제18강
네트워크 개요, 라우터 구조

Computer Networking: A Top Down Approach

컴퓨터 네트워크
(2019년 1학기)

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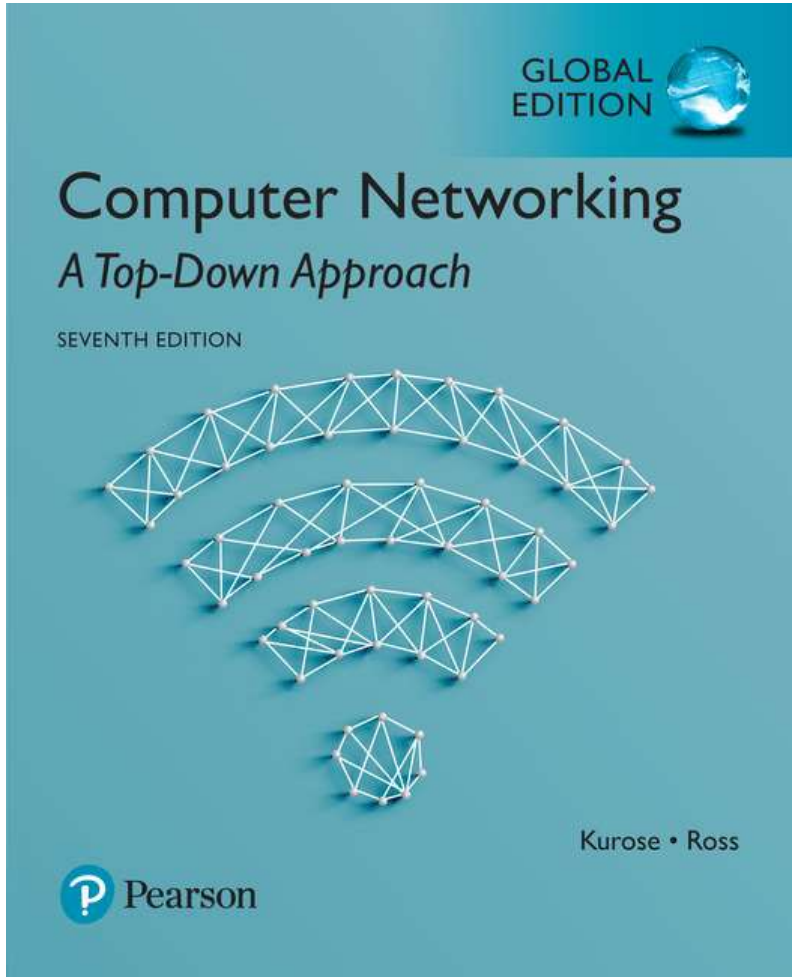
컴퓨터공학부



Pre-study Test :

1) 네트워크 계층의 역할이 아닌 것은?

① 패킷 전달 경로 결정
② 패킷 전달
③ TCP 세그먼트 인캡슐레이션(encapsulation)
④ 패킷 전달 순서 보장

2) 네트워크에서 패킷 전달을 책임지는 프로토콜은?

① IP
② ICMP
③ Routing Protocol
④ ARP

3) 다음 중 인터넷에 대한 설명 중 맞는 것은?

① 전송속도를 보장한다.
② 오류 복구를 보장한다.
③ 전달 순서를 보장한다.
④ 패킷 오류 검출을 보장한다.

4) 라우터가 패킷의 전송경로를 선택할 때 사용하는 주소 정보는?

① 출발지 IP 주소
② 목적지 IP 주소
③ 출발지 MAC 주소
④ 목적지 MAC 주소

5) 다음과 같은 라우팅 테이블을 사용한다. 목적지 주소가
11001000 00010111 00010110 10100001 일 때 선택하는 링크는?

① 0
② 1
③ 2
④ 3

Destination Address Range	Link interface
11001000 00010111 00010*** *********	0
11001000 00010111 00011000 *********	1
11001000 00010111 00011*** *********	2
otherwise	3

6) 링크 전송속도가 1Gbps인 라우터에서 서로 다른 가중치(w1,w2,w3)를 가진 3개의 큐를 사용하고 있다. w1가 20%일 때 해당 큐에 할당되는 최소 대역폭과 최대 대역폭은?

① 0Mbps, 200Mbps
② 0Mbps, 1Gbps
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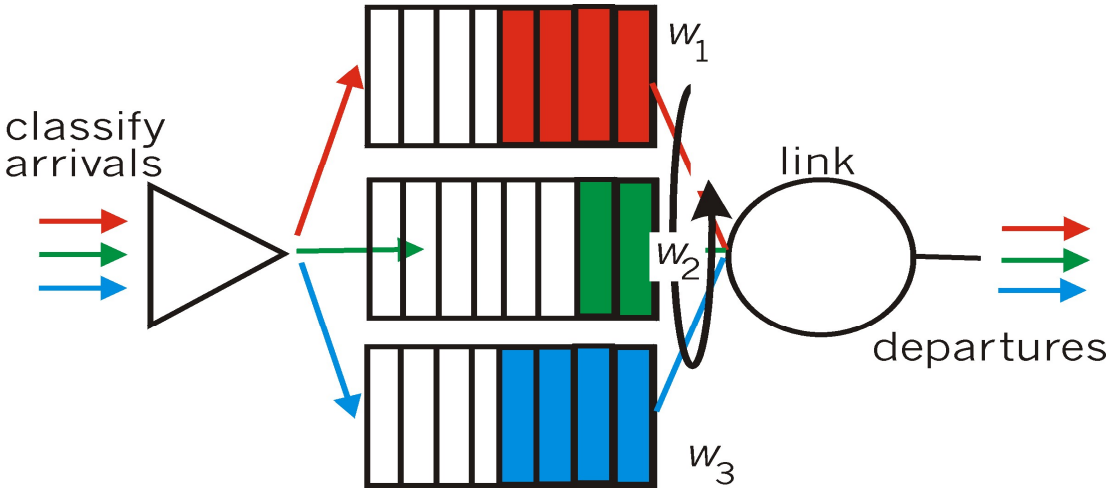


Chapter 4: outline

4.1 Overview of Network layer
- data plane
- control plane

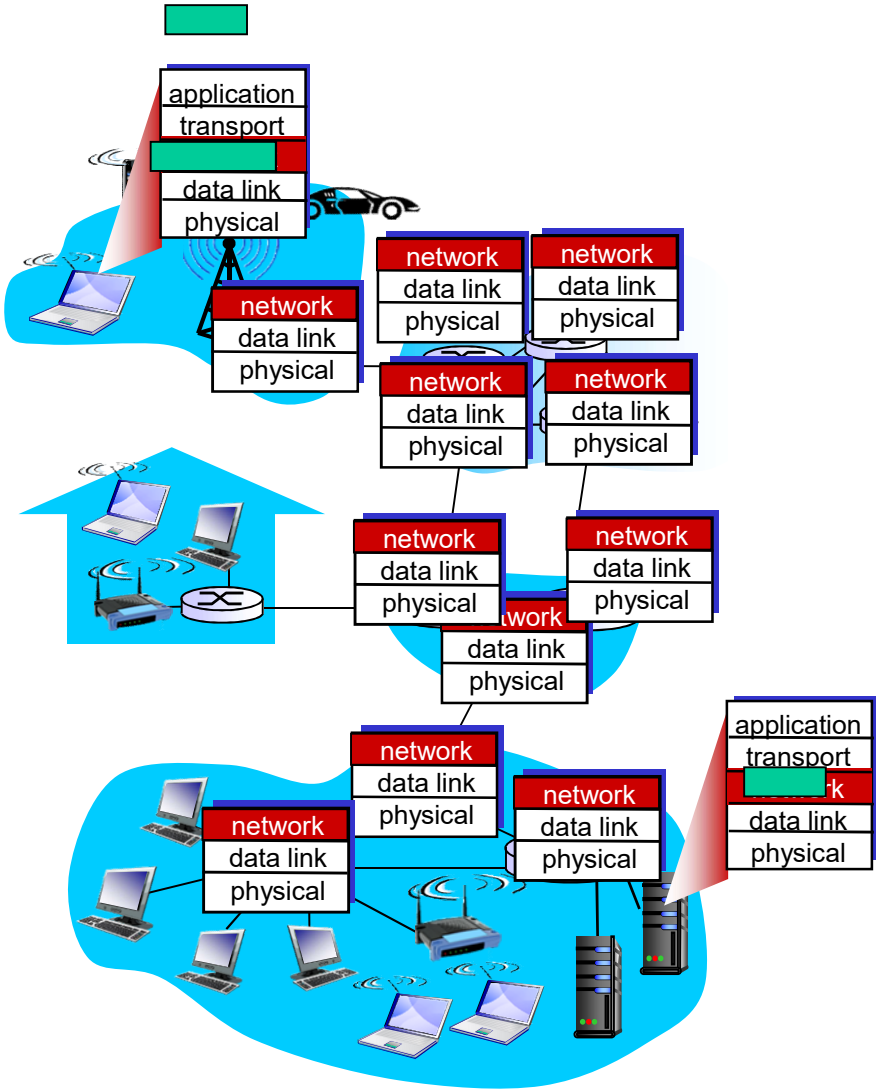
4.2 What's inside a router

4.3 IP: Internet Protocol
- datagram format
- fragmentation
- IPv4 addressing
- network address translation
- IPv6

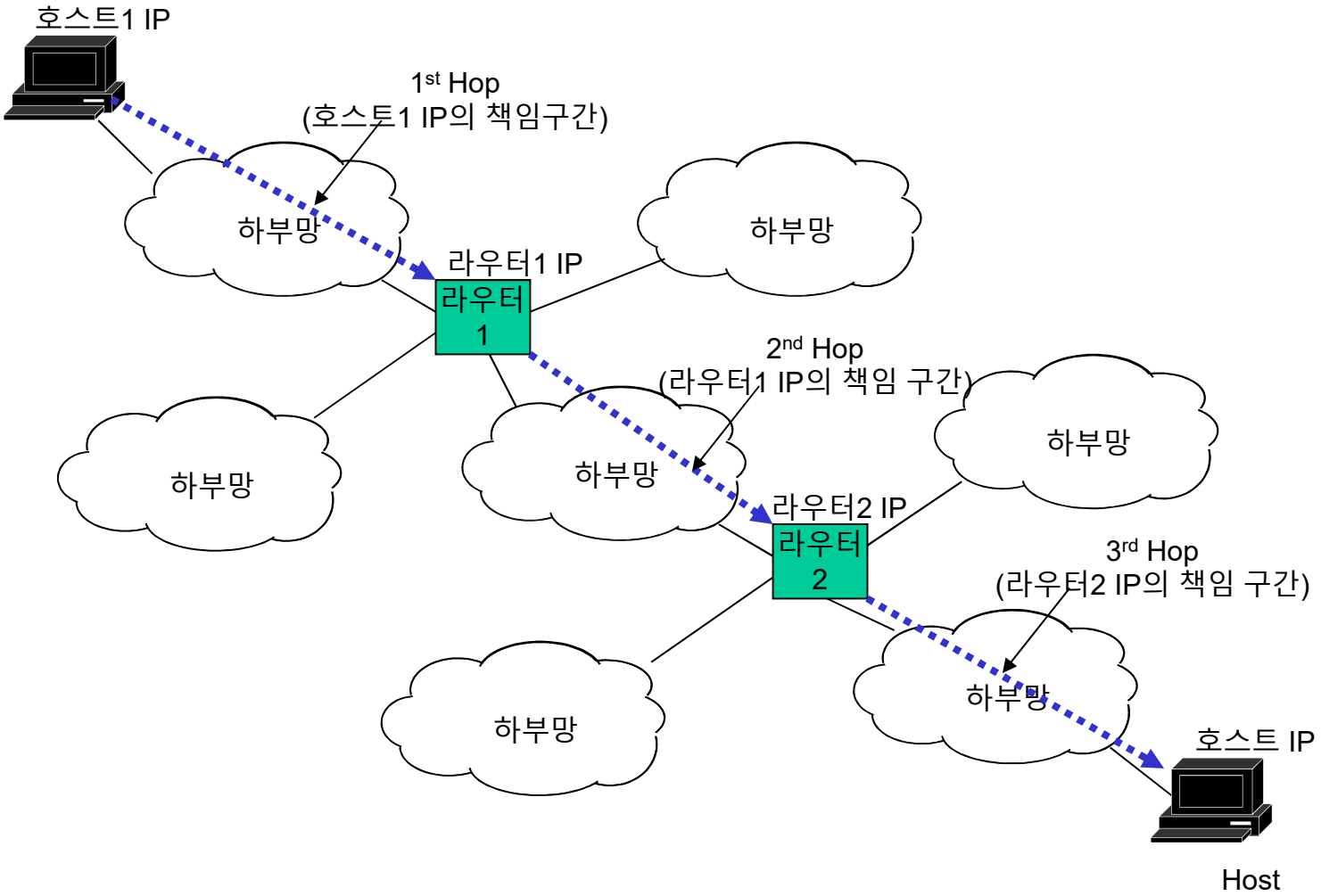
4.4 Generalized Forward and SDN
- match
- action
- OpenFlow examples of match-plus-action in action

Network layer

- transport segment from sending to receiving host
- on sending side encapsulates segments into datagrams
- on receiving side, delivers segments to transport layer
- network layer protocols in *every* host, router
- router examines header fields in all IP datagrams passing through it



Network layer



Two key network-layer functions

network-layer functions:

- *Forwarding(전달):* move packets from router's input to appropriate router output
- *Routing(라우팅):* determine route taken by packets from source to destination
  - *routing algorithms*

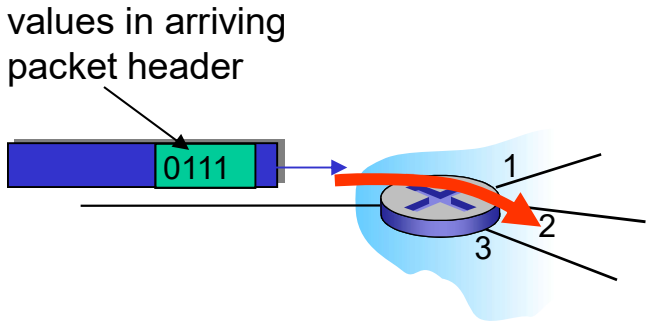
analogy: taking a trip

- *forwarding:* process of getting through single interchange
- *routing:* process of planning trip from source to destination

Network layer: data plane, control plane

Data plane

- local, per-router function
- determines how datagram arriving on router input port is forwarded to router output port
- forwarding function

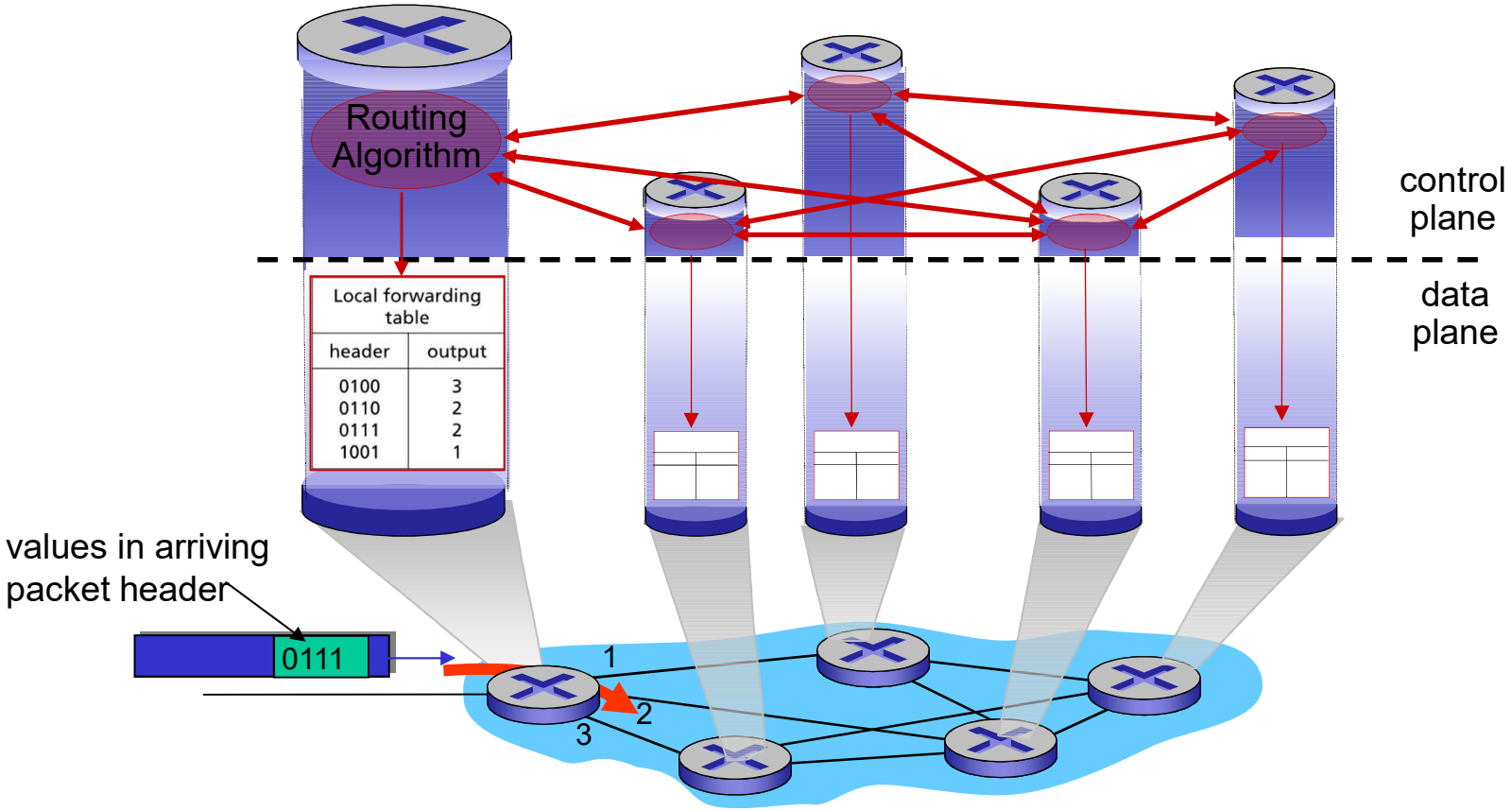


Control plane

- network-wide logic
- determines how datagram is routed among routers along end-end path from source host to destination host
- two control-plane approaches:
  - *traditional routing algorithms:* implemented in routers
  - *software-defined networking (SDN)*: implemented in (remote) servers

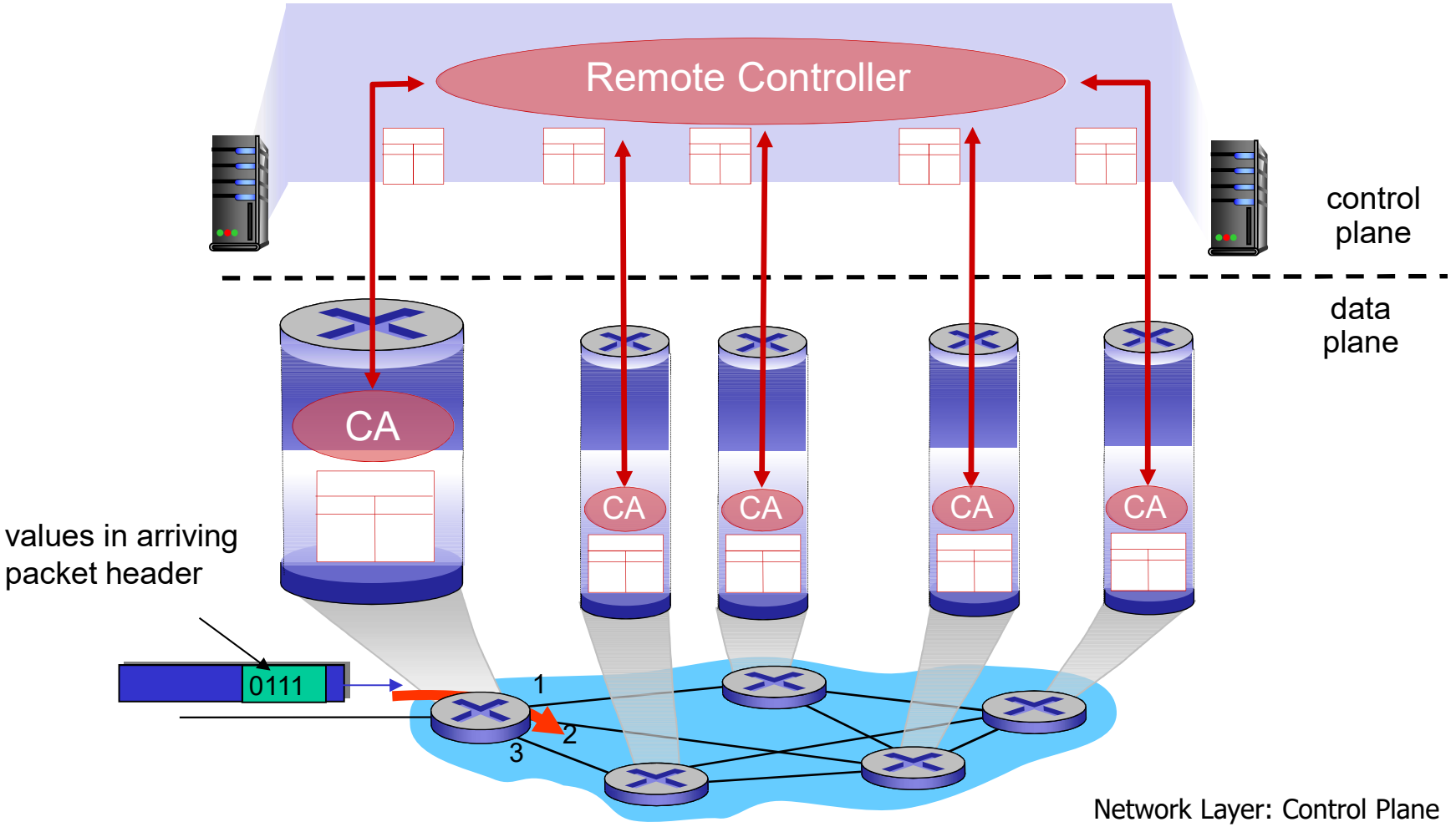
Per-router control plane

Individual routing algorithm components *in each and every router* interact in the control plane



Logically centralized control plane

A distinct (typically remote) controller interacts with local control agents (CAs)



Network layer service models:

Network Architecture	Service Model	Guarantees ?				Congestion feedback
		Bandwidth	Loss	Order	Timing	
Internet	best effort	none	no	no	no	no (inferred via loss)
ATM	CBR	constant rate	yes	yes	yes	no congestion
ATM	VBR	guaranteed rate	yes	yes	yes	no congestion
ATM	ABR	guaranteed minimum	no	yes	no	yes
ATM	UBR	none	no	yes	no	no

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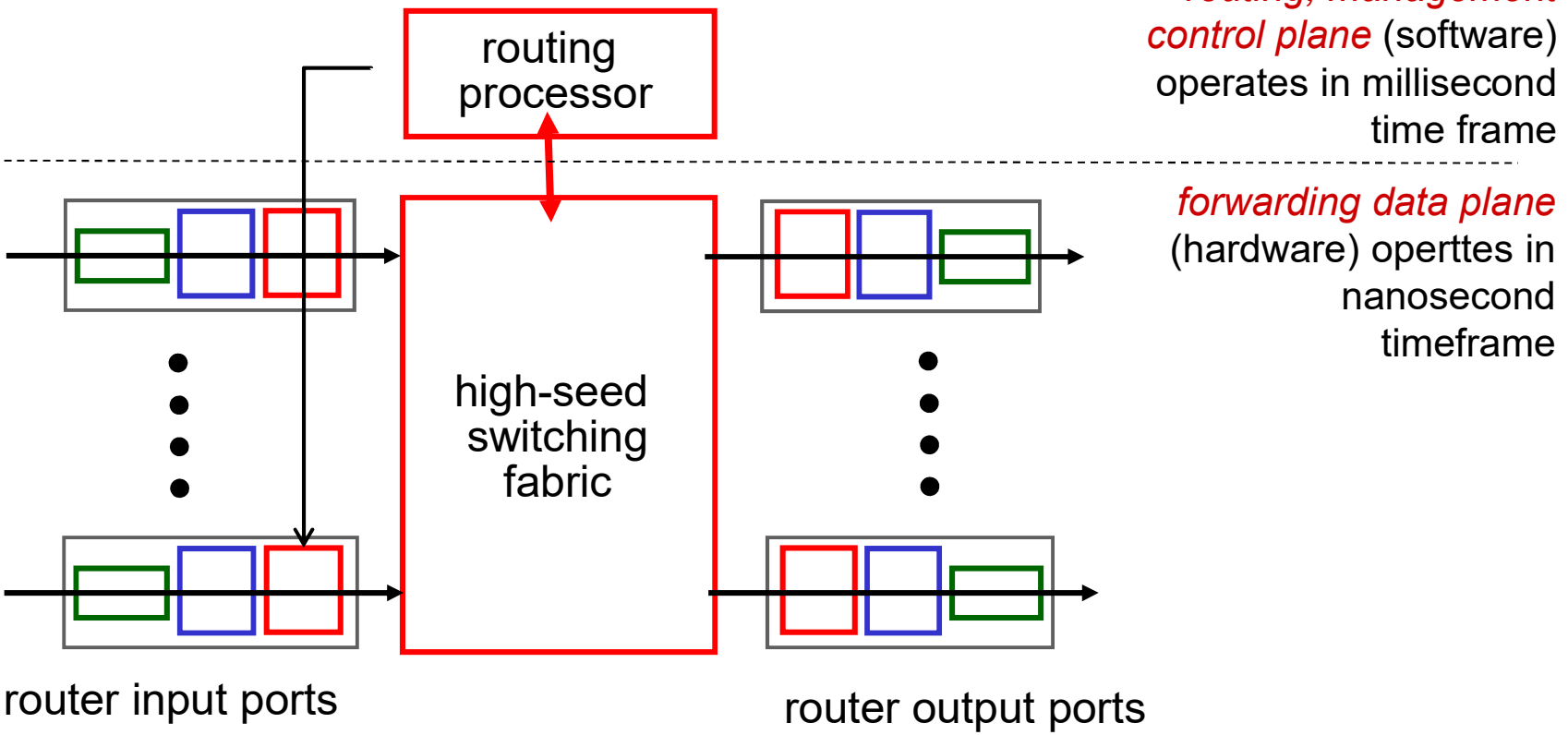
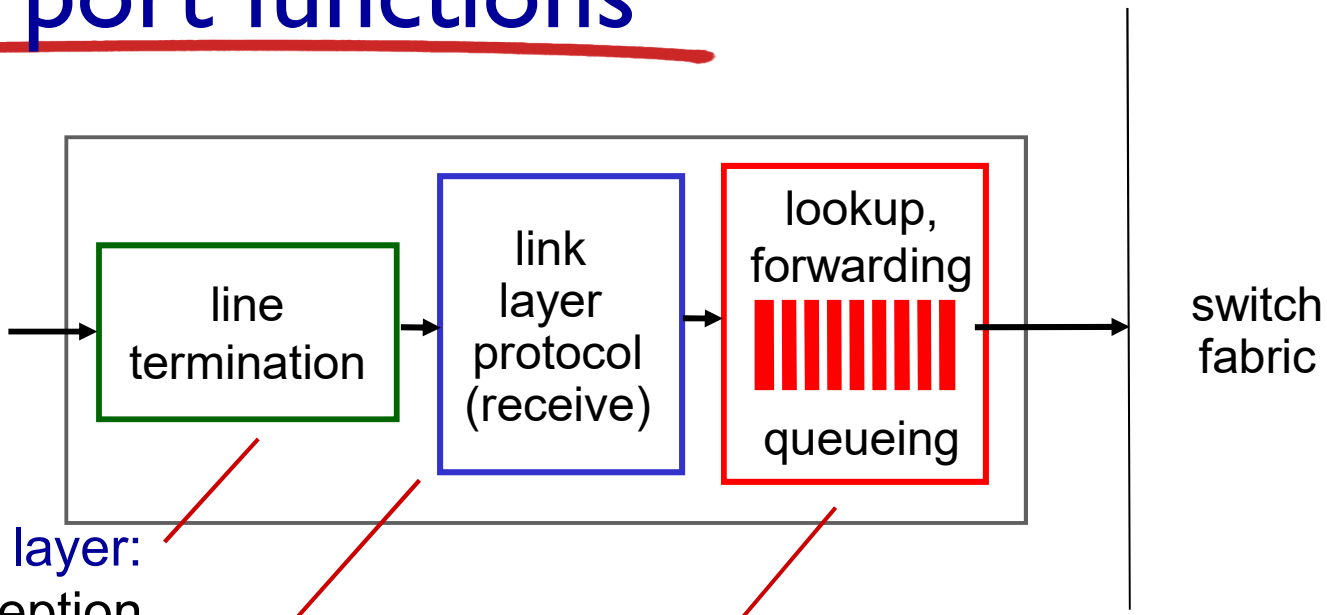
Router architecture overview

- high-level view of generic router architecture:



Input port functions



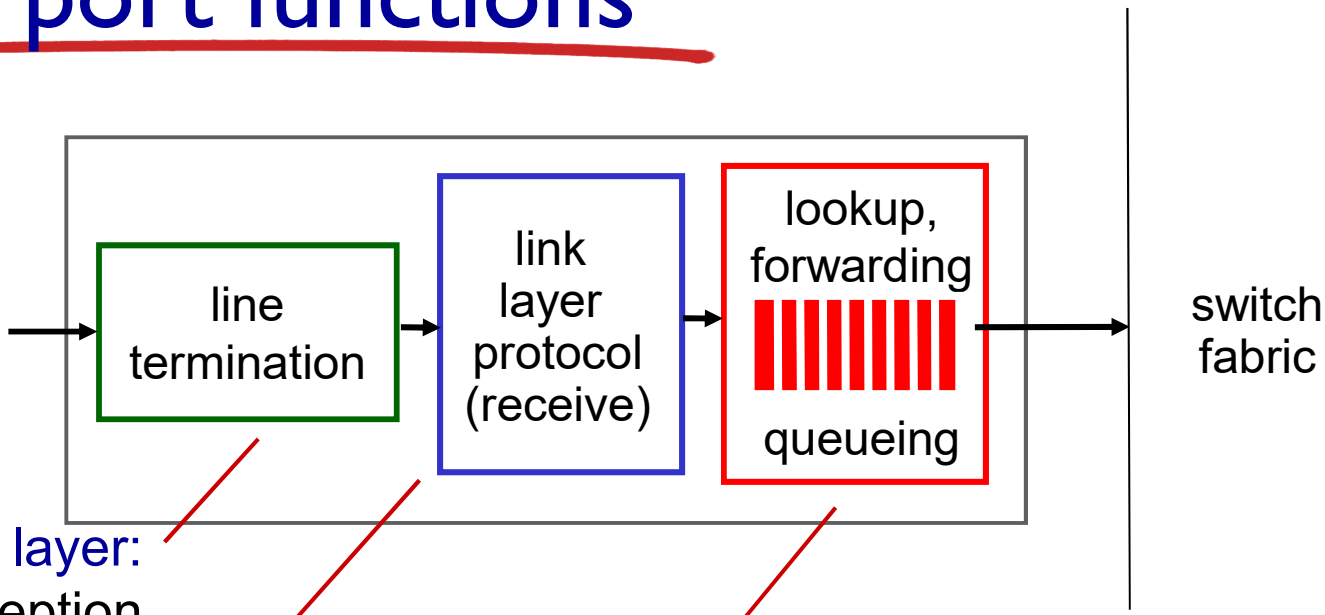
physical layer:
bit-level reception

data link layer:
e.g., Ethernet
see chapter 5

decentralized switching:

- using header field values, lookup output port using forwarding table in input port memory *("match plus action")*
- goal: complete input port processing at 'line speed'
- queuing: if datagrams arrive faster than forwarding rate into switch fabric

Input port functions



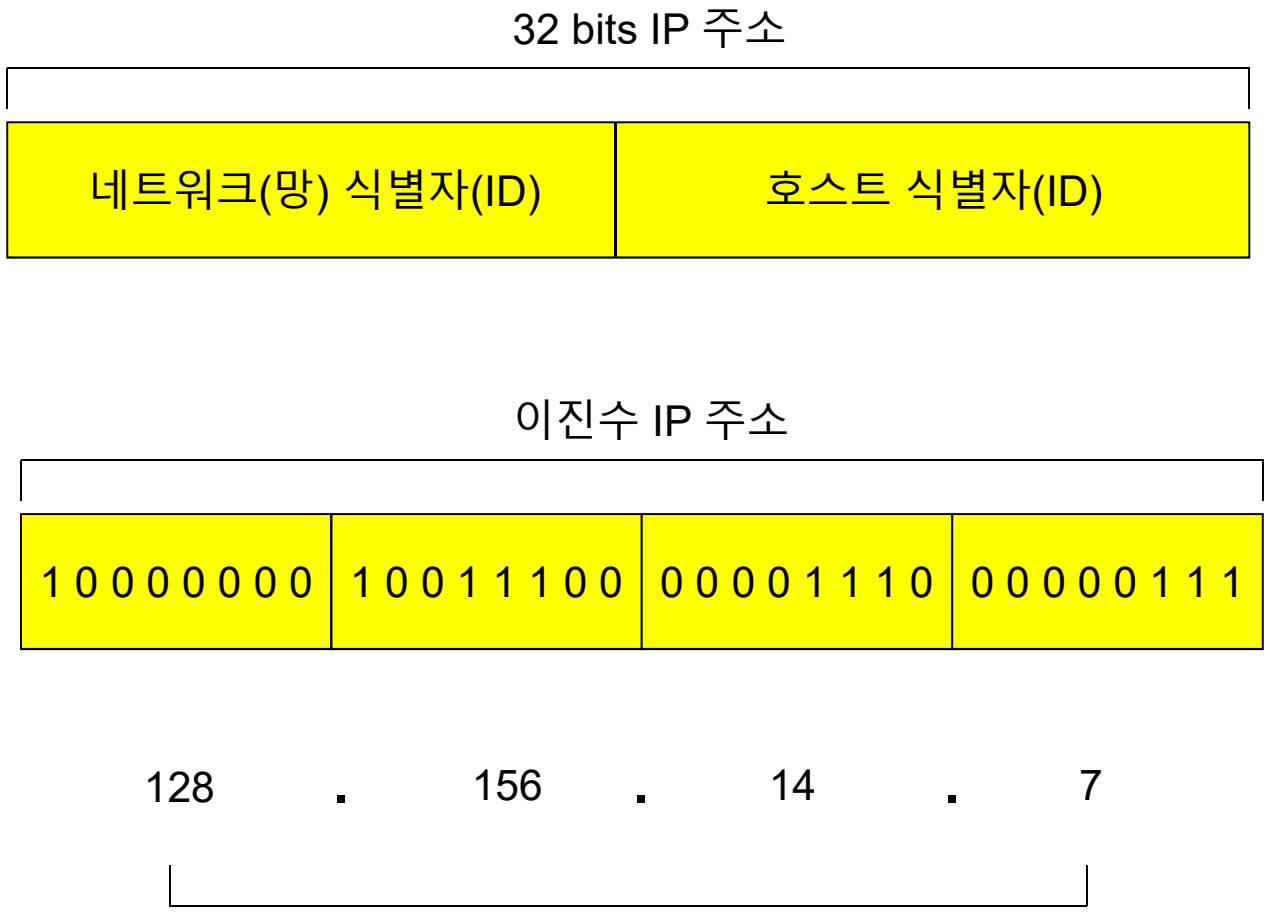
physical layer:
bit-level reception

data link layer:
e.g., Ethernet
see chapter 5

decentralized switching:

- using header field values, lookup output port using forwarding table in input port memory (*"match plus action"*)
- *destination-based forwarding:* forward based only on destination IP address (traditional)
- *generalized forwarding:* forward based on any set of header field values

IP 주소


32 bits IP 주소
네트워크(망) 식별자(ID)
호스트 식별자(ID)
이진수 IP 주소
1 0 0 0 0 0 0 0
1 0 0 1 1 1 0 0
0 0 0 0 1 1 1 0
0 0 0 0 0 1 1 1
128 . 156 . 14 . 7
십진수 점 표기법
(dotted decimal notation)

Destination-based forwarding

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

Q: but what happens if ranges don't divide up so nicely?

Longest prefix matching

longest prefix matching

when looking for forwarding table entry for given destination address, use *longest* address prefix that matches destination address.

Destination Address Range	Link interface
11001000 00010111 00010*** *********	0
11001000 00010111 00011000 *********	1
11001000 00010111 00011*** *********	2
otherwise	3

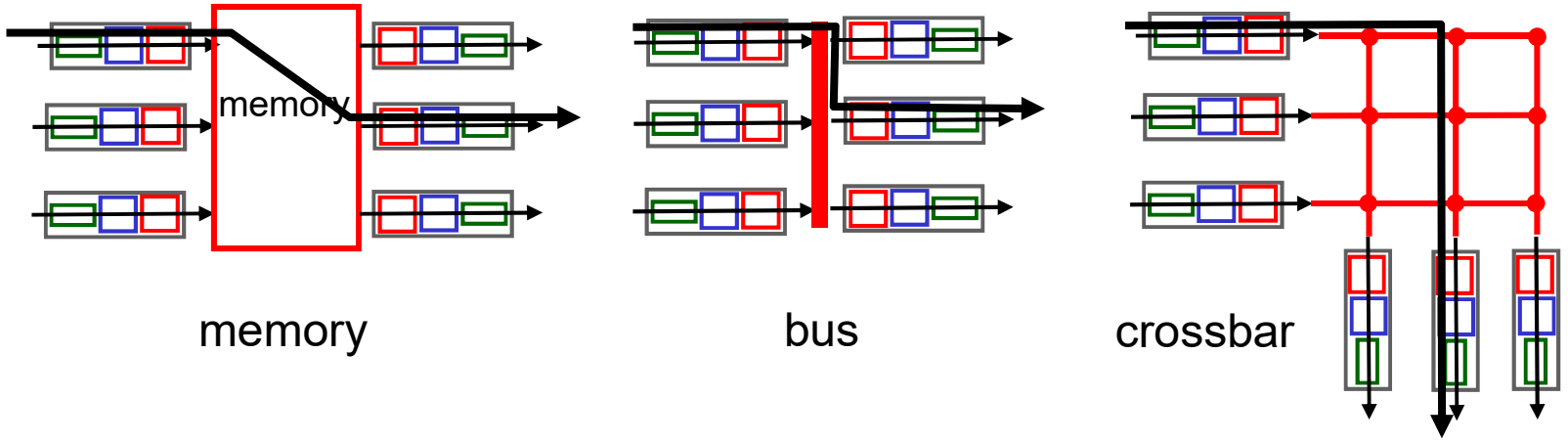
examples:

DA: 11001000 00010111 00010110 10100001 which interface?

DA: 11001000 00010111 00011000 10101010 which interface?

Switching fabrics

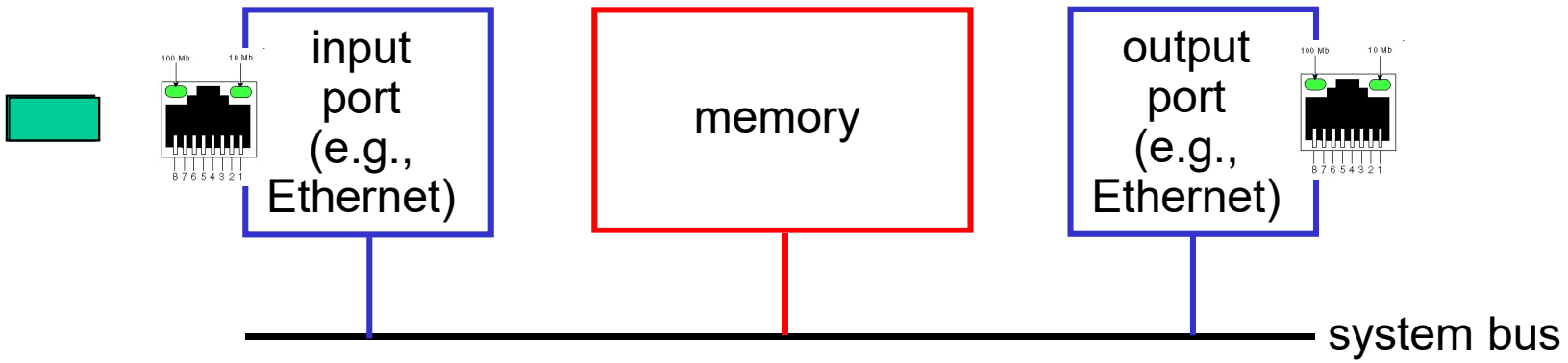
- transfer packet from input buffer to appropriate output buffer
- switching rate: rate at which packets can be transfer from inputs to outputs
  - often measured as multiple of input/output line rate
  - N inputs: switching rate N times line rate desirable
- three types of switching fabrics



Switching via memory

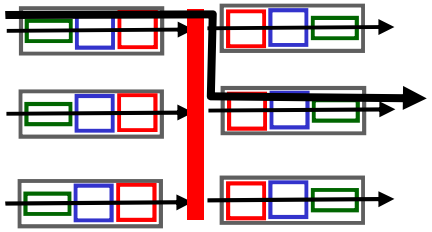
first generation routers:

- traditional computers with switching under direct control of CPU
- packet copied to system's memory
- speed limited by memory bandwidth (2 bus crossings per datagram)



Switching via a bus

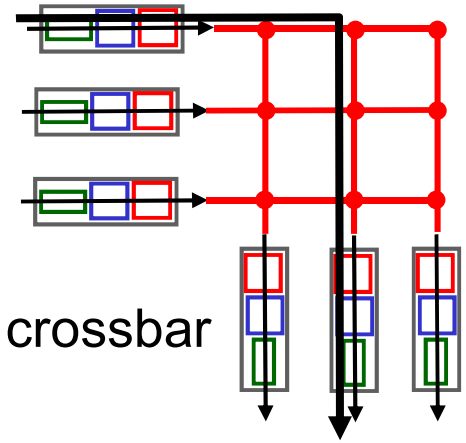
- datagram from input port memory to output port memory via a shared bus
- *bus contention:* switching speed limited by bus bandwidth
- 32 Gbps bus, Cisco 5600: sufficient speed for access and enterprise routers



bus

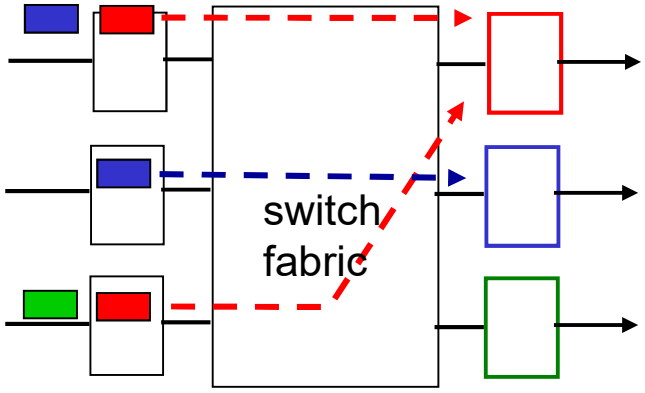
Switching via interconnection network

- overcome bus bandwidth limitations
- banyan networks, crossbar, other interconnection nets initially developed to connect processors in multiprocessor
- advanced design: fragmenting datagram into fixed length cells, switch cells through the fabric.
- Cisco 12000: switches 60 Gbps through the interconnection network

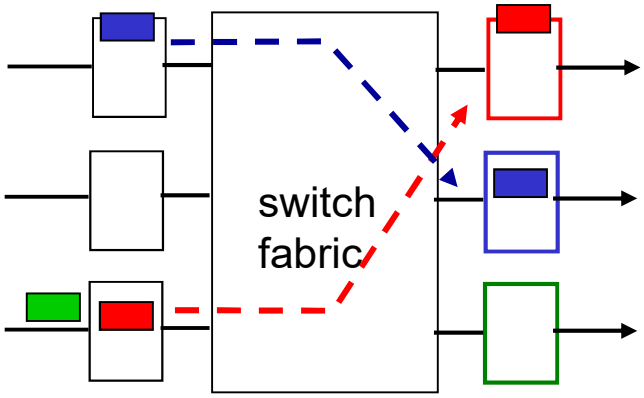


Input port queuing

- fabric slower than input ports combined -> queueing may occur at input queues
  - *queueing delay and loss due to input buffer overflow!*
- Head-of-the-Line (HOL) blocking: queued datagram at front of queue prevents others in queue from moving forward



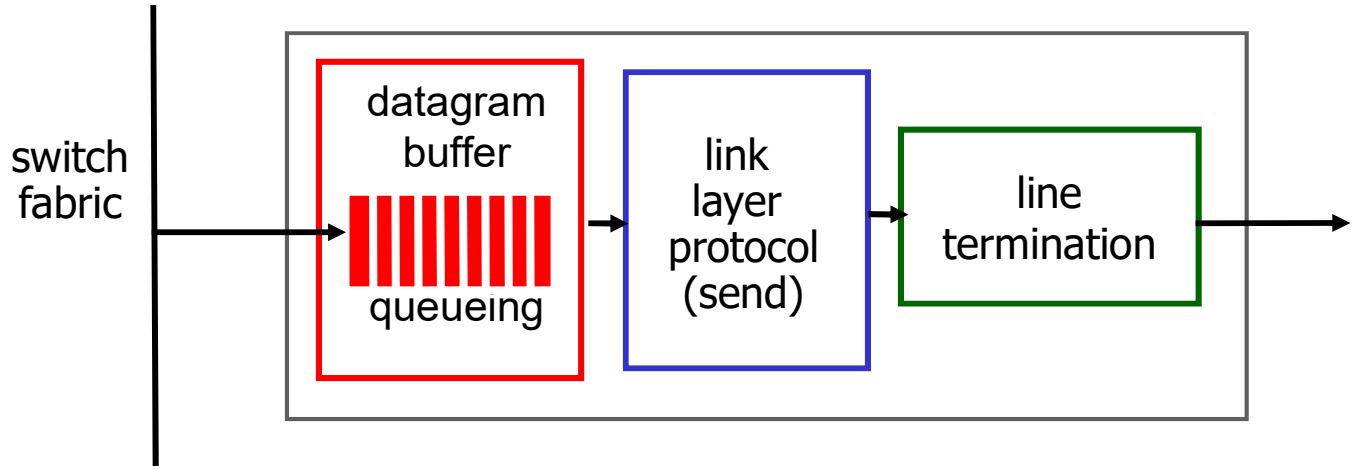
output port contention:
only one red datagram can be transferred.
lower red packet is blocked



one packet time later:
green packet
experiences HOL
blocking

Output ports

This slide in HUGELY important!



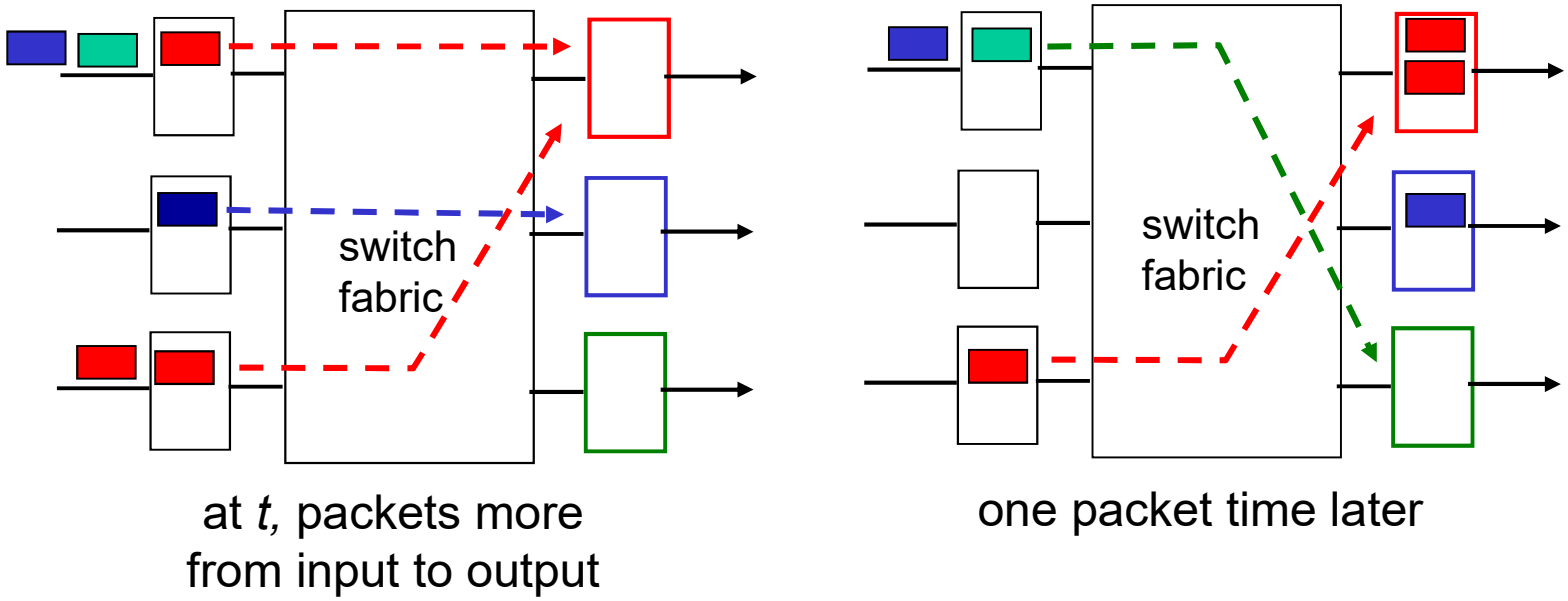
- *buffering* required from fabric faster rate

Datagram (packets) can be lost due to congestion, lack of buffers

- *scheduling* datagrams

Priority scheduling – who gets best performance, network neutrality

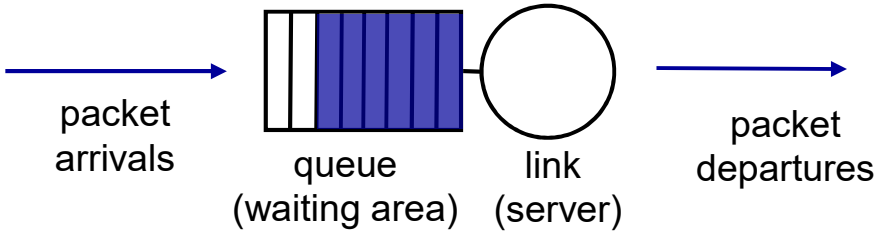
Output port queueing



- buffering when arrival rate via switch exceeds output line speed
- *queueing (delay) and loss due to output port buffer overflow!*

Scheduling mechanisms

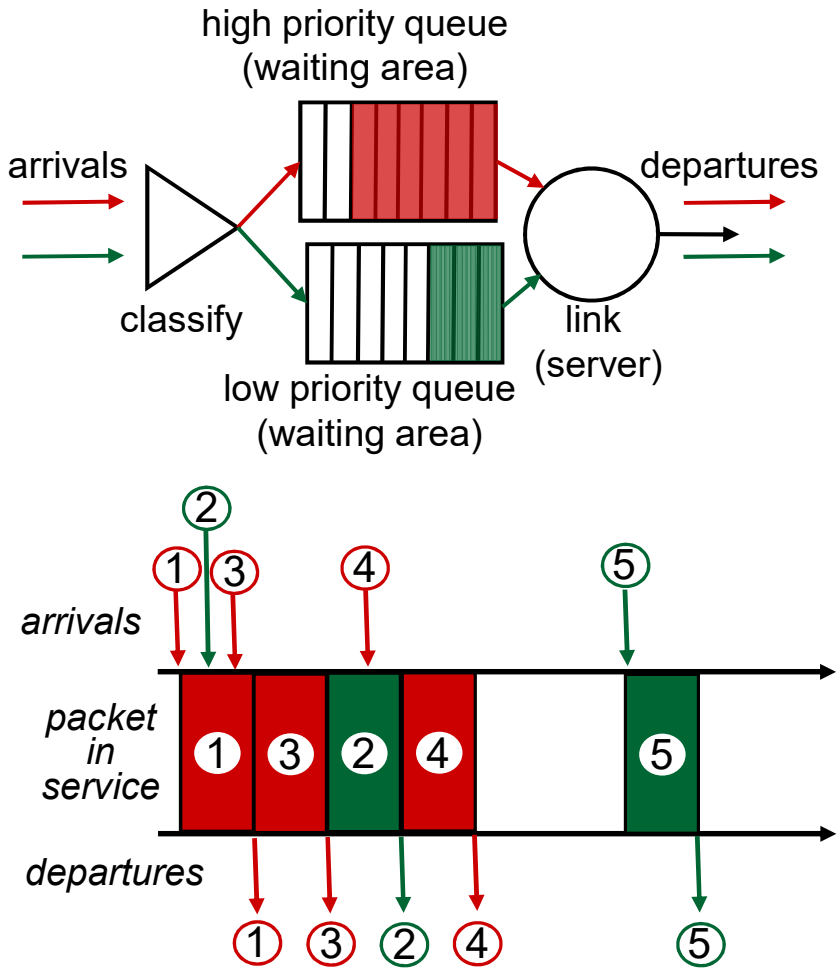
- *scheduling:* choose next packet to send on link
- *FIFO (first in first out) scheduling:* send in order of arrival to queue
  - real-world example?
  - *discard policy:* if packet arrives to full queue: who to discard?
    - *tail drop:* drop arriving packet
    - *priority:* drop/remove on priority basis
    - *random:* drop/remove randomly



Scheduling policies: priority

priority scheduling: send highest priority queued packet

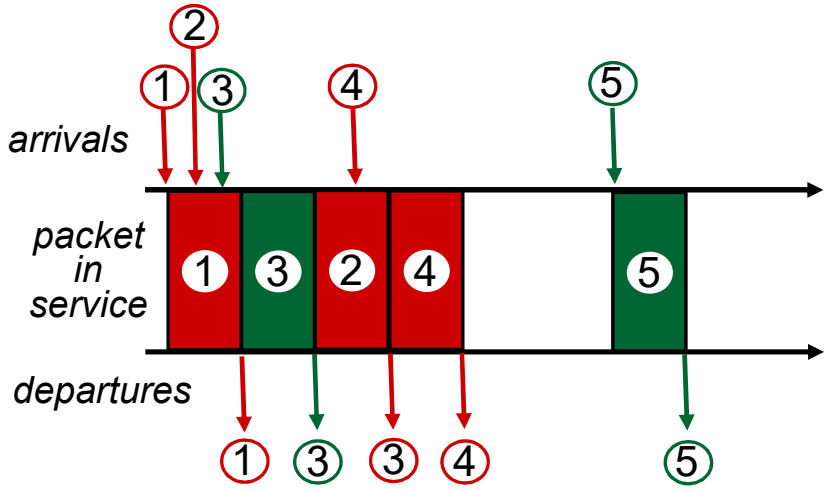
- multiple *classes*, with different priorities
  - class may depend on marking or other header info, e.g. IP source/dest, port numbers, etc.
  - real world example?



Scheduling policies: still more

Round Robin (RR) scheduling:

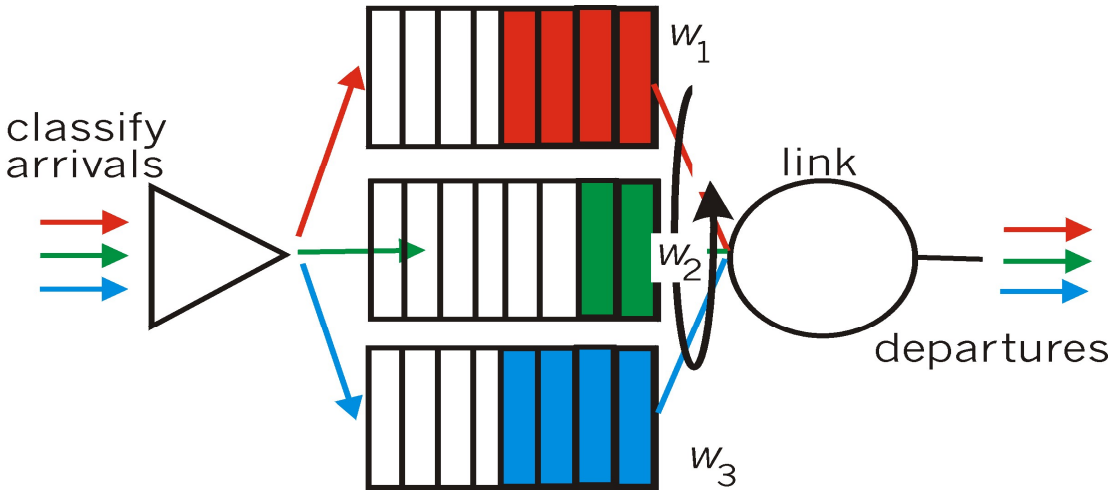
- multiple classes
- cyclically scan class queues, sending one complete packet from each class (if available)
- real world example?



Scheduling policies: still more

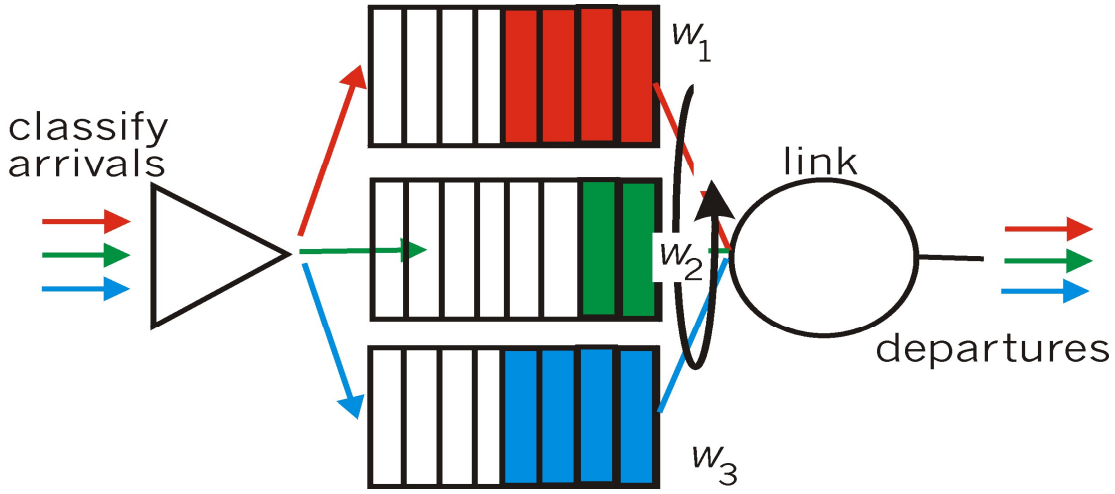
Weighted Fair Queuing (WFQ):

- generalized Round Robin
- each class gets weighted amount of service in each cycle
- real-world example?



Weighted Fair Queuing (WFQ)

- 링크 전송속도 : 1Gbps, 실시간 서비스 큐의 가중치(w1)가 20%일 때 실시간 서비스에 할당되는 대역폭은? (최소, 최대 대역폭?)



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