

CSCI 491-01

Topics: Internet Programming

Fall 2008

Network Layer

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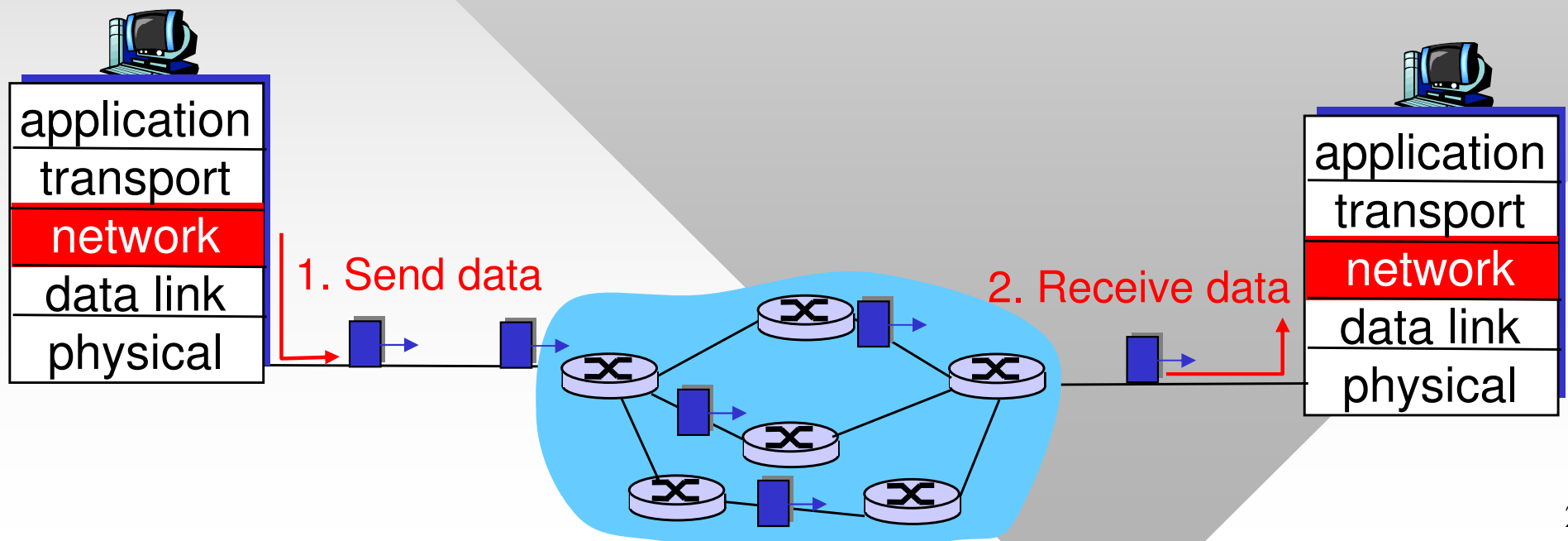
Hendrix College

October 31, 2008

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Datagram Networks (1960s)

- No call setup at network layer
- Routers: no state about end-to-end connections
 - No network-level concept of “connection”
- Packets forwarded using **destination host address**
 - Packets between the same source-dest pair may take different paths (**multi-path routing**)



Datagram Forwarding Table

4 billion
possible entries

Destination Address Range (32 bit)

Link Interface

11001000 00010111 00010000 00000000
through
11001000 00010111 00010111 11111111

0

11001000 00010111 00011000 00000000
through
11001000 00010111 00011000 11111111

1

11001000 00010111 00011000 00000000
through
11001000 00010111 00011111 11111111

2

otherwise

3

Longest Prefix Matching

<u>Prefix Match</u>	<u>Link Interface</u>
11001000 00010111 00010	0
11001000 00010111 00011000	1
11001000 00010111 00011	2
otherwise	3

Examples (DA = destination address)

DA: 11001000 00010111 00010110 10100001
DA: 11001000 00010111 00011001 10101010
DA: 11001000 00010111 00011000 10101010

Which interface?

Datagram or VC Network: Why?

Internet

- Data exchange among computers
 - “Elastic” service, no strict timing requirements
- “Smart” end systems (computers)
 - Can adapt, perform control, error recovery
 - Simple inside network, complexity at “edge”
- Many link types
 - Different characteristics
 - Uniform service difficult

ATM

- Evolved from telephony
- Human conversation:
 - Strict timing, reliability requirements
 - Need for guaranteed service
- “Dumb” end systems
 - Telephones
 - Complexity inside network

Chapter 4: Roadmap

4.1 Introduction

4.2 Virtual circuit and datagram networks

4.3 What's inside a router

4.4 IP: Internet Protocol

4.5 Routing algorithms

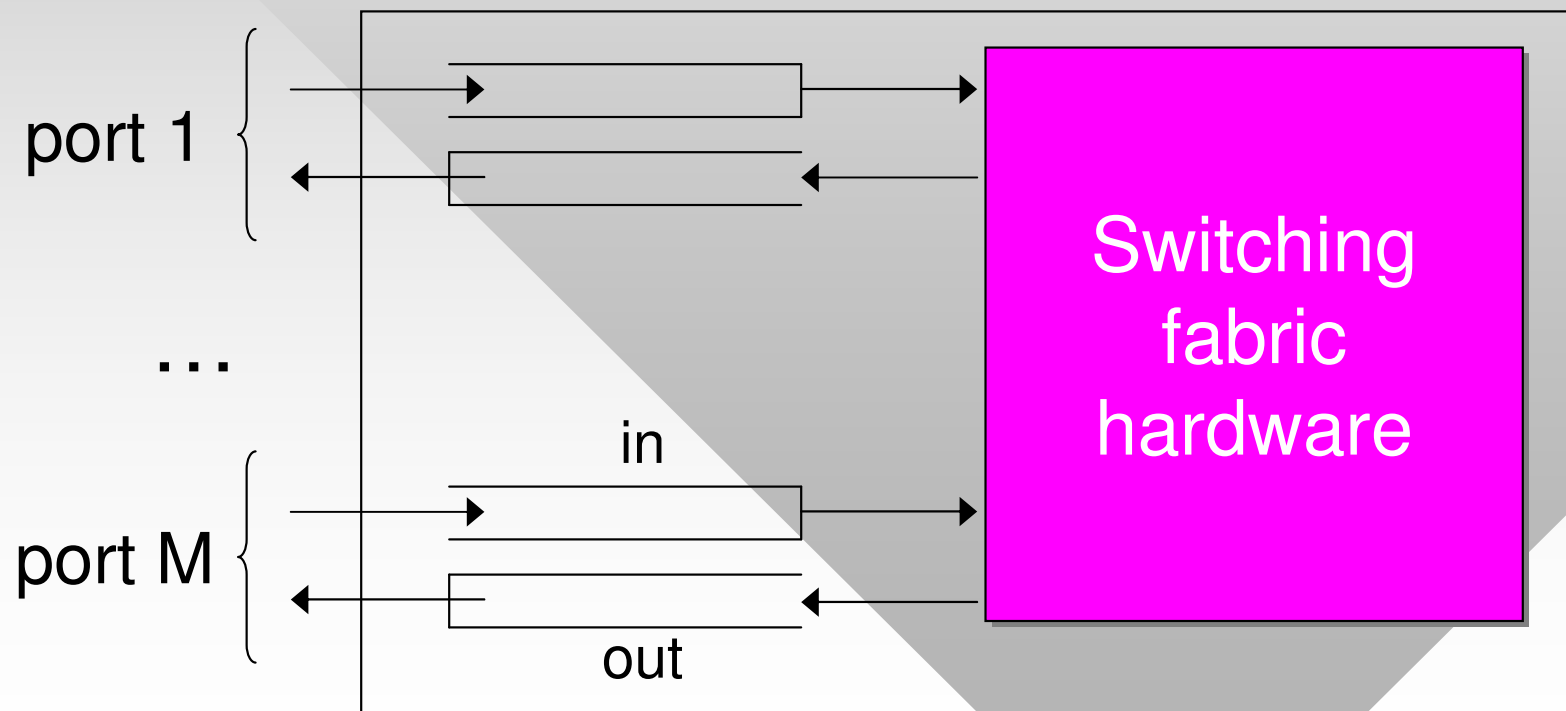
4.6 Routing in the Internet

4.7 Broadcast and multicast routing

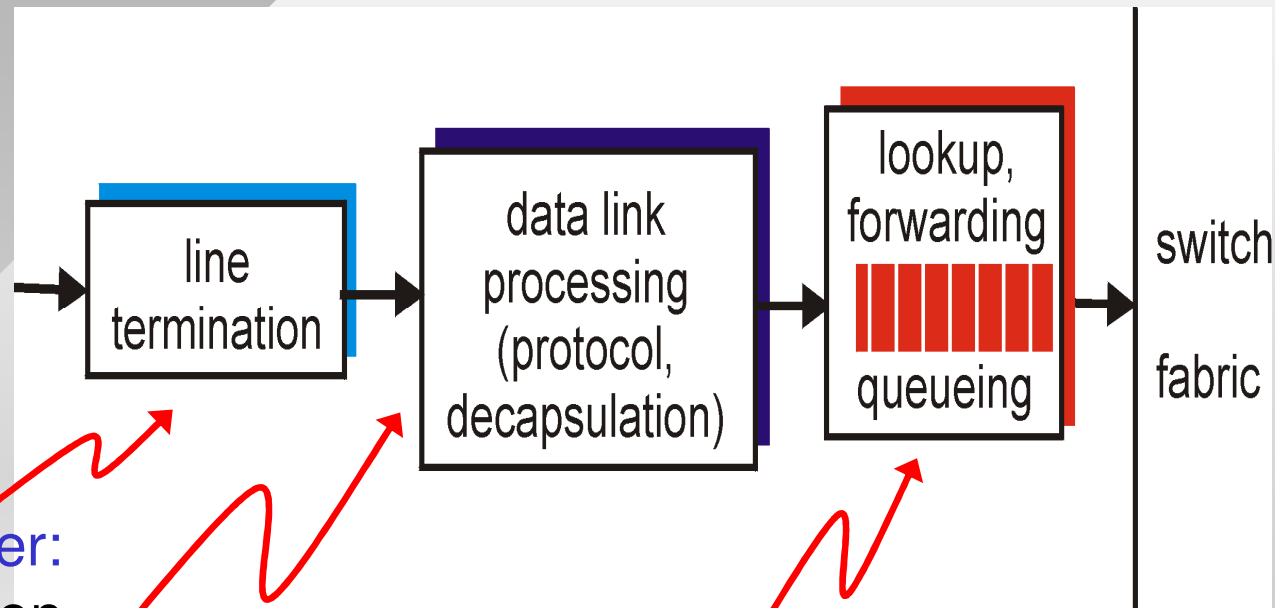
Router Architecture Overview

Two key router functions:

- Run routing algorithms/protocol (RIP, OSPF, BGP)
- Forward datagrams from incoming to outgoing link
 - Terminology: **port** = interface capable of sending/receiving



Input Port (Queue) Functions



Physical layer:
bit-level reception

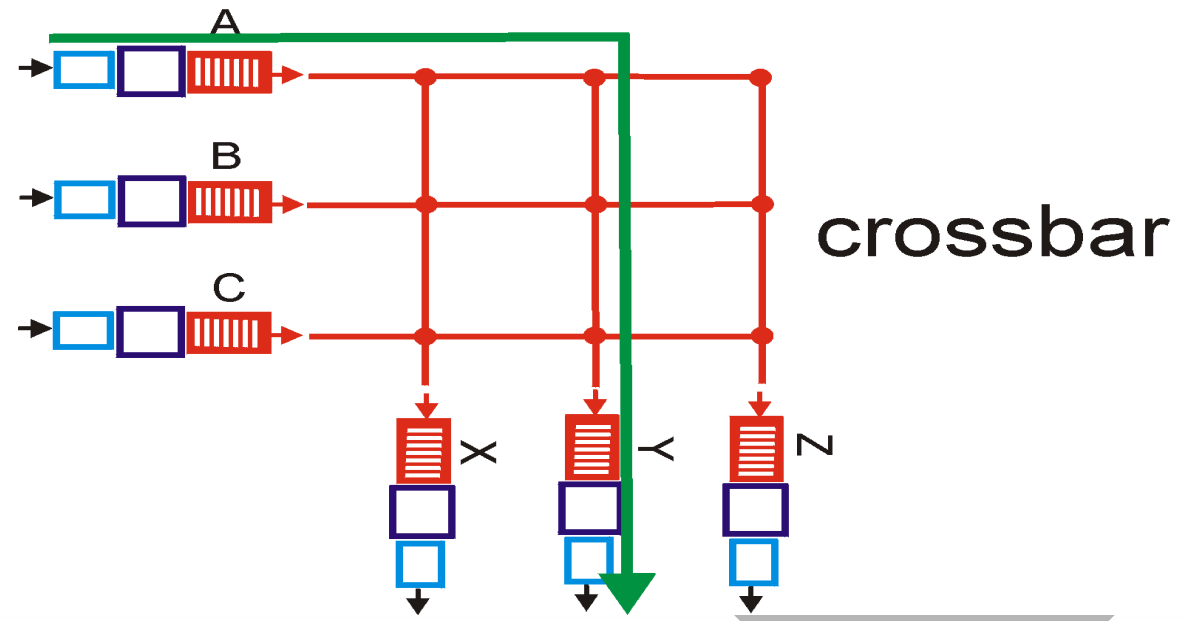
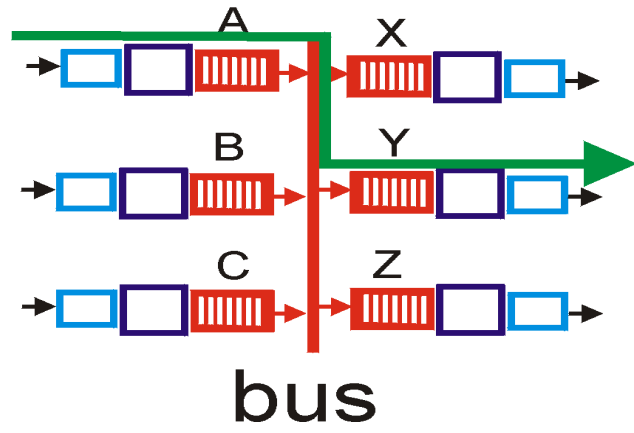
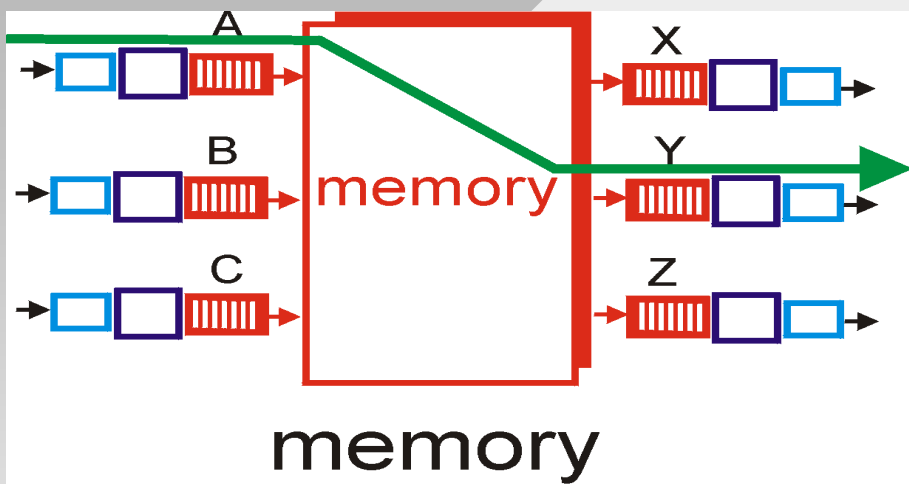
Data link layer

(e.g., Ethernet,
ATM, Token Ring,
802.11b): see ch. 5

Decentralized switching:

- Given datagram destination, look up output port using forwarding table in input port memory
- **Goal:** complete input port processing at “line speed”
- **Queueing:** if datagrams arrive faster than forwarding rate into switch fabric

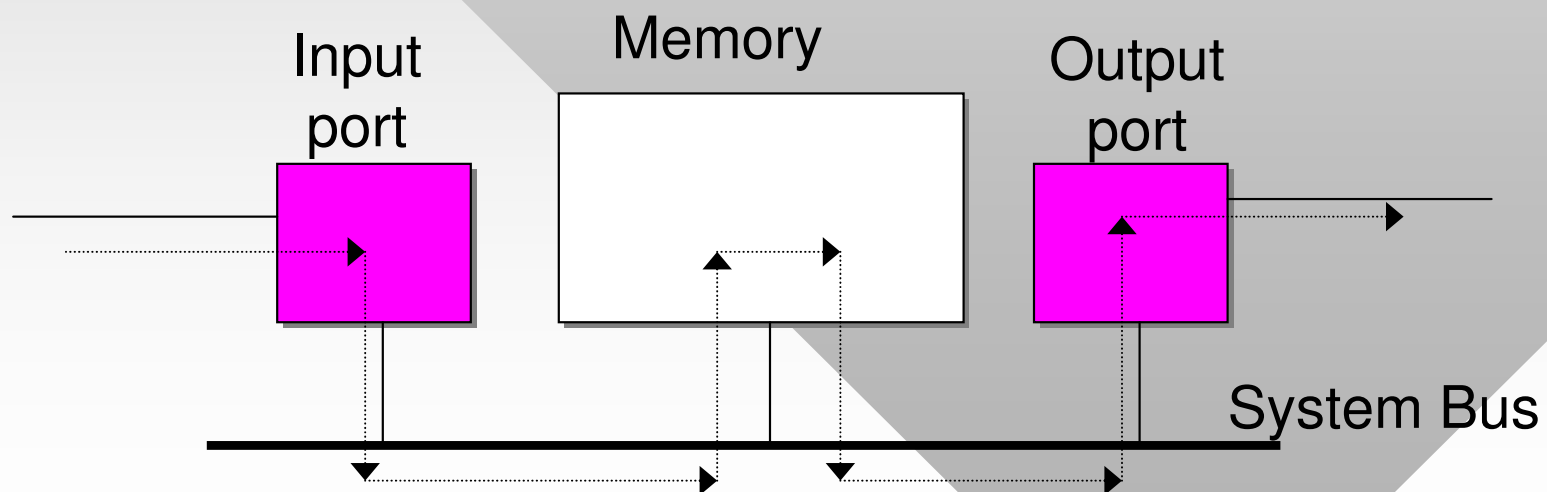
Three Types of Switching Fabrics



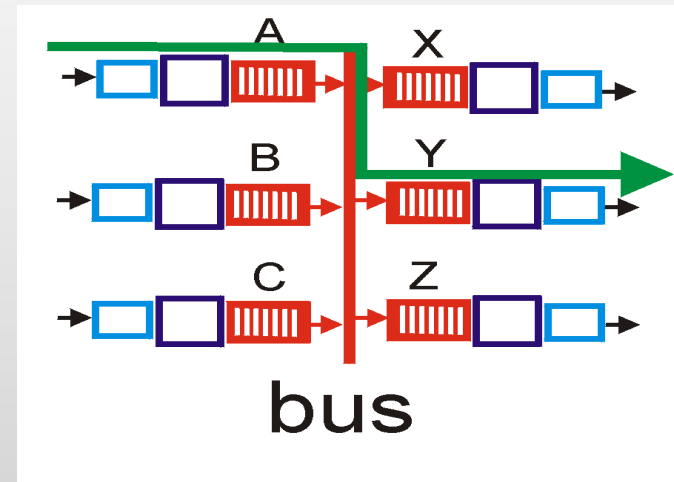
Switching Via Memory

First generation routers (1960s-mid 1980s):

- Traditional computers with switching under direct control of CPU
- Packet copied to system memory
- Speed limited by memory bandwidth (2 bus crossings per datagram)



Switching Via a Bus



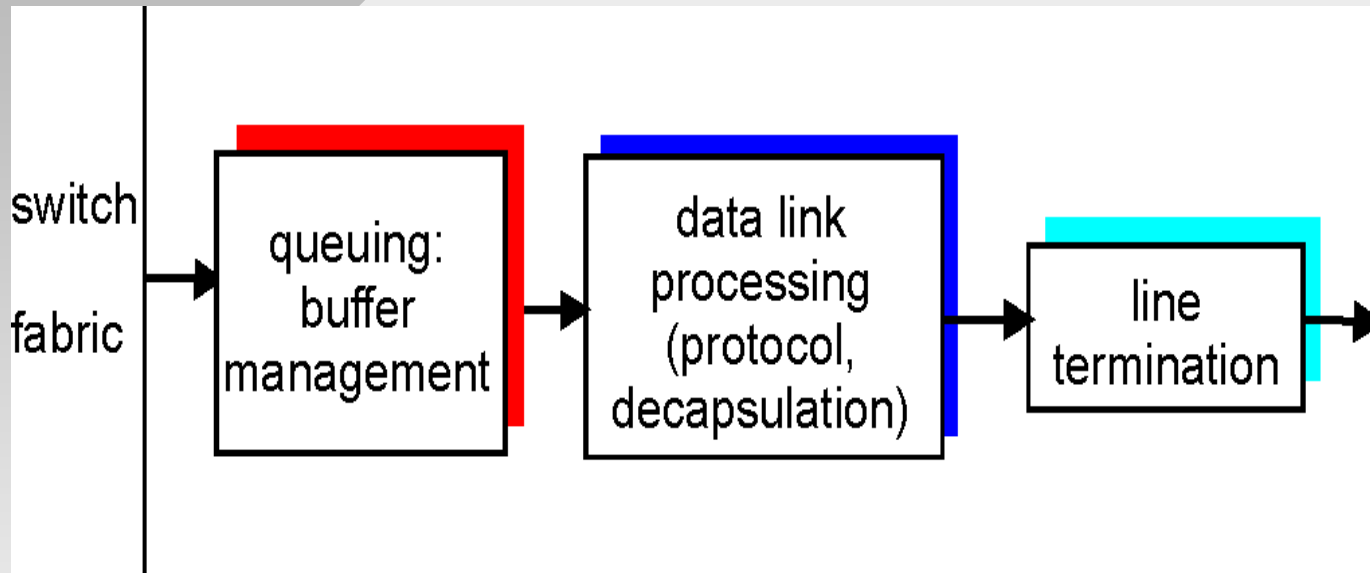
- Datagram from input port memory to output port memory via a shared bus
- **Bus contention:** switching speed limited by bus bandwidth
- 1 gb/s bus in Cisco 1900: sufficient speed for access and enterprise networks (not regional or backbone ISPs)

Switching Via An Interconnection Network

- Overcomes bus bandwidth limitations
 - Packets may be transmitted in parallel as long as they do not occupy the same horizontal or vertical wire
- Cisco 12000: switches hundreds of gb/s through an interconnection network
 - Terabit switching is available today in layer-2 devices

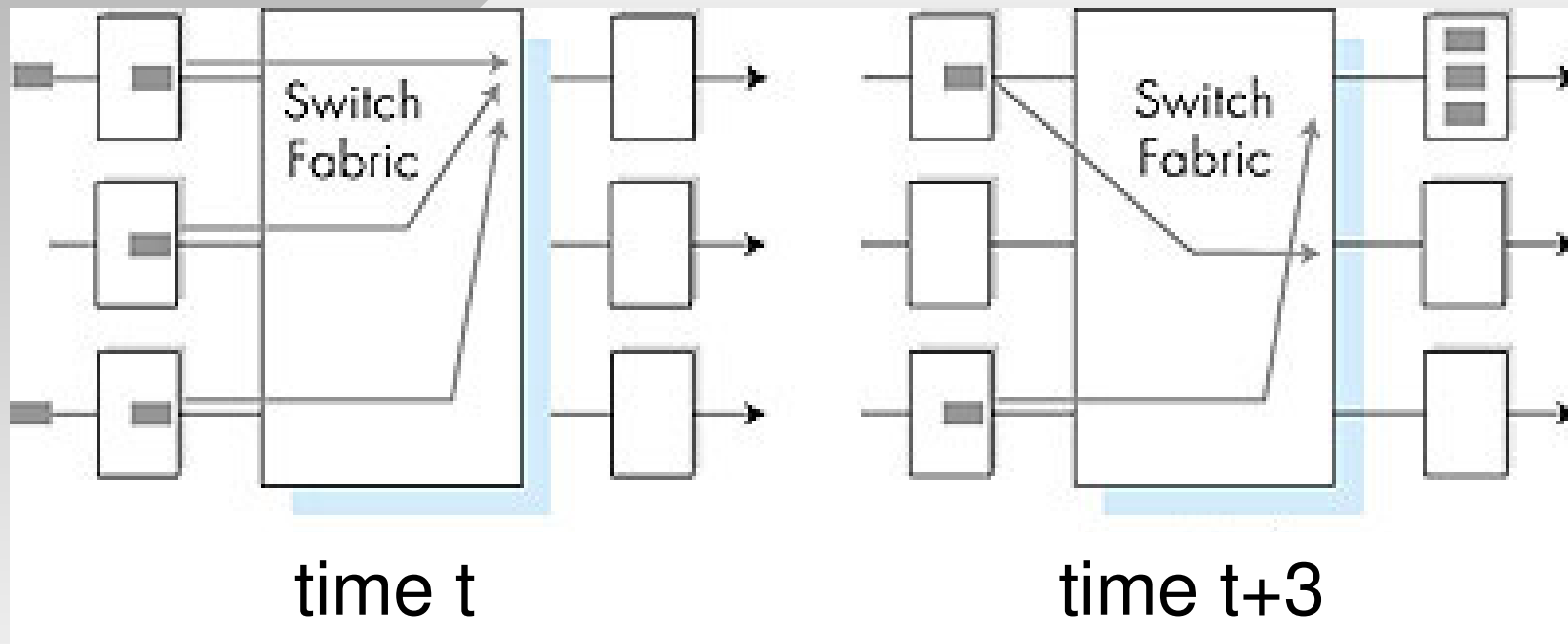


Output Ports



- *Buffering/queuing* required when datagrams arrive from fabric faster than the transmission rate
- *Scheduling discipline* chooses among queued datagrams for transmission

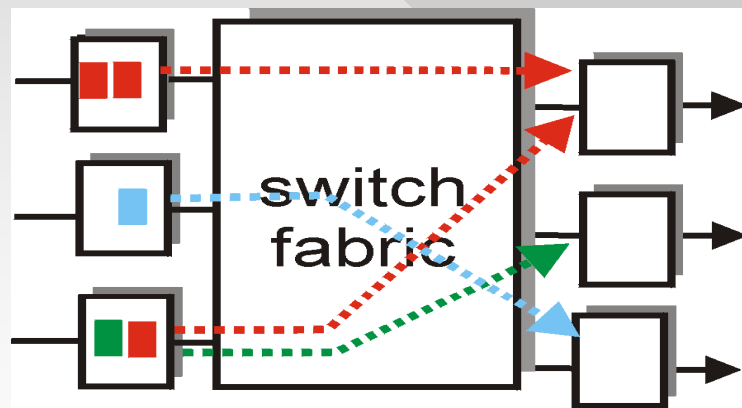
Output Port Queuing



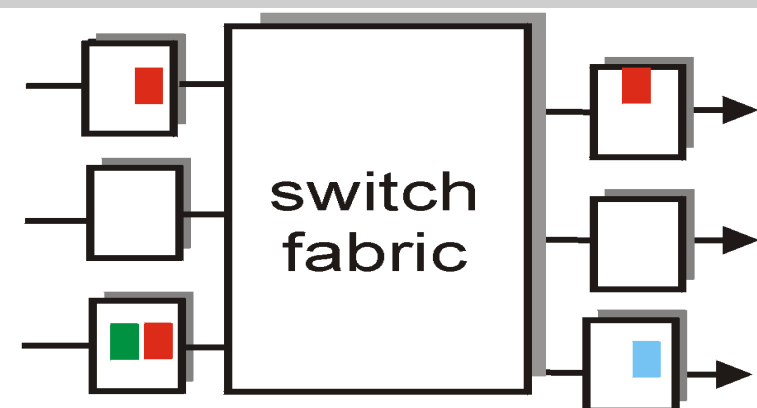
- Buffering when arrival rate via switch fabric exceeds output line speed
 - Result: queuing (delay) and loss due to output port buffer overflow

Input Port Queuing

- Reasons for input-port queuing:
 - Fabric slower than all input ports combined (not likely if router is properly designed)
 - **Head-of-Line (HOL) blocking**: queued datagram at front of queue prevents others in queue from moving forward
- Queuing delay and loss due to input buffer overflow!



output port contention
at time t - only one red
packet can be transferred



green packet
experiences HOL blocking