Lecture 14: Network Layer – Data Plane I

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Contents of Chapter 4

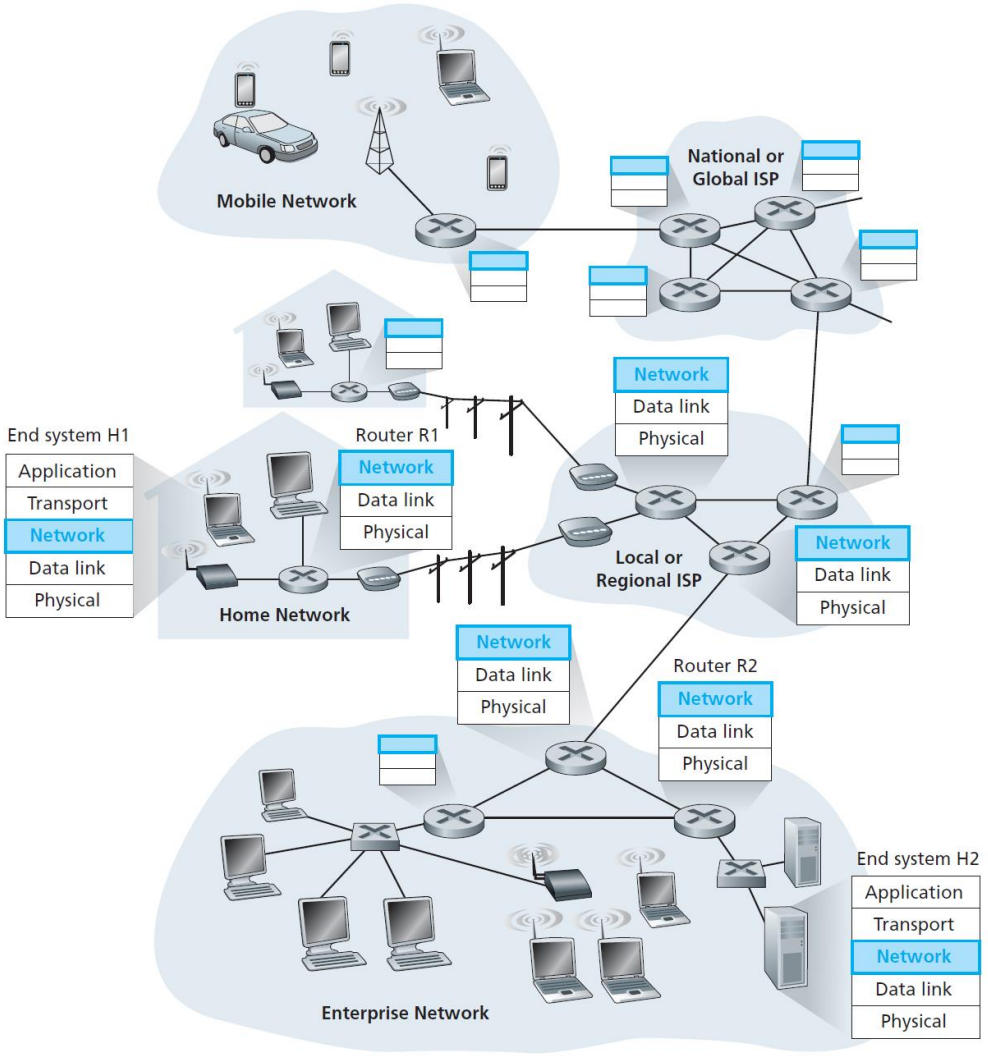
- Overview of network layer
- What's inside a router?
- The internet protocol (IP): IPv4, addressing, IPv6, and more
- Generalized forwarding and SDN

Contents of Chapter 4

- **Overview of network layer**
  - Forwarding and routing: The network data and control planes
  - Network service models
- **What's inside a router?**
- **The internet protocol (IP): IPv4, addressing, IPv6, and more**
- **Generalized forwarding and SDN**

Overview of Network Layer

- **Network layer**
  - Move packets from a sending host to a receiving host
  - Everywhere in the network
  - Provide a best-effort service
    - E.g., no guarantee on reliable data transfer, bounded delay, in-order delivery
  - Two interacting parts
    - Data plane
    - Control plane

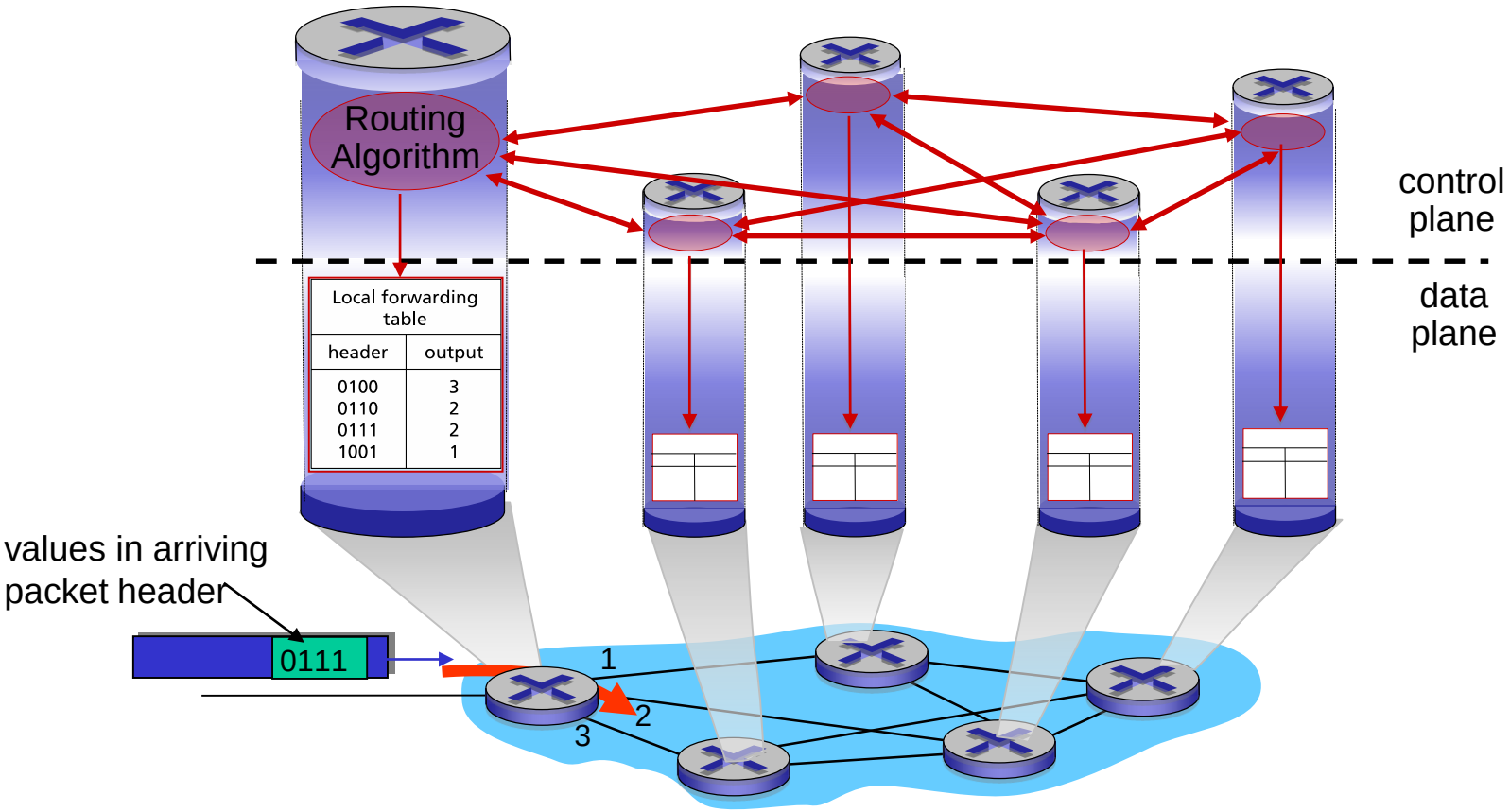


Overview of Network Layer

- **Data plane**
  - Forwarding
    - Router-local action of transferring a packet from an input link interface to the appropriate output link interface
    - Typically a few nanoseconds and typically implemented in hardware
    - Forwarding table: Contain information indicating appropriate output link
- **Control plane**
  - Routing
    - Network-wide process that determines the end-to-end paths that packets take from source to destination
    - Typically milliseconds or seconds and often implemented in software
    - Routing algorithm: Determine values in forwarding tables

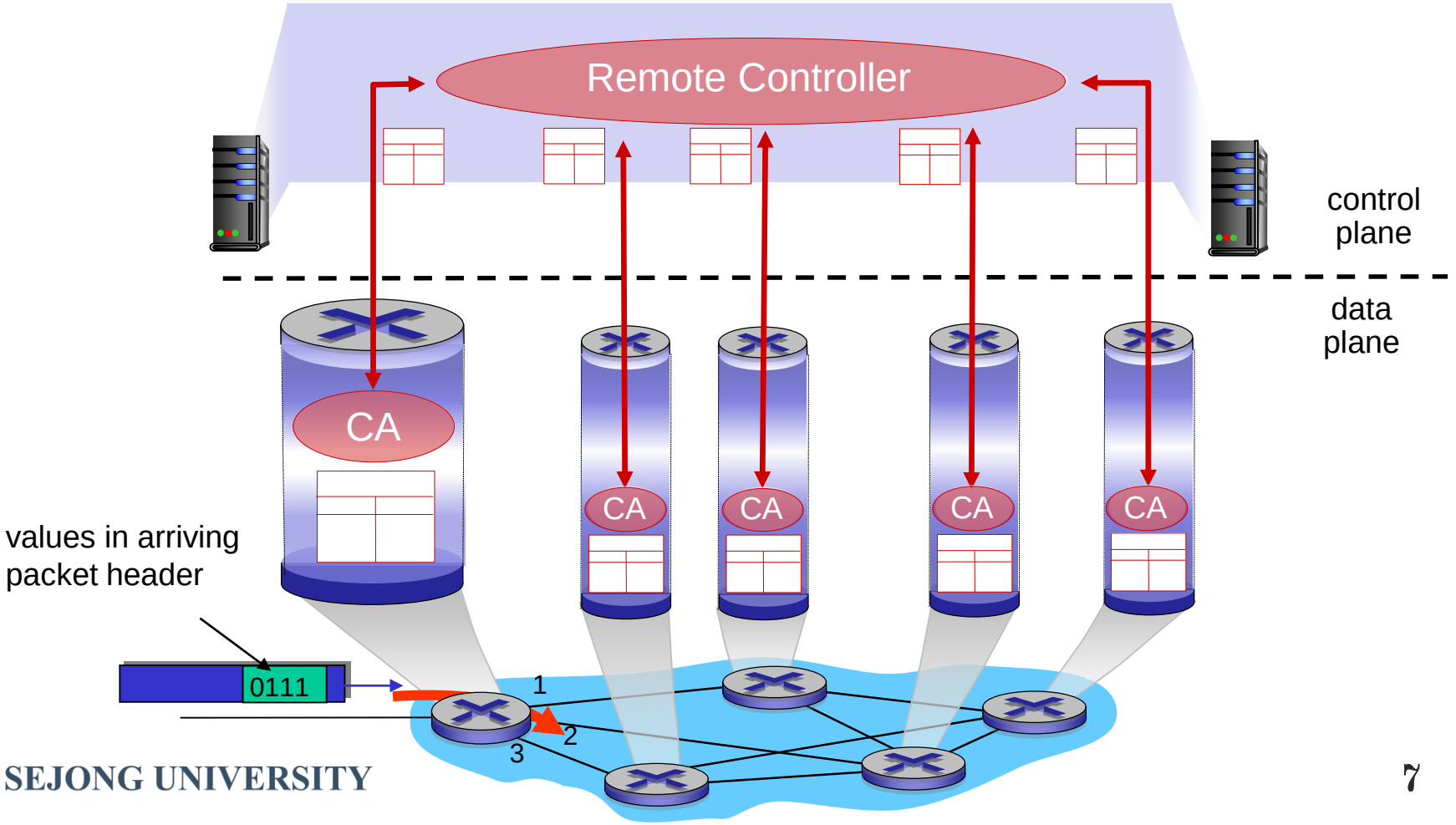
Control Plane: The Traditional Approach

- Routing algorithms determine values in forwarding tables.



Control Plane: The SDN Approach

- A remote controller determines and distributes values in forwarding tables: Software-defined networking (SDN)

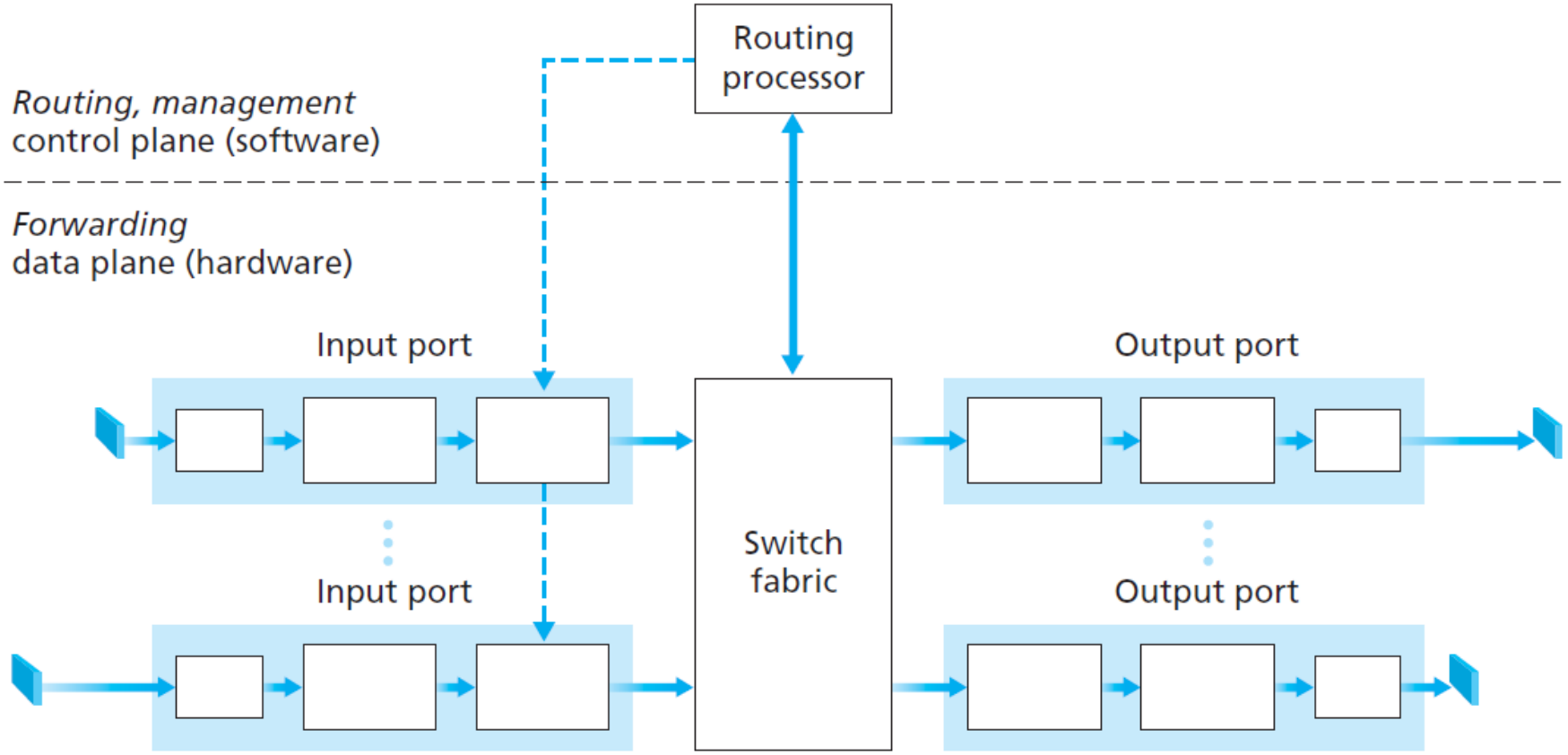


Contents of Chapter 4

- Overview of network layer
- **What's inside a router?**
  - Input port processing and destination-based forwarding
  - Switching
  - Output port processing
  - Where does queuing occur?
  - Packet scheduling
- The internet protocol (IP): IPv4, addressing, IPv6, and more
- Generalized forwarding and SDN

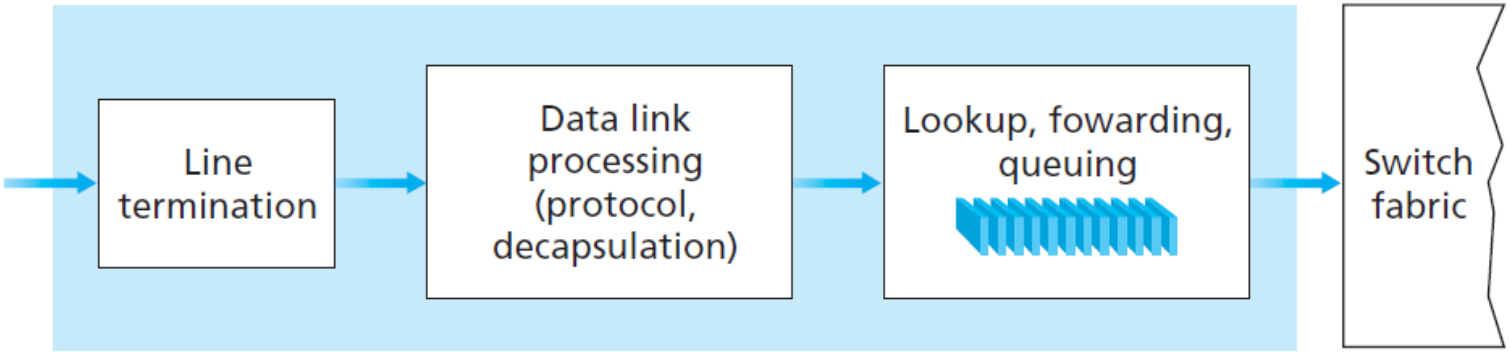
Router Architecture

- A high-level view of a generic router architecture



Router Components

- **Input port processing**
  - Use the forwarding table to look up the output port to which an arriving packet will be forwarded via the switching fabric



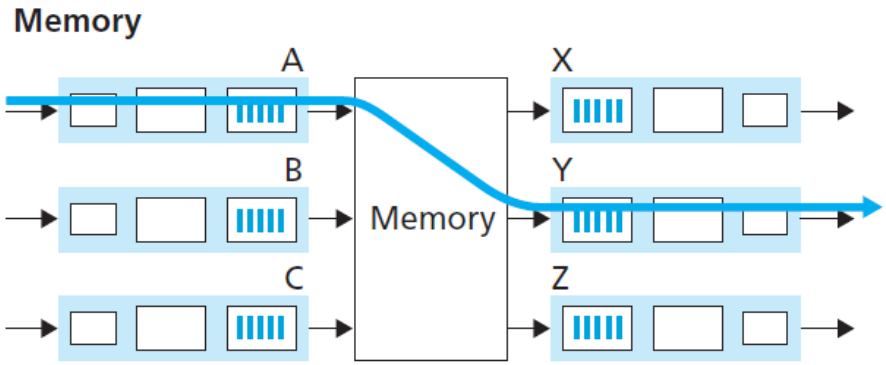
Router Components

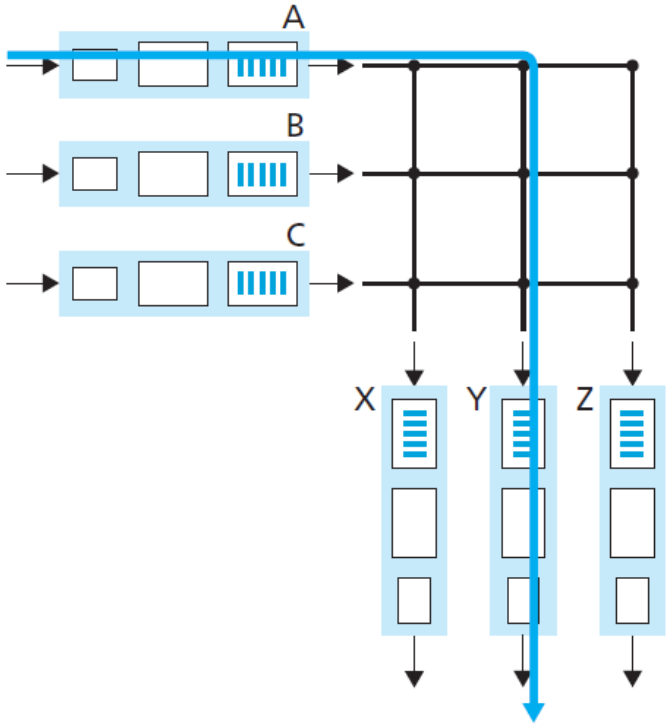
- **Forwarding**
  - Destination-based forwarding
    - Based on the packet's destination address
  - Generalized forwarding
    - Based on a generalized set of packet header fields

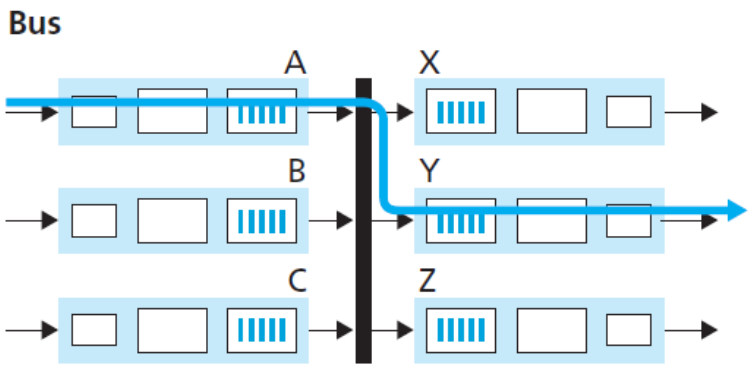
Router Components

Switching

- Packets are switched from an input port to an output port.

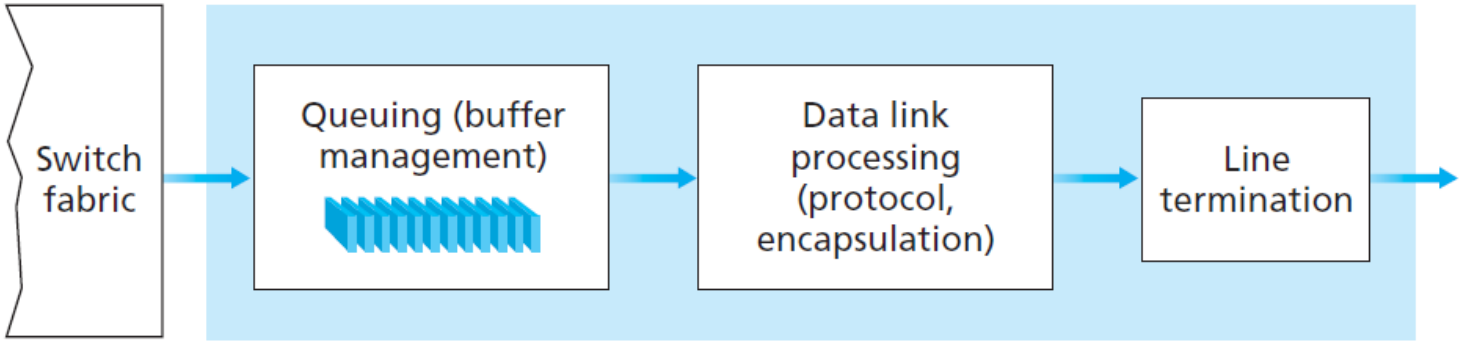






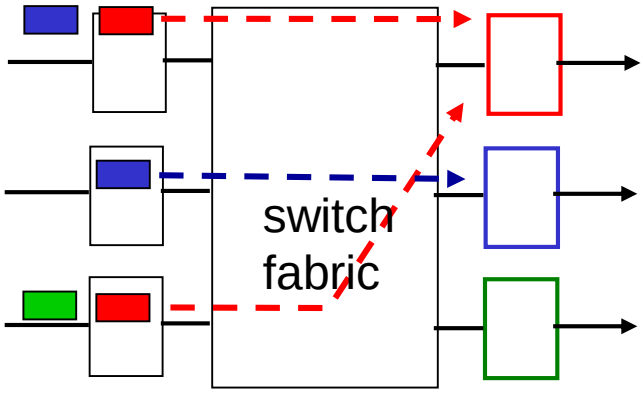
Router Components

- **Output port processing**
  - Take packets that have been stored in the output port's memory and transmits them over the output link

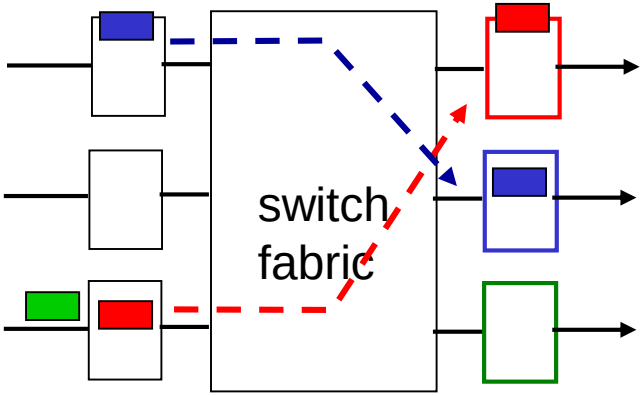


Where Does Queuing Occur?

- **Input queuing**
  - Head-of-the-line (HOL) blocking
    - A queued packet in an input queue must wait for transfer through the fabric because it is blocked by another packet at the head of the line.



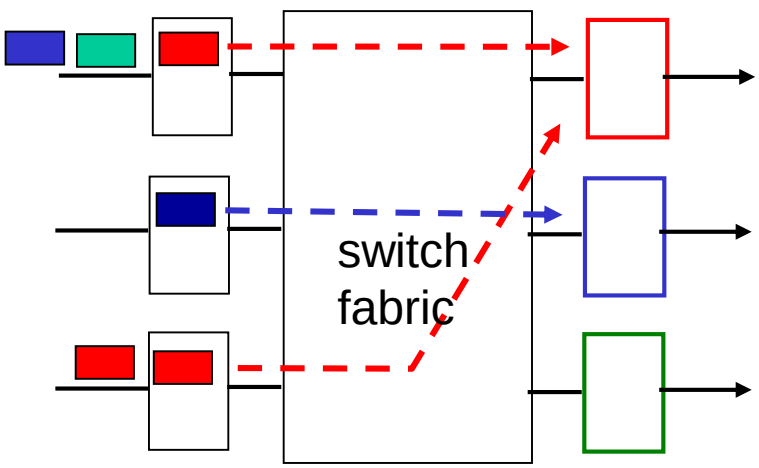
output port contention:
only one red datagram can be transferred.
lower red packet is blocked



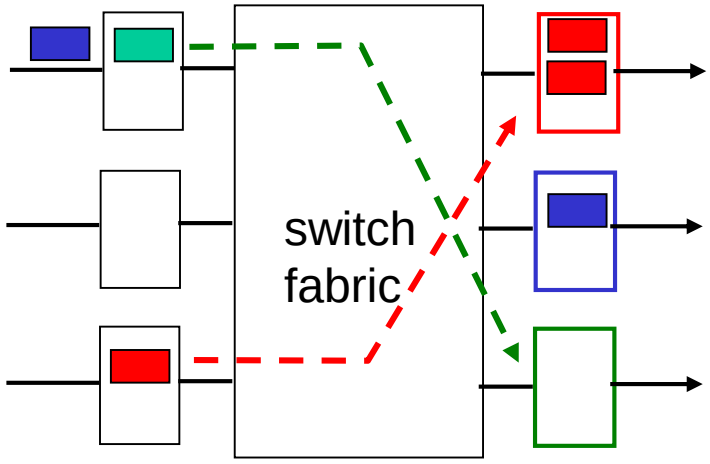
one packet time later:
green packet
experiences HOL
blocking

Where Does Queuing Occur?

- **Output queuing**
  - Buffering required when datagram arrive from fabric faster than the transmission rate
  - Scheduling needed



at *t*, packets more from input to output



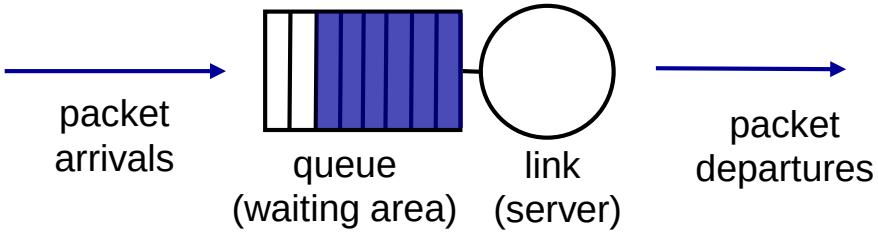
one packet time later

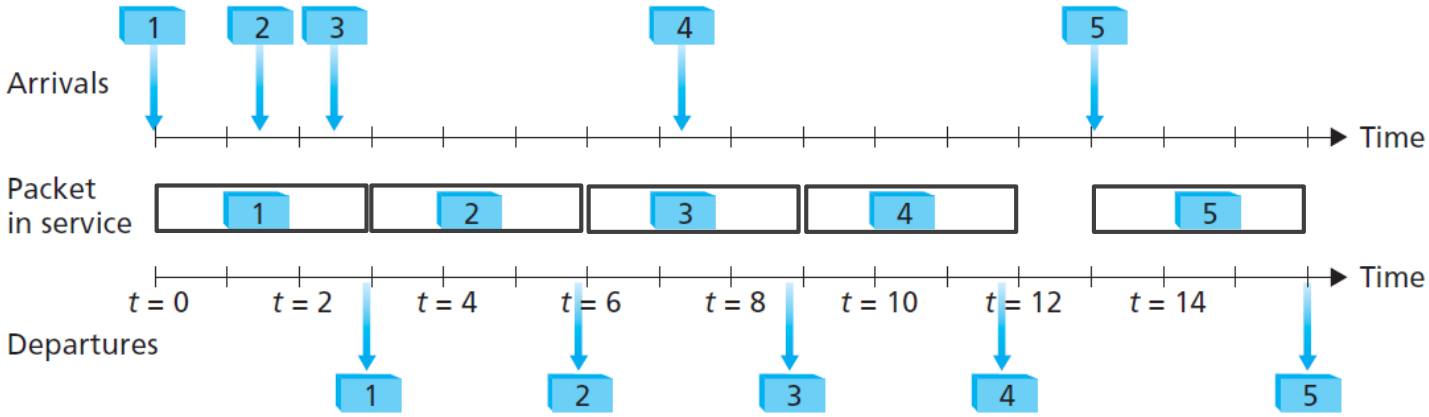
Packet Scheduling

- **Packet scheduling**
  - Determining the order in which queued packets are transmitted over an outgoing link
- **Scheduling policies**
  - First-in-first-out (FIFO)
  - Priority queuing
  - Round robin queuing
  - Weighted fair queuing (WFQ)

Packet Scheduling

- **First-in-first-out (FIFO) (or first-come-first-served, FCFS)**
  - Select packets for link transmission in the same order in which they arrived at the output link queue

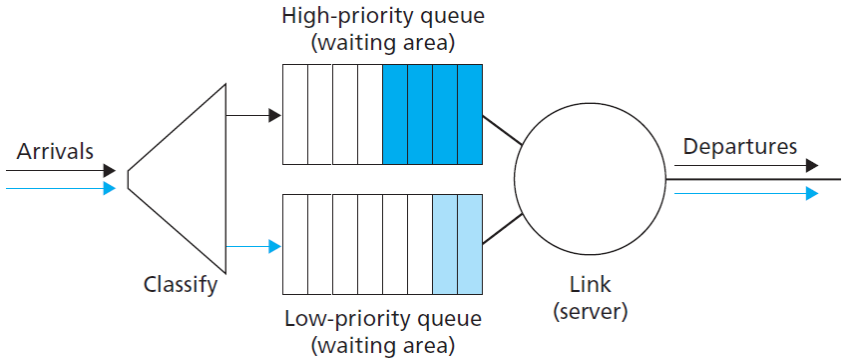


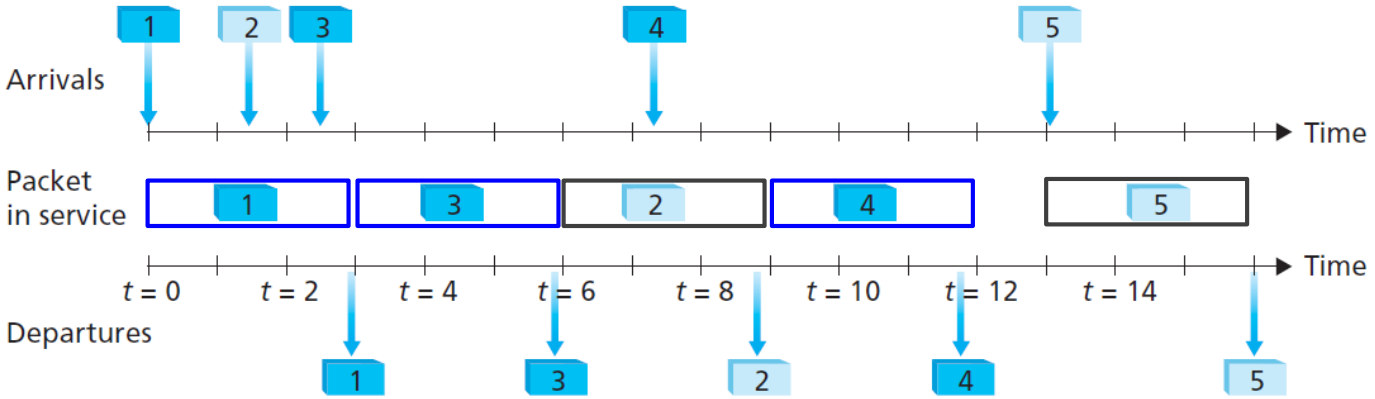


Packet Scheduling

Priority queueing

- Packets arriving at the output link are classified into priority classes.
- Transmit a packet from the highest priority class

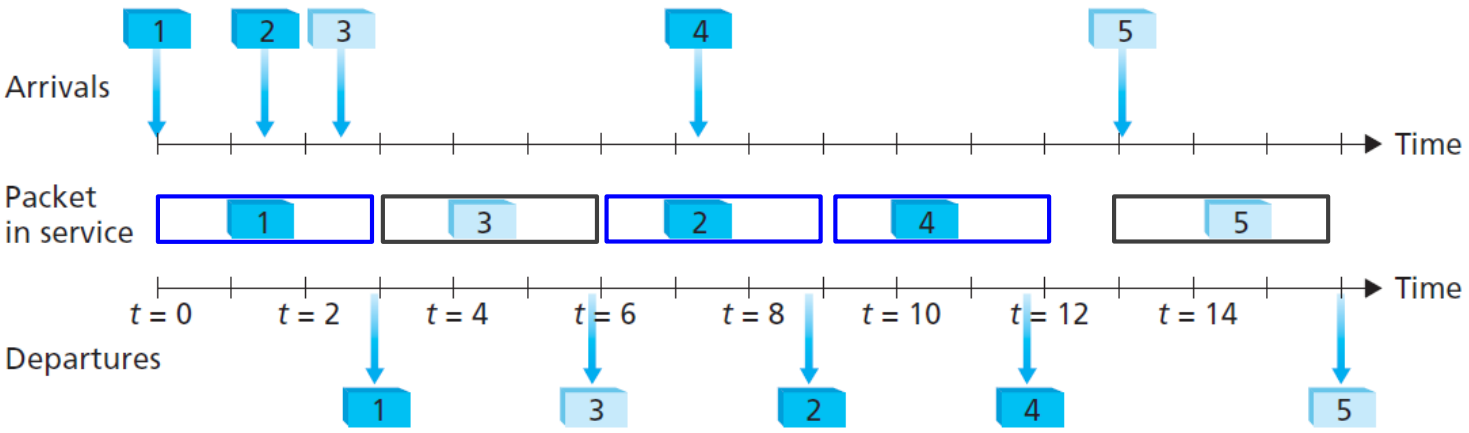




Packet Scheduling

Round robin queuing

- Packets are sorted into classes and transmit a packet alternatively among the classes.



Packet Scheduling

Weighted fair queuing (WFQ)

- As in round robin scheduling, arriving packets are classified and queued.
- Each class i is assigned a weight w_i.
- Class i receive a fraction of service equal to $\frac{w_i}{\sum w_j}$