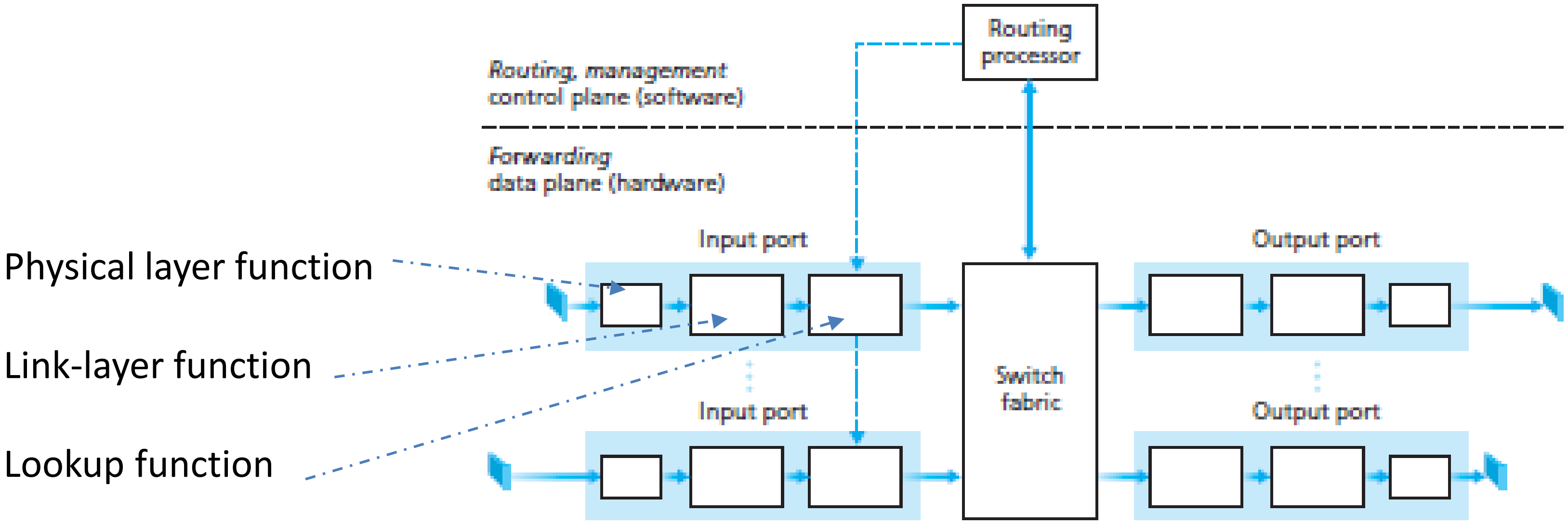
- Ans.: None for all condition.

- For short message
  - Circuit switching might be faster

- For long message
  - Virtual Circuit switching might be faster

- w.r.t. average delay, flexibility, reliability
  - Datagram approach is better

Router Architecture



High-level view of a generic router architecture

- Input Ports
- Switching fabric
- Output Ports
- Routing processor

- SDN: Software Defined Networking
  - Decouples the Data plane and Control plane

Cont…

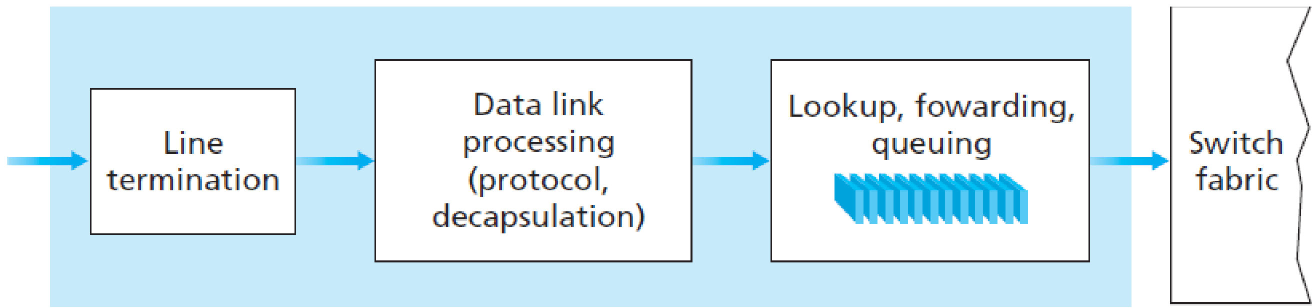


Figure 4.7 ♦ Input port processing

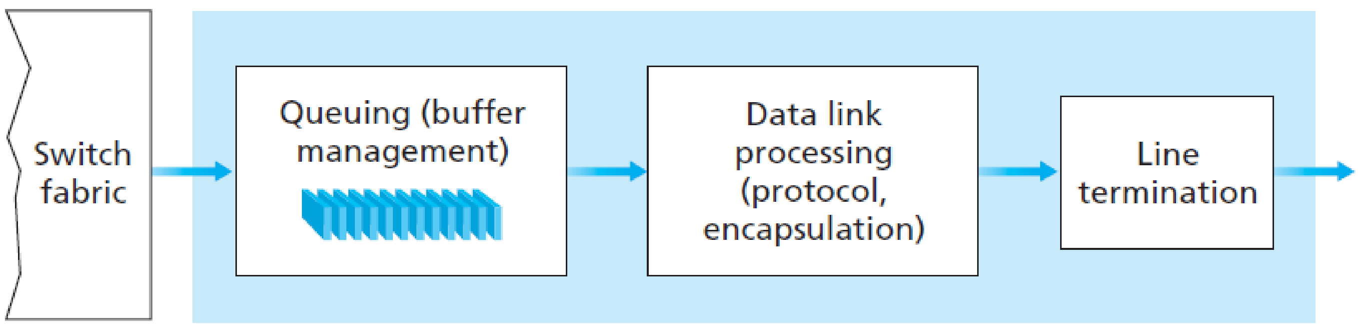
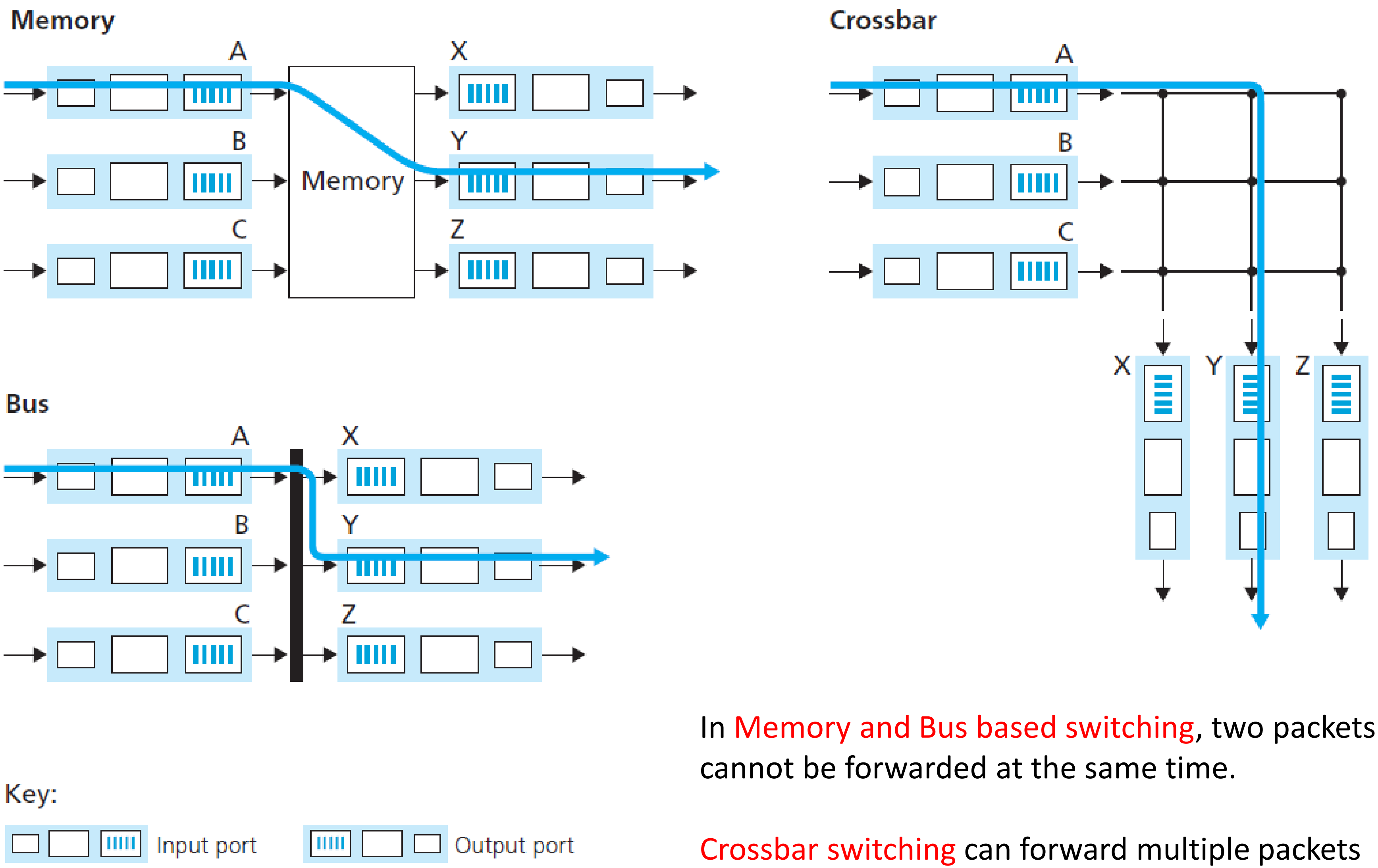


Figure 4.9 ♦ Output port processing

- Buffer Management
  - Drop-tail queuing (i.e. drop the arriving packet)
  - Selective drop (i.e. drop one already queued packet using some scheduling policy)
  - Active Queue Management (i.e. drop/mark a packet before the buffer is full. e.g., RED)

Cont…

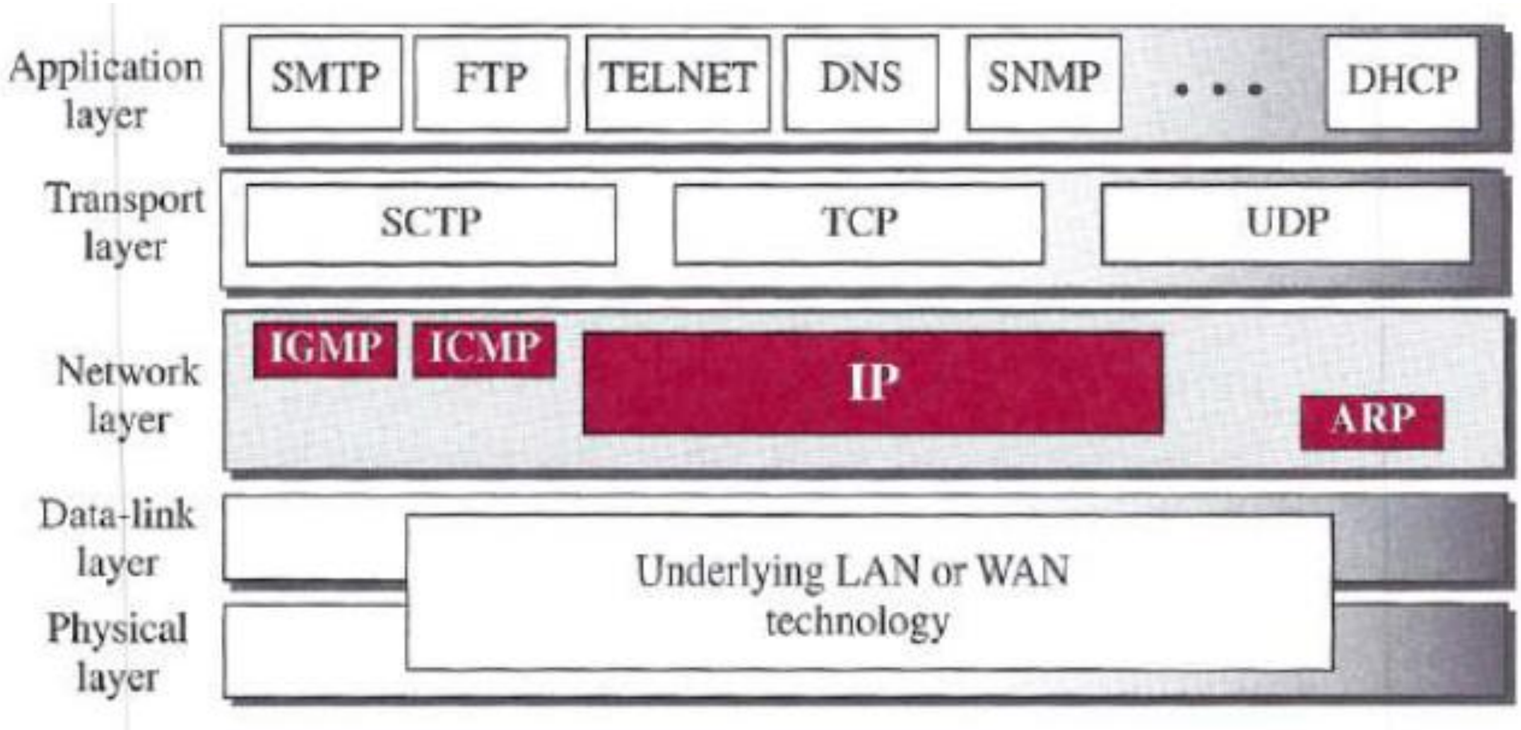


In Memory and Bus based switching, two packets cannot be forwarded at the same time.

Crossbar switching can forward multiple packets

Figure 4.8 ♦ Three switching techniques

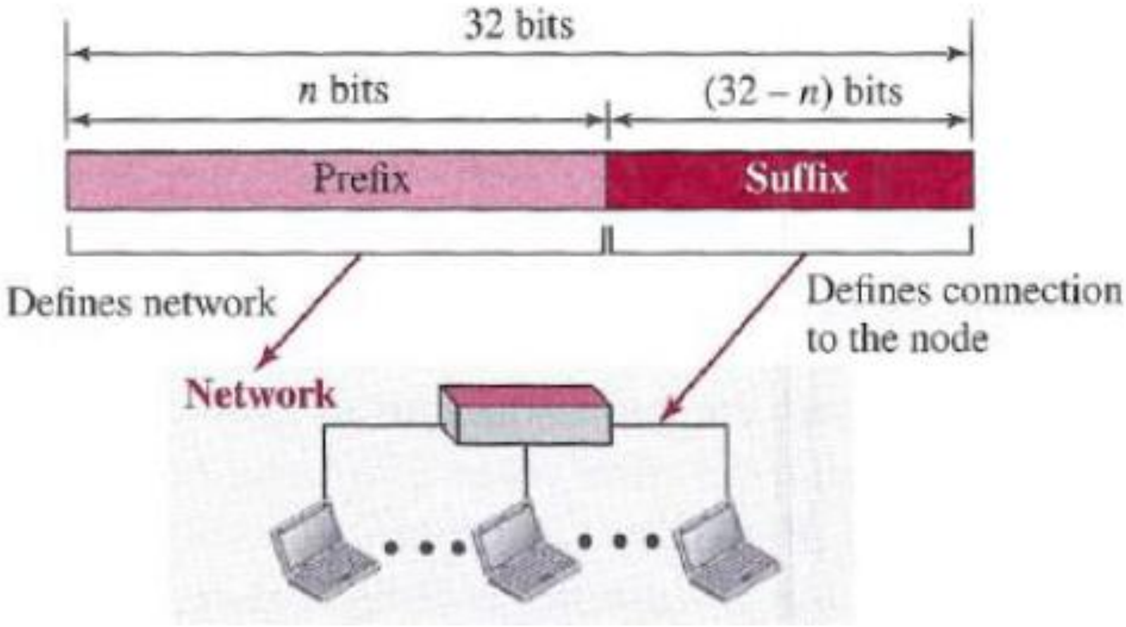
TCP/IP Protocol Suite



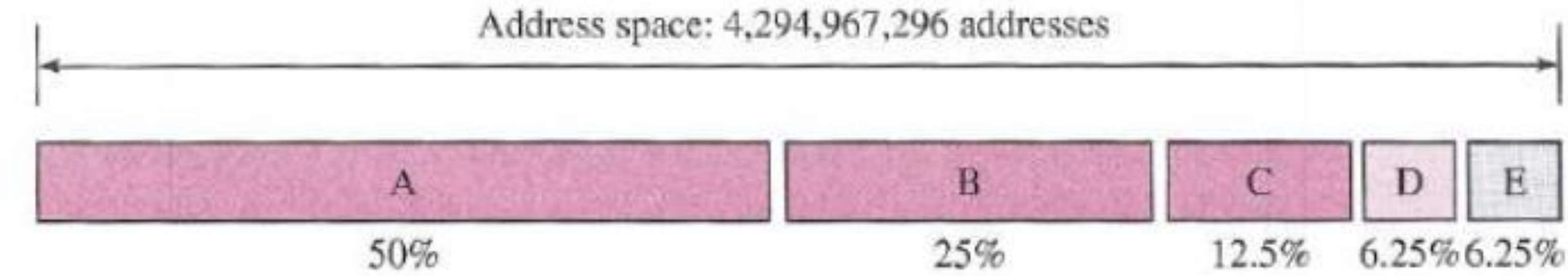
- IP Addressing
- IP Packet format
- Routing Protocol

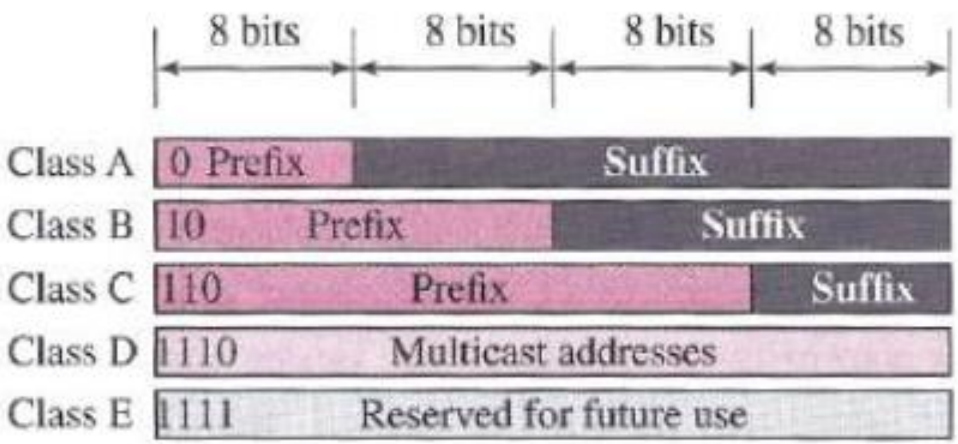
IP Addressing

- IP Address: 32 bits used to represent IPv4
  - E.g., 192.19.241.18 in dotted decimal notation
- Total address space: 2^n for *n* bit address
  - Last address: 255.255.255.255 if n=32



Classful Addressing





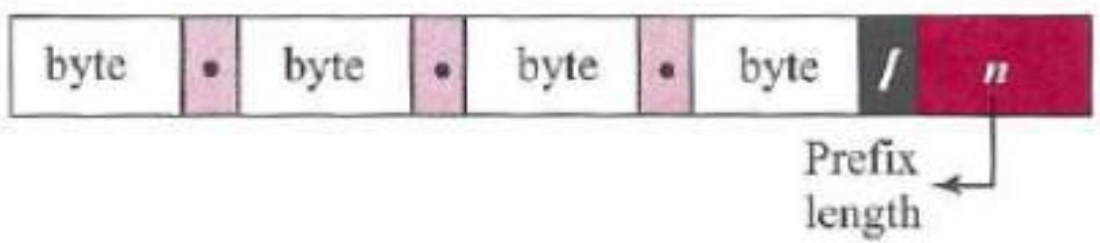
Class	Prefixes	First byte
A	$n = 8$ bits	0 to 127
B	$n = 16$ bits	128 to 191
C	$n = 24$ bits	192 to 223
D	Not applicable	224 to 239
E	Not applicable	240 to 255

Problem and Solution

- Problem in Classful Addressing: Address Depletion

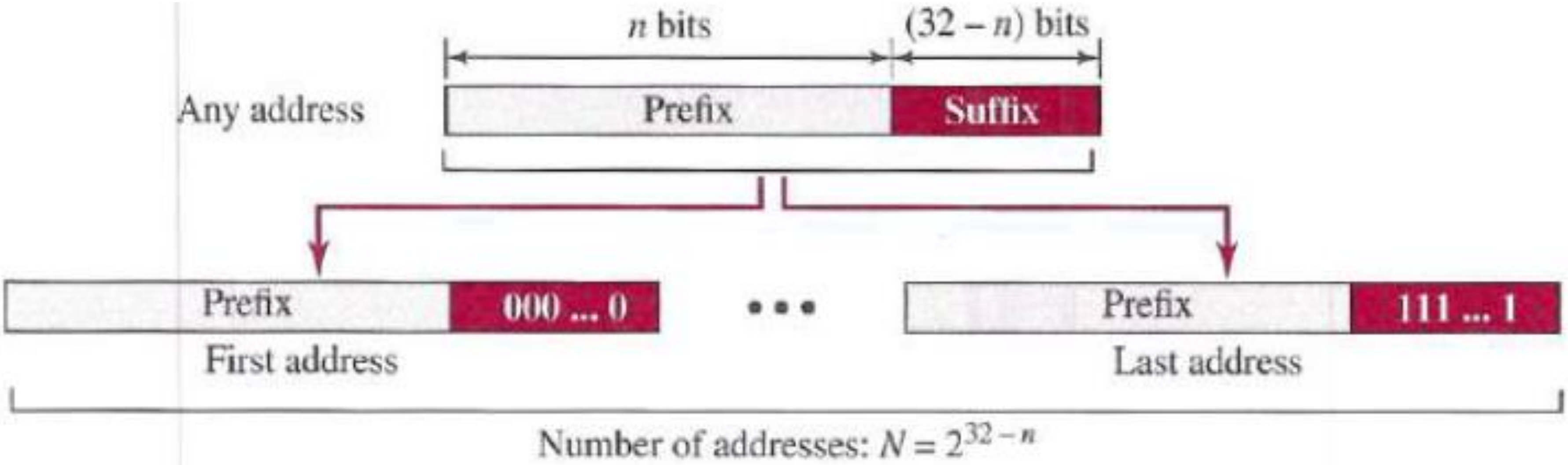
- Solution:
  - Subnetting: a larger block of address is divided into several subnets
  - Supernetting: several smaller blocks of addresses are combined to make a larger block

- Better Solution:
  - Classless addressing: variable length blocks that belong to no classes; uses slash notation to identify prefix length



Examples:
12.24.76.8/8
23.14.67.92/12
220.8.24.255/25

Extract block from an Address



Let an address: 167.199.170.82/27 . . .01010010

Number of Address: $2^{(32-27)} = 32$

First Address: 167.199.170.64/27 . . .01000000

Last Address: 167.199.170.95/27 . . .01011111

Address Mask

It is a 32-bit number in which the *n* leftmost bits are set to 1s and the rest of the bits (*32 - n*) are set to 0s.

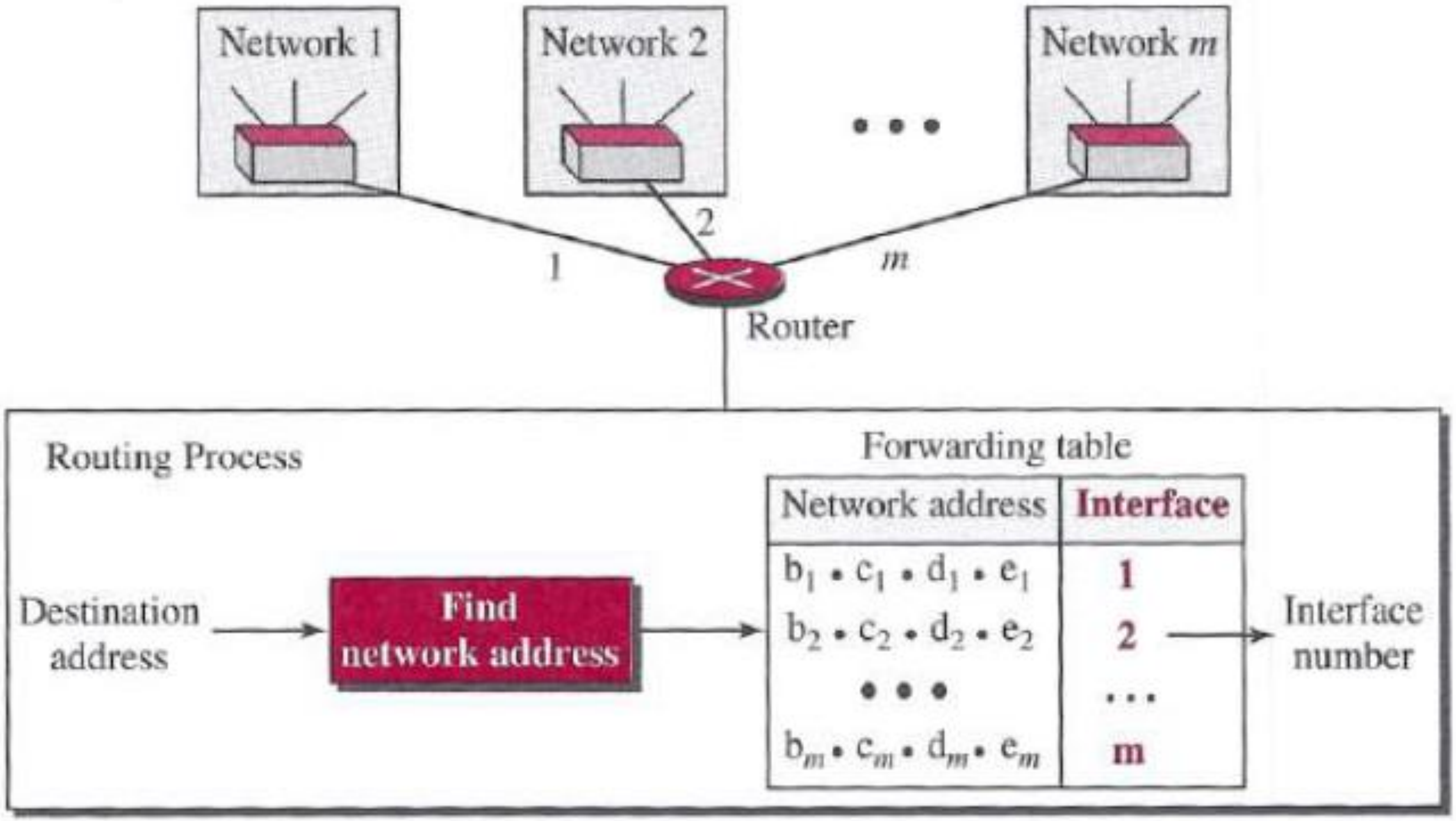
It can be used by a computer program to extract the information in a block, using the three bit-wise operations NOT, AND, and OR.

Given address: 167.199.170.82/27 . . .01010010
Mask: 255.255.255.224 . . .11100000

Number of address in the block: NOT (mask) + 1 = 31+1 = 32

First Address: (address) AND (mask) 167.199.170.64 (01000000)
Last Address: (address) OR (NOT (mask)) 167.199.170.95 (01011111)

Network Address



- Network address: first address of the block

Block Allocation

- Internet Corporation for Assigned Names and Numbers (ICANN) is the global authority.
- ICANN assigns a large block of address to ISP
- ISP assigns individual IP to stations/ small block to an organization
- Rules:
  1. The number of requested addresses, *N,* needs to be a power of 2. (as, $N=2^{32-n} \Rightarrow n = 32 - \log_2 N$)
  2. The allocated first address needs to be divisible by the number of addresses in the block. (for contiguous address)

Designing Subnets

- More levels of hierarchy can be created using subnetting.

- Rules:
  1. The number of addresses (N) in each subnetwork should be a power of 2; i.e., $N = 2^k$
  2. The prefix length (in bits) for each subnetwork should be found using the following formula:
     $$n_{subnet} = 32 - \log_2 N$$
  3. The starting address in each subnetwork should be divisible by the number of addresses in that subnetwork. (i.e., *least significant k bits* ***should all be 0)***

Example

- An organization is granted a block of addresses with the beginning address 14.24.74.0/24.
- The organization needs to have 3 sub-blocks of addresses to use in its three subnets: one sub-block of 10 addresses, one sub-block of 60 addresses, and one sub-block of 120 addresses. Design the sub-blocks.

- Solution: Allocated no. of address: $2^{32-24} = 256$

  First address: 14.24.74.0/24; Last address: 14.24.74.255/24

  Mask: 255.255.255.0

  We should start with largest sub-blocks.

  - N_1=120 => N_1=128 => n_1=32-$\log_2$128 = 25

    First address: 14.24.74.0/25

    Last address: 14.24.74.127/25 Mask: 255.255.255.128 (as last octet: 1000 0000)

  - N_2=60 => N_2=64 => n_2=32-$\log_2$64 = 26

    First address: 14.24.74.128/26

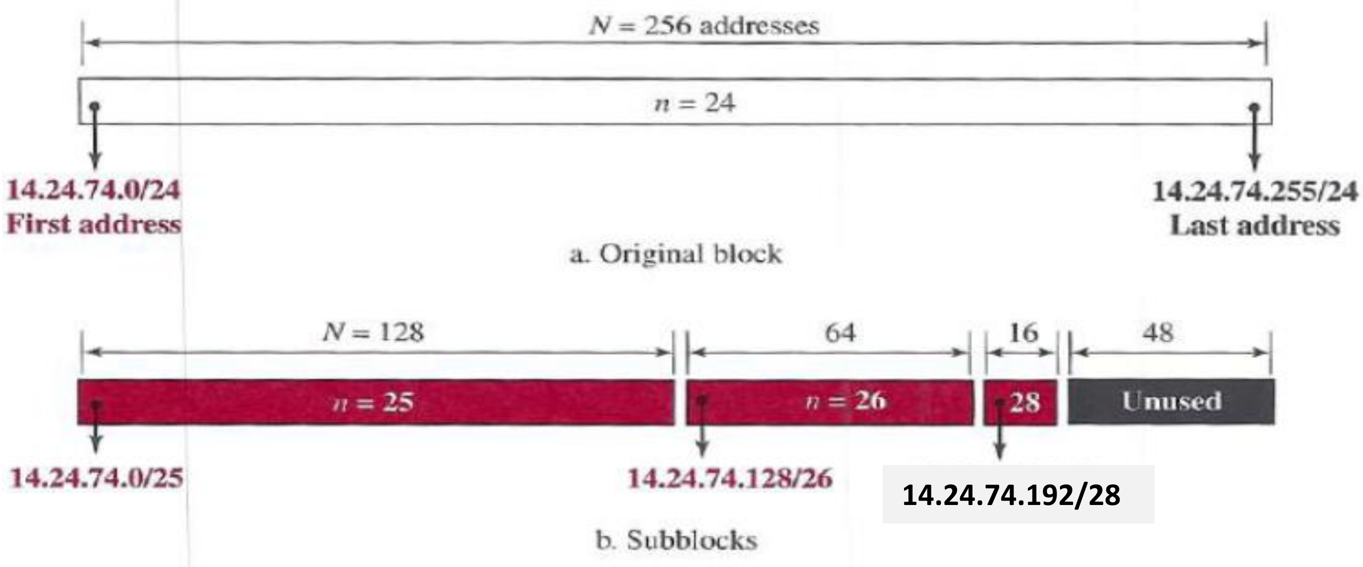
    Last address: 14.24.74.191/26 Mask: 255.255.255.192 (as last octet: 1100 0000)

  - N_3=10 => N_3=16 => n_3=32-$\log_2$16 = 28

    First address: 14.24.74.192/28

    Last address: 14.24.74.207/28 Mask: 255.255.255.240 (as last octet: 1111 0000)

Cont…



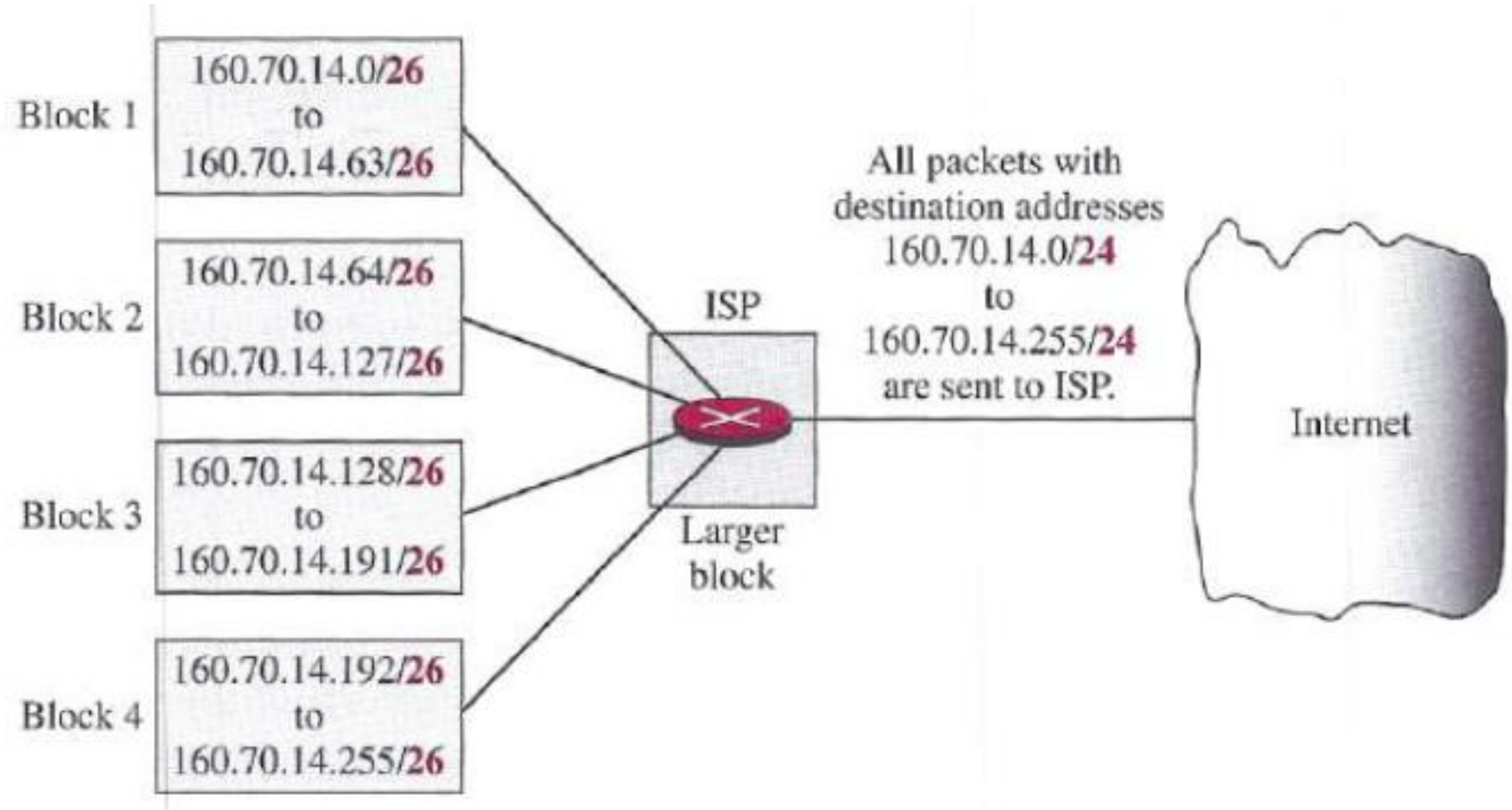
- Example: Let destination IP of a packet 14.24.74.195
  So, Network Address= (14.24.74.195) AND (255.255.255.0) = 14.24.74.0

- Subnet 3: (14.24.74.195) AND (255.255.255.240) = . . . (1100 0011 AND 1111 0000) = 14.24.74.192
  => Correct

- Subnet 2: (14.24.74.195) AND (255.255.255.192) = . . . (1100 0011 AND 1100 0000) = 14.24.74.192
  => Not Correct

- Subnet 1: (14.24.74.195) AND (255.255.255.128) = . . . (1100 0011 AND 1000 0000) = 14.24.74.128
  => Not correct

Address Aggregation

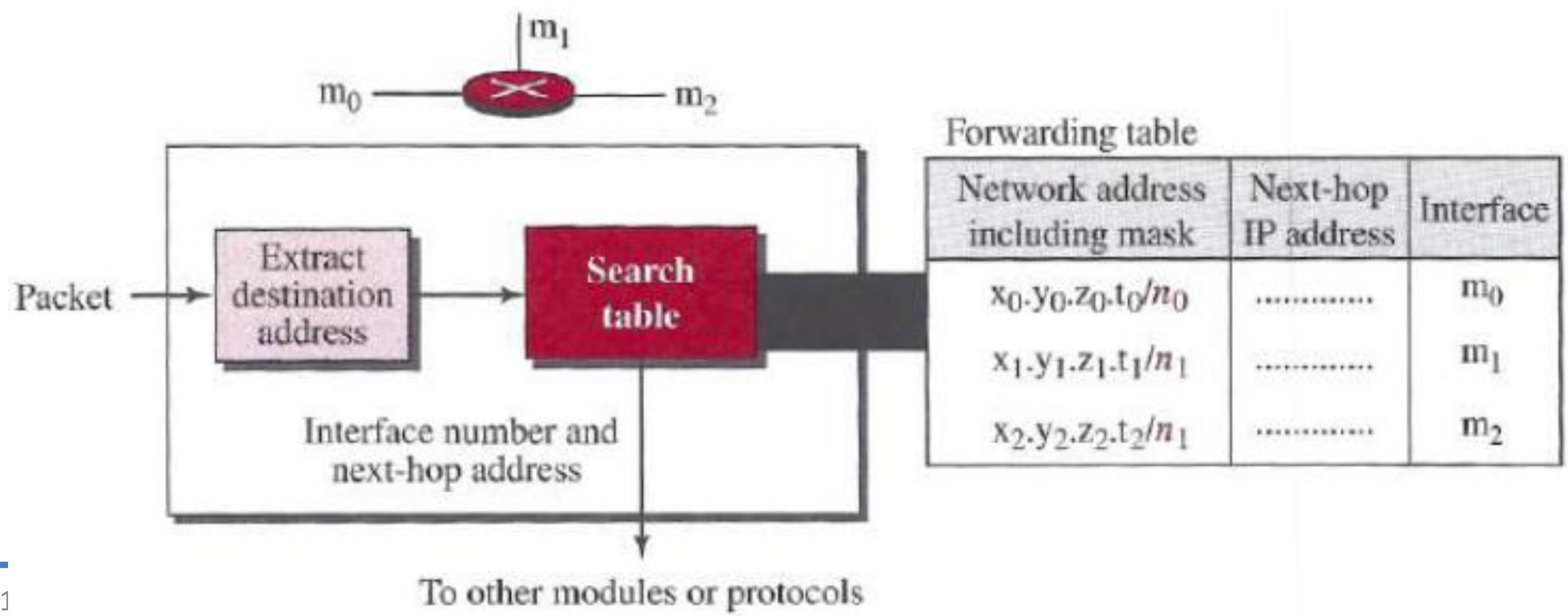


Special Addresses

- *This-host Address:* 0.0.0.0/32
  - It is used whenever a host needs to send an IP datagram but it does not know its own address to use as the source address.
- *Limited-broadcast Address:* 255.255.255.255/32
  - It is used whenever a router or a host needs to send a datagram to all devices in a network.
- *Loopback Address:* 127.0.0.0/8
  - Any address in the block is used to test a piece of software in the machine.
- *Private Addresses:* 10.0.0.0/8, *172.16.0.0/12, 192.168.0.0/16,* and 169.254.0.0/16
  - Used in NAT
- *Multicast Addresses: 224.0.0.0/4*
  - Reserved for multicast

IP Packet Forwarding

- Two Approaches:
  - Based on Destination IP
    - For connectionless protocol
  - Based on Label
    - For connection oriented protocol



Forwarding (by Dest. IP)

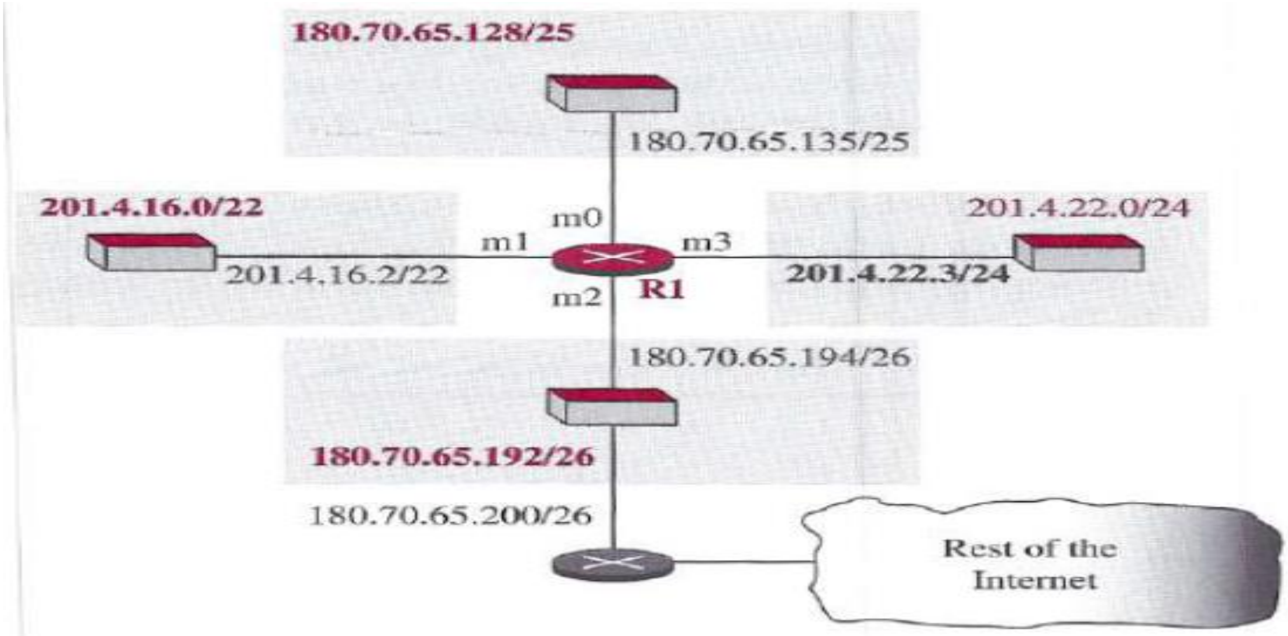
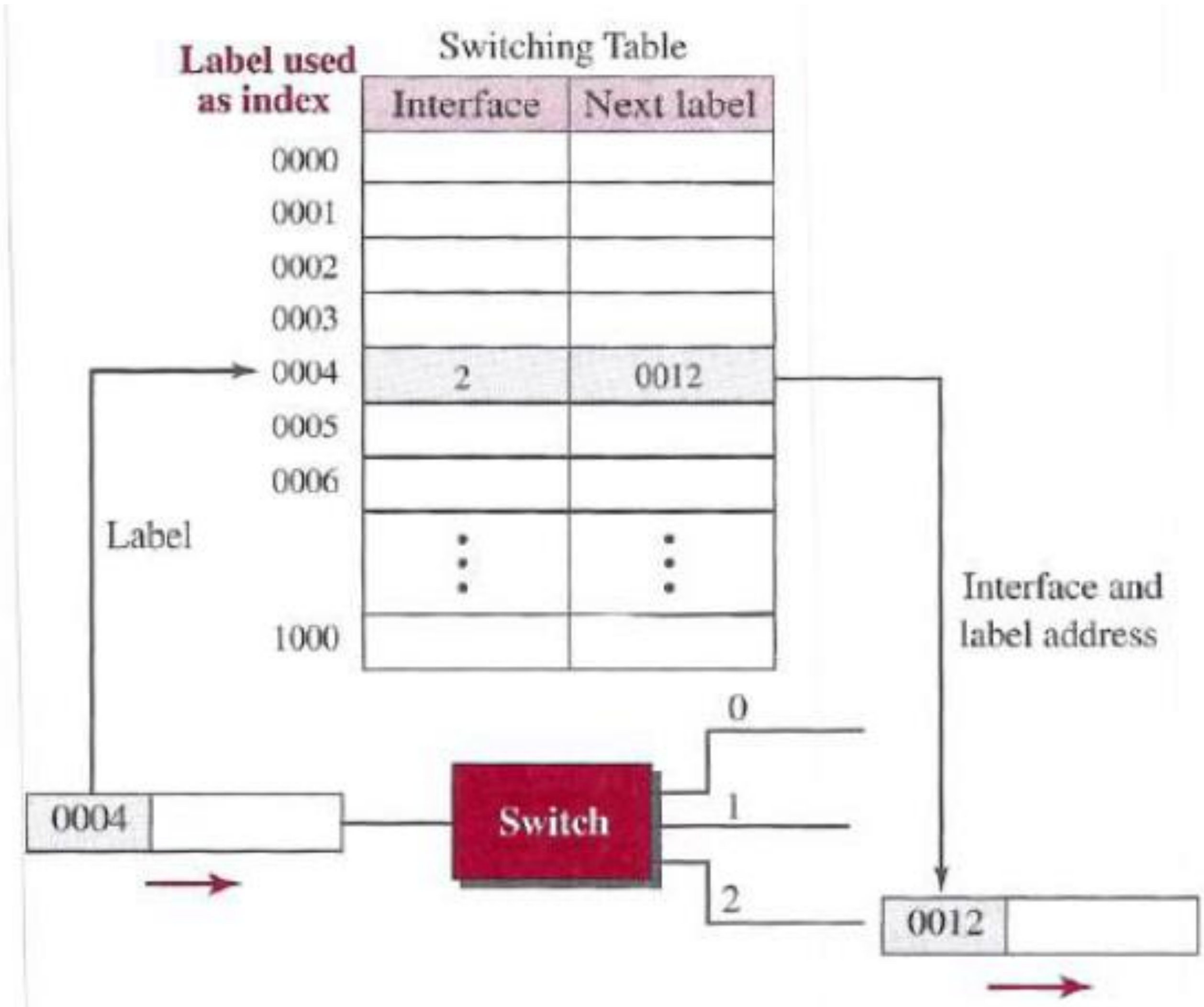


Table for Router R1

Network address/mask	*Next hop*	*Interface*
180.70.65.192/**26**	—	m2
180.70.65.128/**25**	—	m0
201.4.22.0/**24**	—	m3
201.4.16.0/**22**	—	m1
Default	180.70.65.200	m2

Forwarding (by Label)



Thanks!