Computer Networks (CS F303)

Virendra Singh Shekhawat
Department of Computer Science and Information Systems

BITS Pilani
Pilani Campus

BITS Pilani
Pilani Campus

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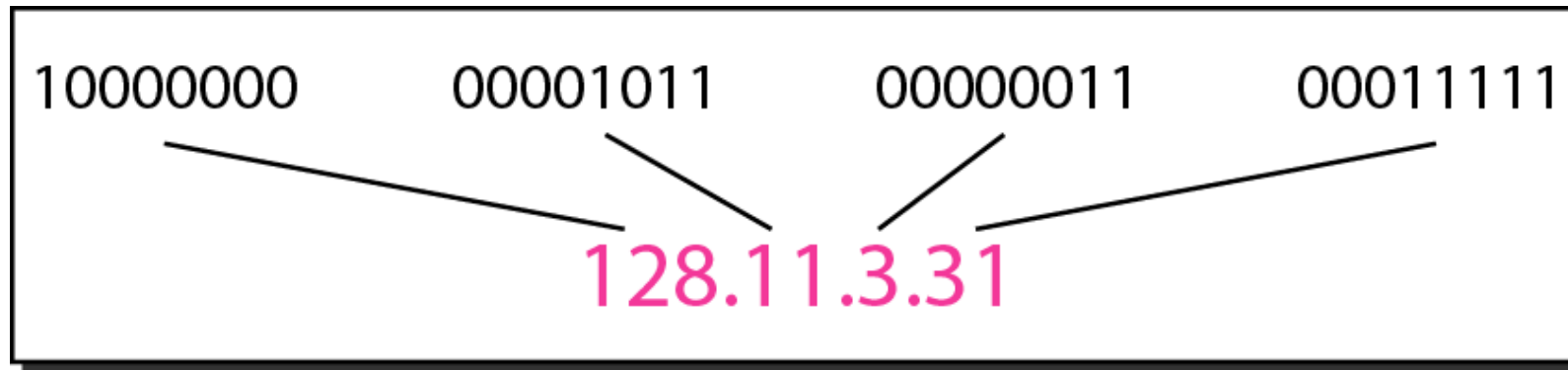**Module-4 <Network Layer>**

Agenda

- Datagram Forwarding

- Longest Prefix Matching

- IP Addressing
  - Hierarchical Addressing
  - Subnetting

IPv4 Addressing

- An IPv4 address is a 32-bit address

- Uniquely and universally defines the connection of a device (for example, a computer or a router) to the Internet.

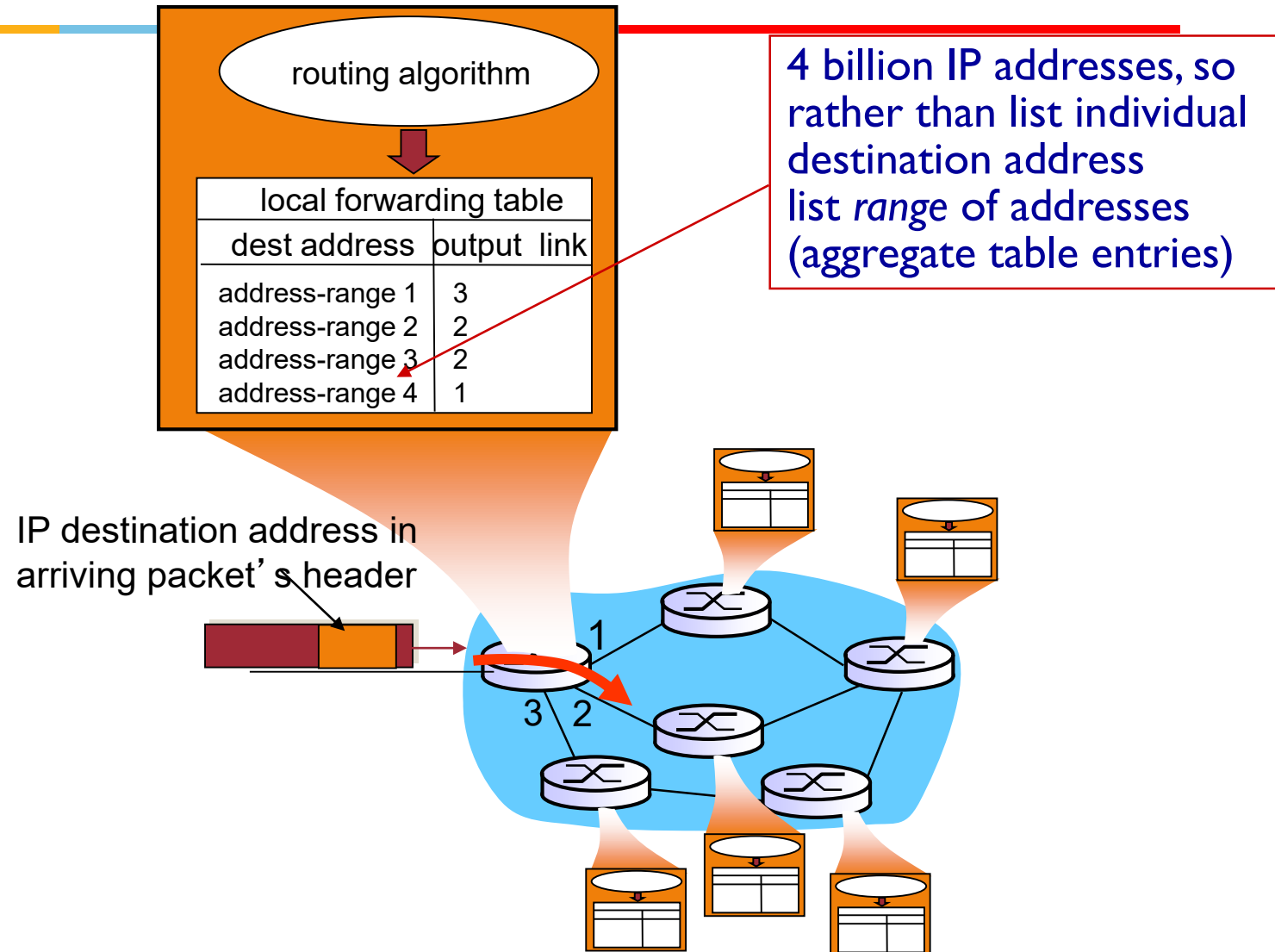- The address space of IPv4 is 2^{32} or 4,294,967,296

Datagram Forwarding Table

routing algorithm

local forwarding table	
dest address	output link
address-range 1	3
address-range 2	2
address-range 3	2
address-range 4	1

4 billion IP addresses, so rather than list individual destination address
list *range* of addresses (aggregate table entries)

IP destination address in arriving packet's header

1

3   2

Forwarding Table

Destination Address Range	Link Interface
11001000 00010111 00010000 00000000 through 11001000 00010111 00010111 11111111	0
11001000 00010111 00011000 00000000 through 11001000 00010111 00011000 11111111	1
11001000 00010111 00011001 00000000 through 11001000 00010111 00011111 11111111	2
otherwise	3

Longest prefix matching

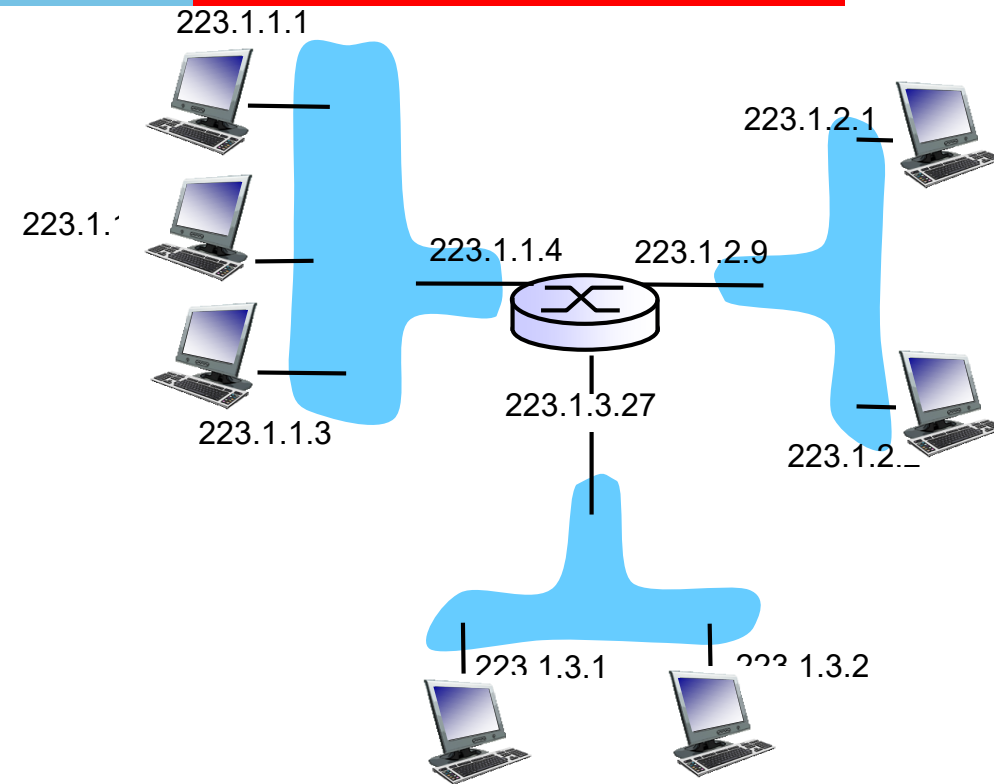| Prefix Match	Link Interface
11001000 00010111 00010	0
11001000 00010111 00011000	1
11001000 00010111 00011	2
otherwise	3

Examples

DA: 11001000 00010111 00010110 10100001   Which interface?

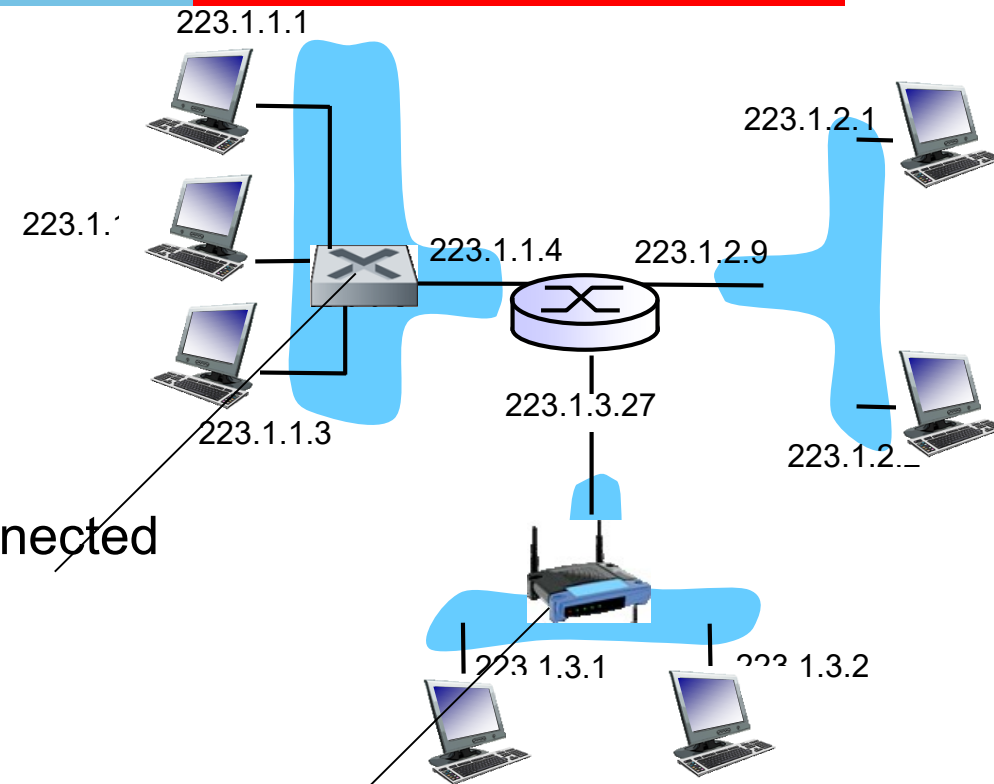DA: 11001000 00010111 00011000 10101010   Which interface?

IP Addressing [.1]

223.1.1.1

223.1.2.1

223.1.1

223.1.1.4   223.1.2.9

223.1.3.27

223.1.1.3

223.1.2._

223.1.3.1   223.1.3.2

223.1.1.1 = 11011111 00000001 00000001 00000001

223   1   1   1

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Q: How are interfaces actually connected?

223.1.1.1

223.1.2.1

223.1.1

223.1.1.4   223.1.2.9

223.1.1.3

223.1.3.27

223.1.2.

wired Ethernet interfaces connected
by Ethernet switches

223.1.3.1   223.1.3.2

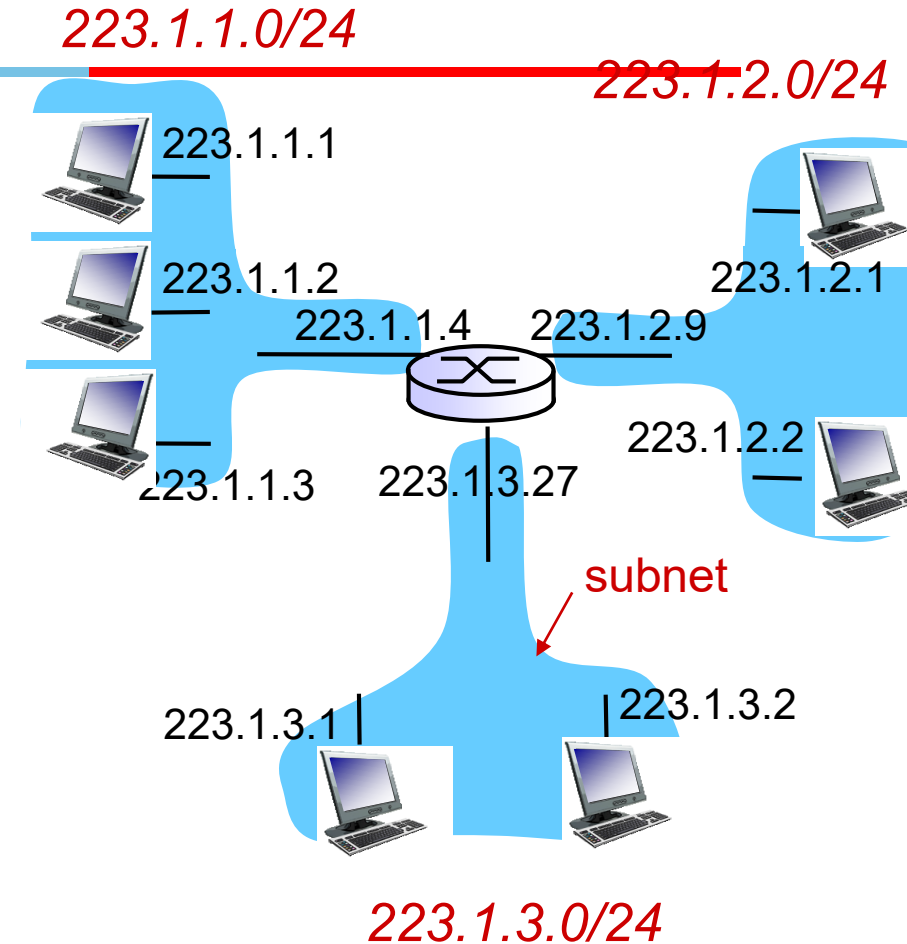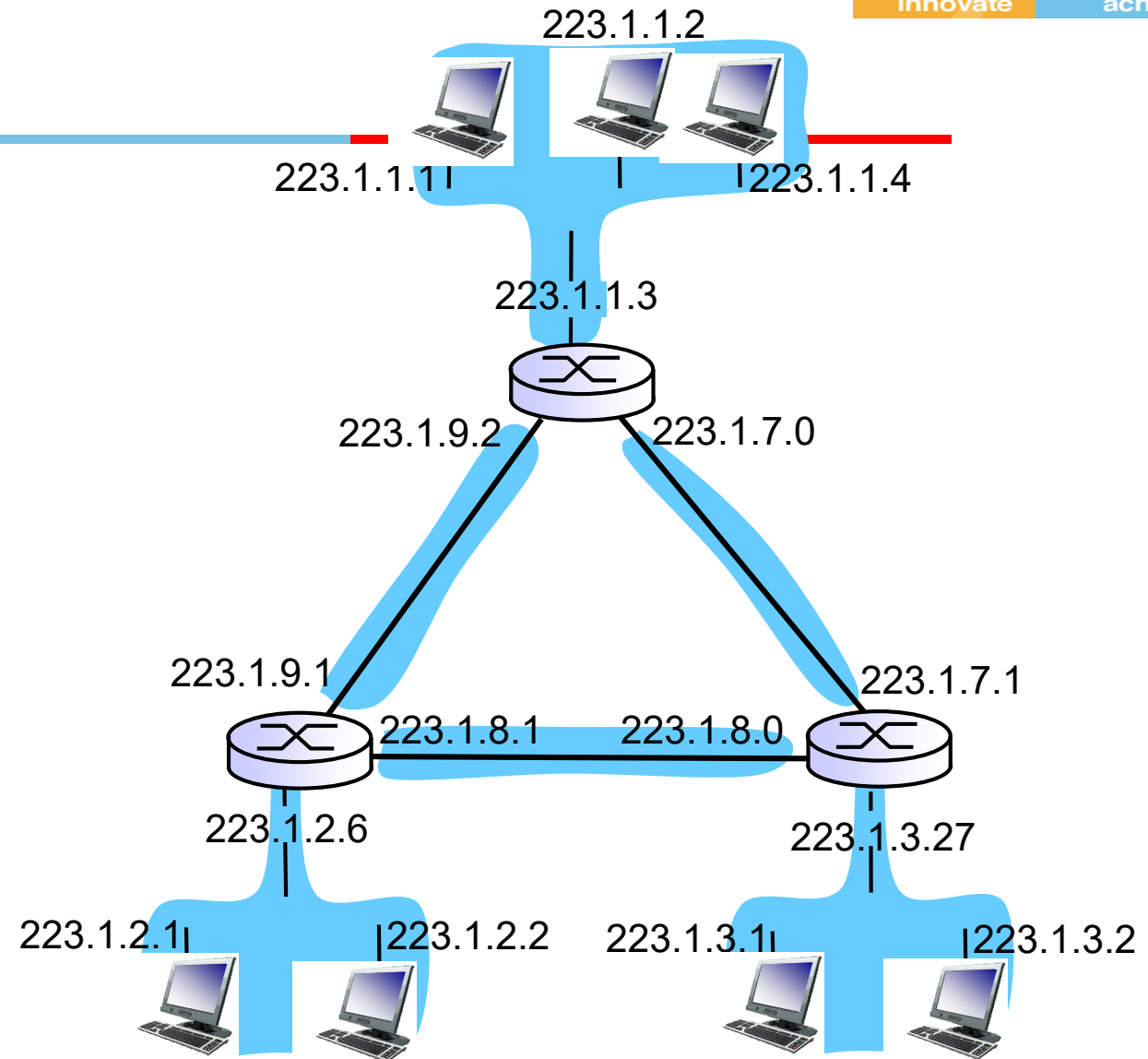wireless WiFi interfaces connected
by WiFi base station

Subnets

- IP address:
  - Subnet part - high order bits
  - Host part - low order bits

- *What's a subnet ?*
  - Device interfaces with same subnet part of IP address
  - Can physically reach each other *without intervening router*

223.1.1.1

223.1.1.2

223.1.1.4

223.1.2.9

223.1.2.1

223.1.2.2

223.1.1.3

223.1.3.27

subnet

223.1.3.1

223.1.3.2

Subnets: Subnet Mask

223.1.1.0/24

223.1.2.0/24

223.1.1.1

223.1.1.2

223.1.1.4   223.1.2.9

223.1.2.1

223.1.1.3   223.1.3.27

223.1.2.2

subnet

223.1.3.1   223.1.3.2

223.1.3.0/24

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Subnets

223.1.1.2

223.1.1.1   223.1.1.4

223.1.1.3

223.1.9.2   223.1.7.0

223.1.9.1   223.1.7.1

223.1.8.1   223.1.8.0

223.1.2.6   223.1.3.27

223.1.2.1   223.1.2.2   223.1.3.1   223.1.3.2
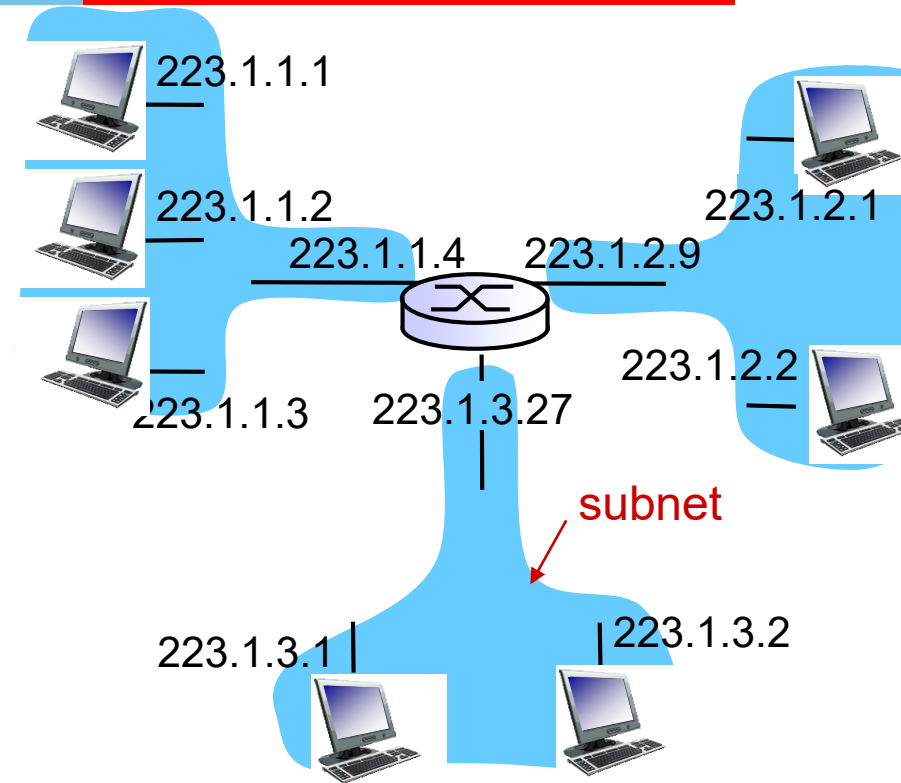
Example: Subnetting

ISP's block   11001000 00010111 00010000 00000000   200.23.16.0/20

Organization 0   11001000 00010111 00010000 00000000   200.23.16.0/23
Organization 1   11001000 00010111 00010010 00000000   200.23.18.0/23
Organization 2   11001000 00010111 00010100 00000000   200.23.20.0/23
    ...   .
Organization 7   11001000 00010111 00011110 00000000   200.23.30.0/23
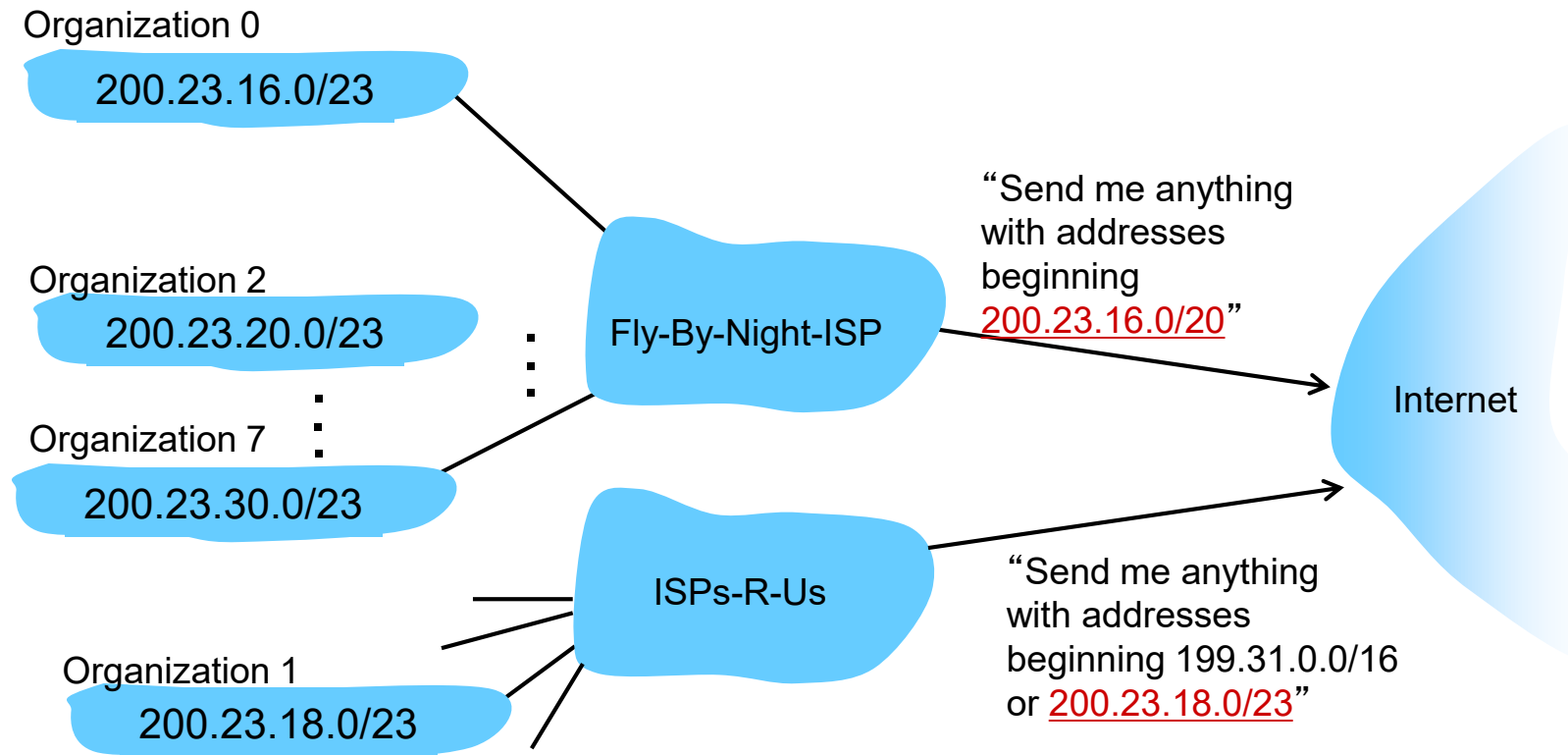
Hierarchical Addressing: Route Aggregation

Hierarchical addressing allows efficient advertisement of routing information
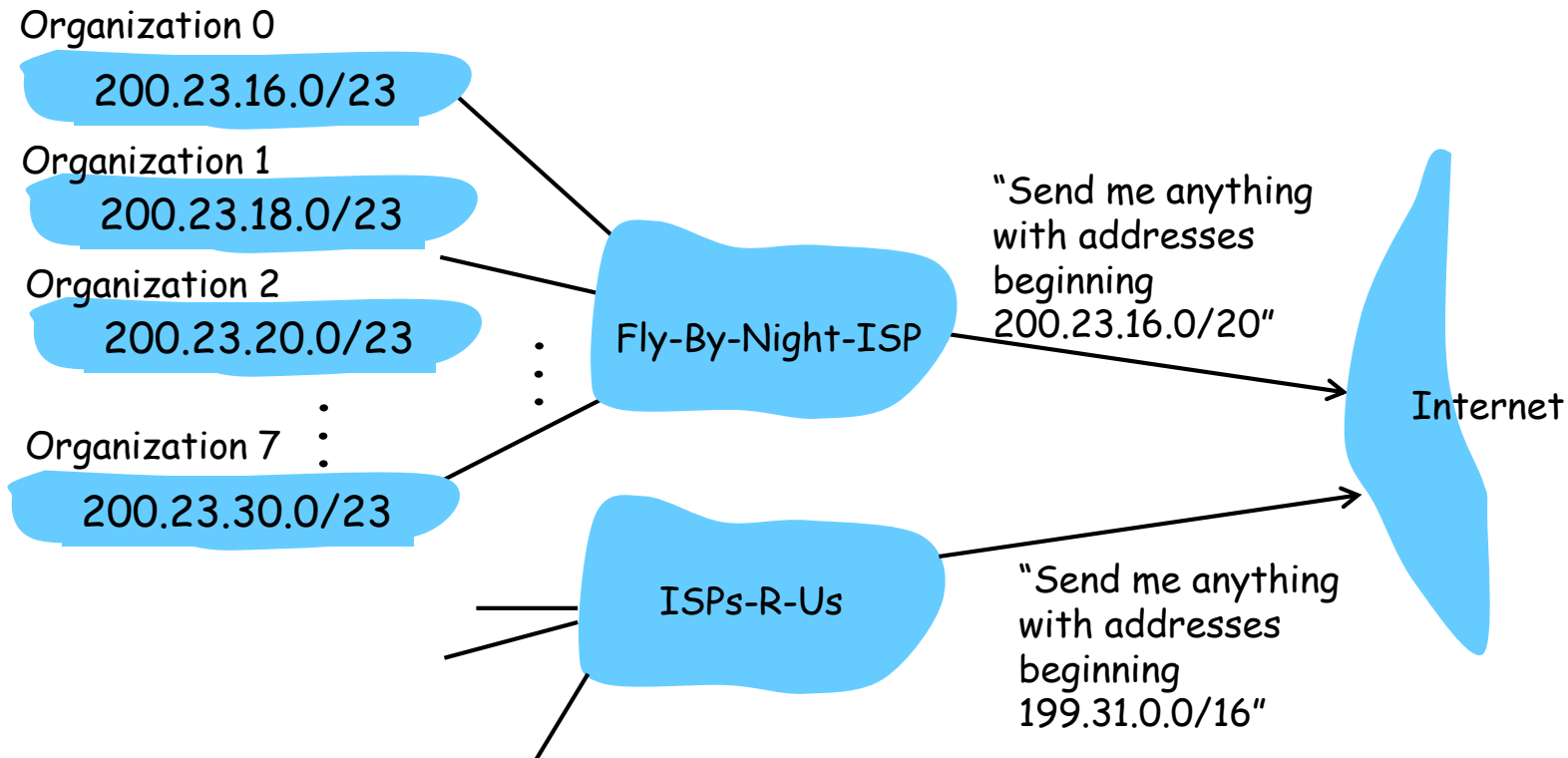
Hierarchical Addressing: More Specific Routes

ISPs-R-Us has a more specific route to Organization 1

Organization 0
200.23.16.0/23

Organization 2
200.23.20.0/23

Organization 7
200.23.30.0/23

Fly-By-Night-ISP

"Send me anything with addresses beginning 200.23.16.0/20"

Internet

ISPs-R-Us

"Send me anything with addresses beginning 199.31.0.0/16 or 200.23.18.0/23"

Organization 1
200.23.18.0/23

15

Class full Addressing

	First byte	Second byte	Third byte	Fourth byte
Class A	0			
Class B	10			
Class C	110			
Class D	1110			
Class E	1111			

a. Binary notation

	First byte	Second byte	Third byte	Fourth byte
Class A	0–127			
Class B	128–191			
Class C	192–223			
Class D	224–239			
Class E	240–255			

b. Dotted-decimal notation

Find the class of each address:
- a. **0**0000001 00001011 00001011 11101111
- b. **110**00001 10000011 00011011 11111111
- c. **14**.23.120.8
- d. **252**.5.15.111

Exercise

- An organization is given a block 17.12.14.0/26

  – How many total addresses in the block???

  – Range of addresses???

  – Organization has Four departments. Wants to divide the addresses into four sub-blocks of equal size.

 – Address of each subnet???

Example: Different Size Subnets

- Organization has three departments. Wants to divide the addresses into three sub-blocks of 32, 16, 16.

- Subnet mask for each subnet???

- Range of addresses in each subnet???
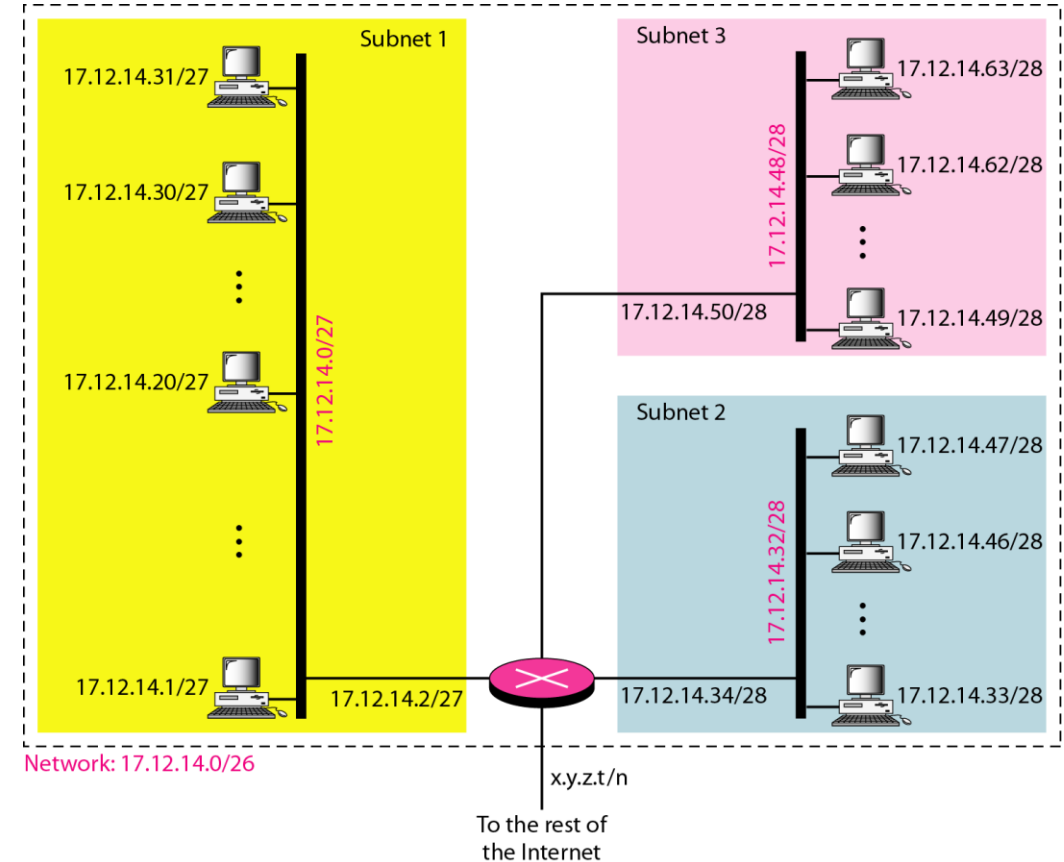
What is Inside a Router?

- ## Forwarding/Switching a datagram
  - The actual transfer of datagram from a router's incoming links to the appropriate outgoing links at the router
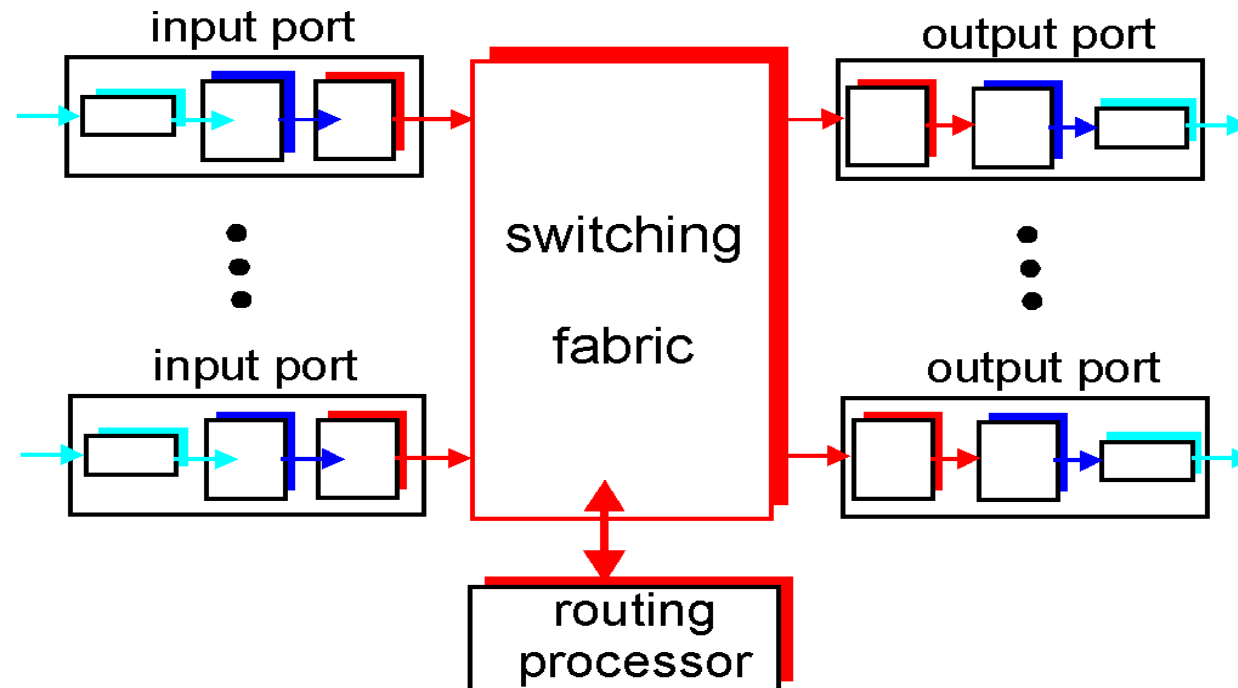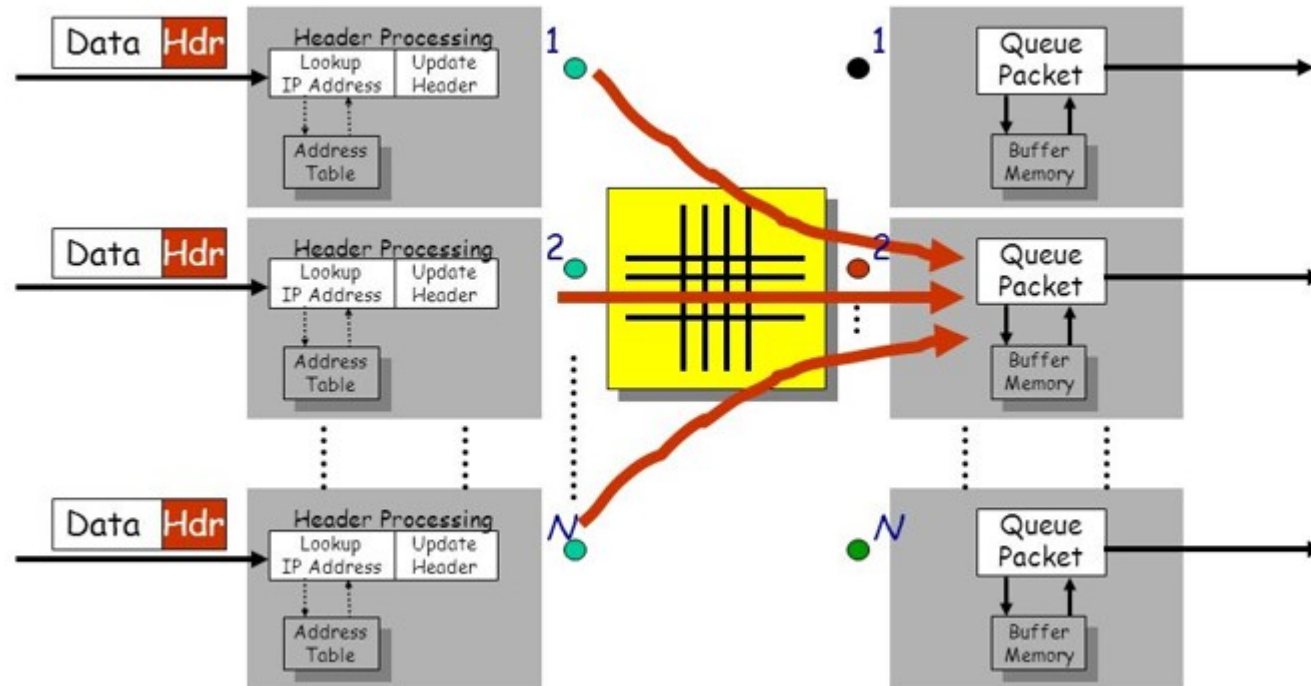
Router architecture overview

Two key router functions:

❖ Run routing algorithms/protocol (RIP, OSPF, BGP)
❖ *Forwarding* datagrams from incoming to outgoing link

forwarding tables computed, pushed to input ports

routing processor

routing, management control plane (software)

forwarding data plane (hardware)

high-seed switching fabric

router input ports

router output ports

Input Port Functions

Physical layer:
bit-level reception

Data link layer:
e.g., Ethernet

Decentralized switching:
- Given datagram dest., lookup output port using forwarding table in input port memory
- **Goal: complete input port processing at 'line speed'**
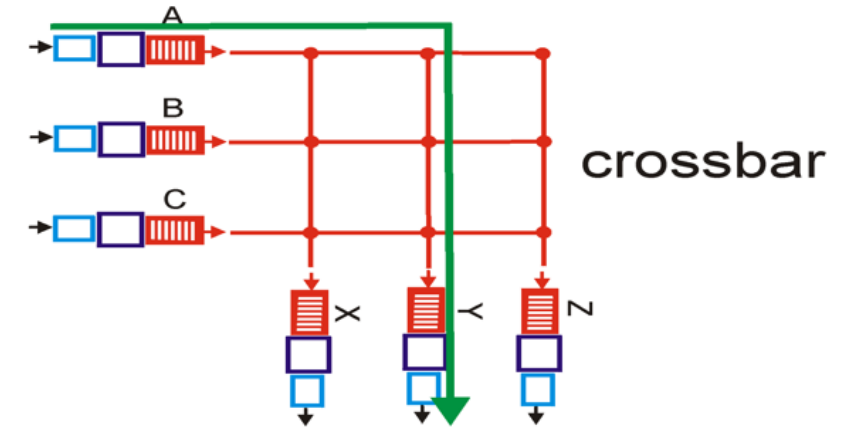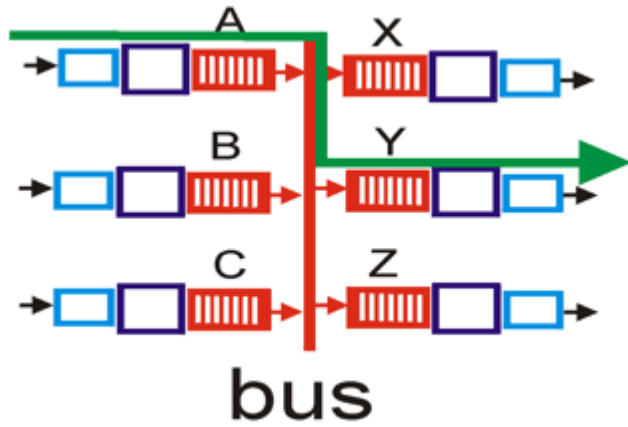
Router Architecture Overview

Switching Fabric [.1]

- **Switching rate**: rate at which packets can be transferred from inputs to outputs
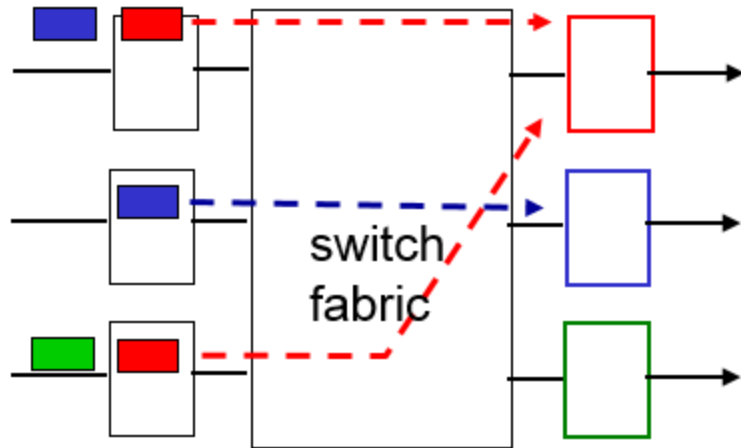 - N inputs: switching rate N times line rate is desirable
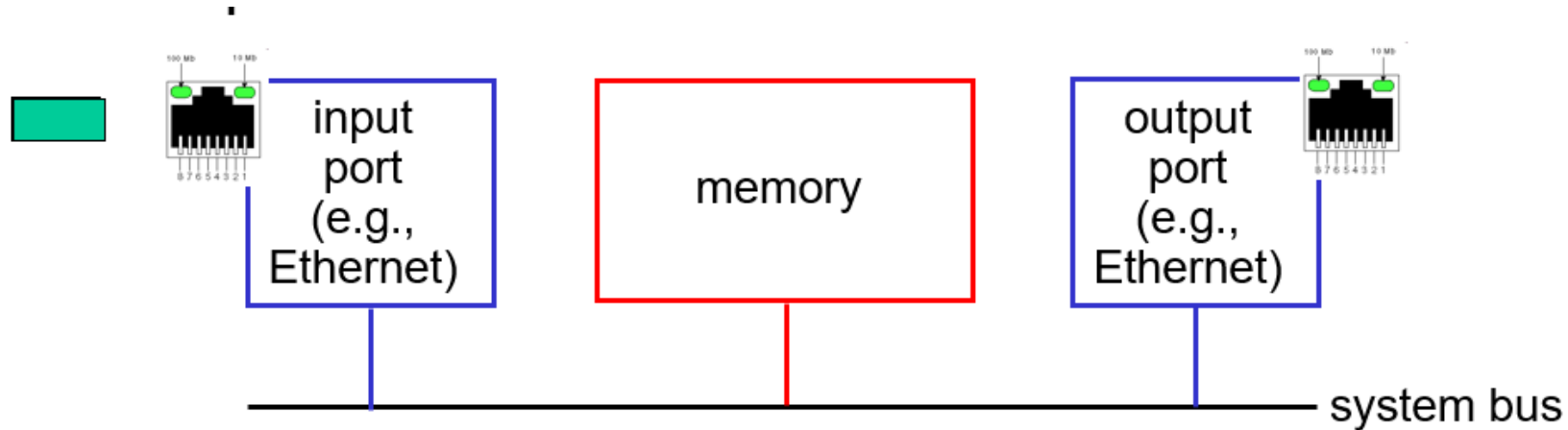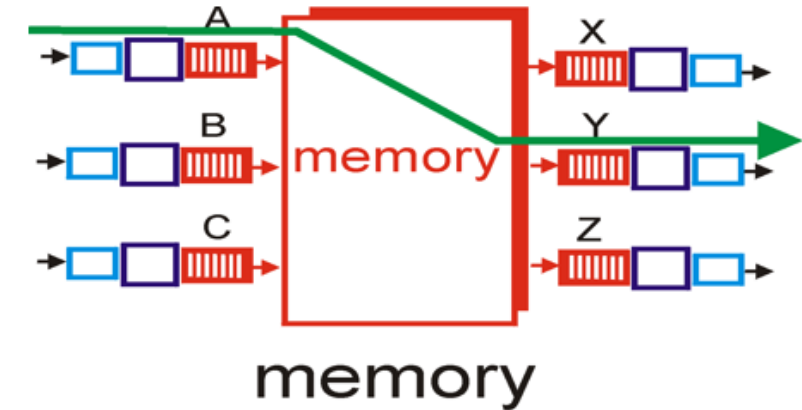
Switching Fabric [..2]

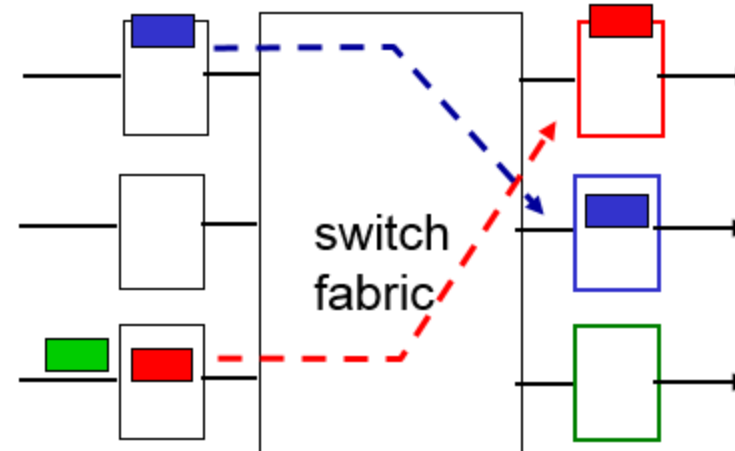
bus

crossbar

Input Ports

Queuing: Fabric slower than input ports combined

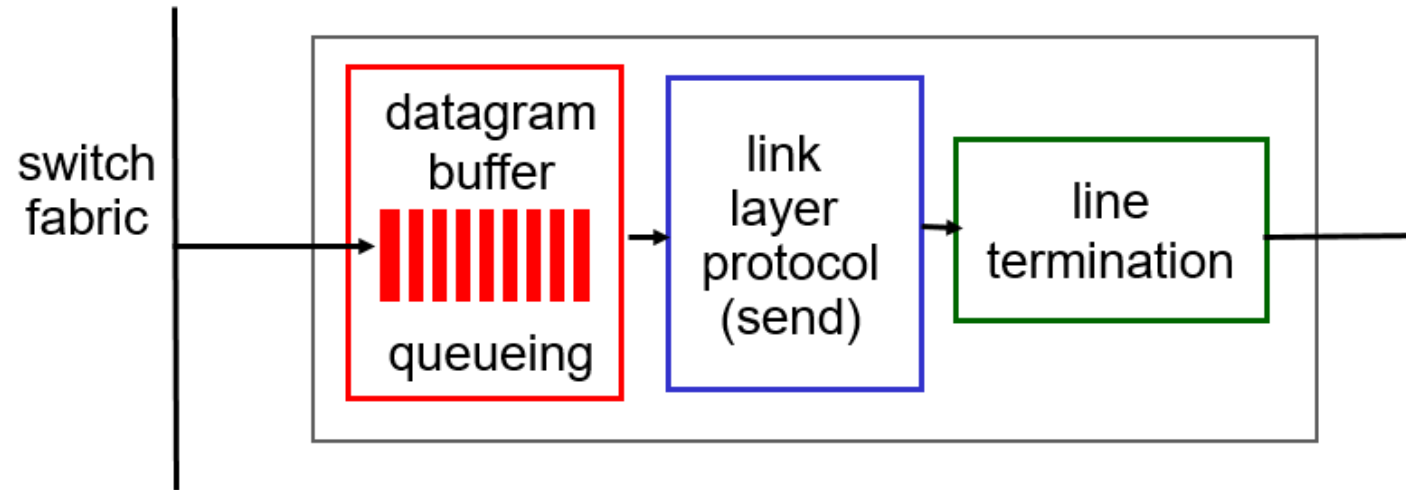output port contention:
only one red datagram can be transferred.
lower red packet is blocked

one packet time later:
green packet experiences HOL blocking

Head Of Line (HOL) Blocking: queued datagram at front of queue prevents others in queue from moving forward
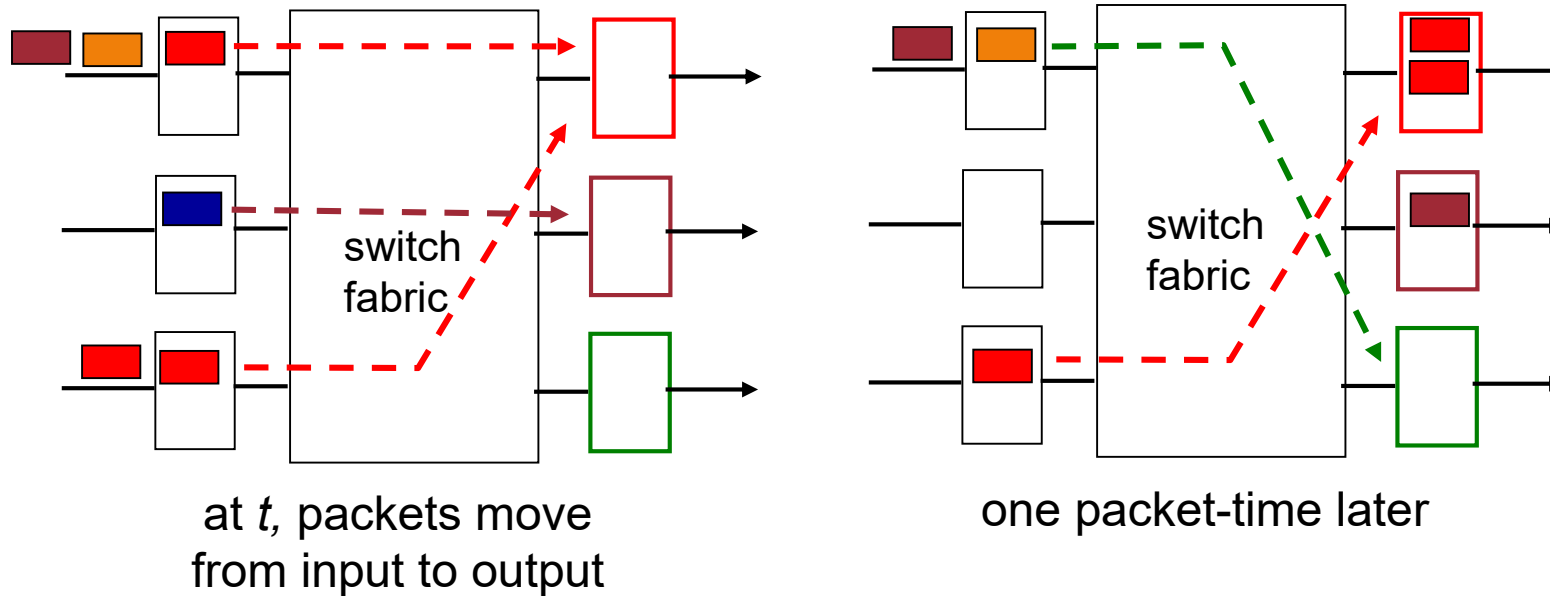
Output Ports

- *Buffering* required when datagrams arrive from fabric faster than the transmission rate
- *Scheduling discipline* chooses among queued datagrams for transmission (FIFO, FQ, WFQ, RED)
- *Queuing (delay) and loss due to output port buffer overflow!*

Output Port Queuing

Suppose R_{switch} is N times faster than R_{line}

at *t,* packets move
from input to output

one packet-time later

Thank You!