

Lecture 19:

Buffering & Scheduling

CSE 123: Computer Networks
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Project 2a due MONDAY

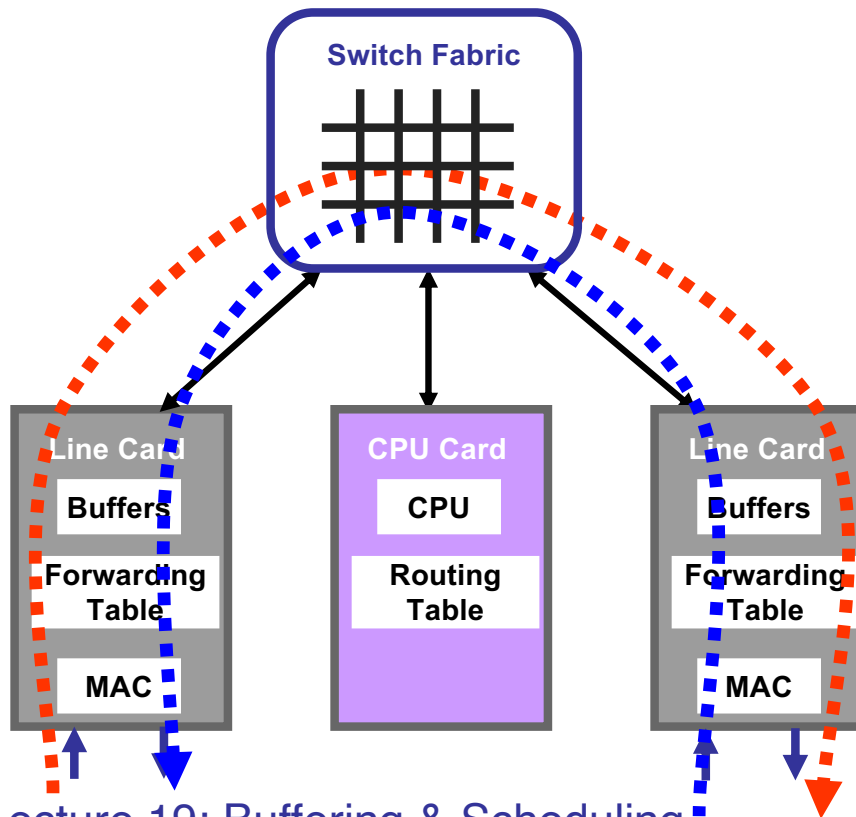


Lecture 19 Overview



- Queues in routers & switches
- Buffer management and scheduling disciplines
 - ◆ RED

Third Generation Routers



Shared interconnect
(frequently crossbar)

Centralized scheduler

Full forwarding table in
line card

Fixed cells

Output queuing



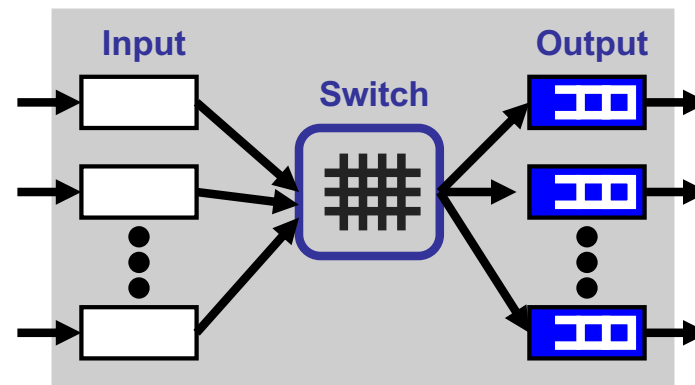
- Output interfaces buffer packets

- Pro

- ◆ Simple algorithms
- ◆ Single **congestion** point

- Con

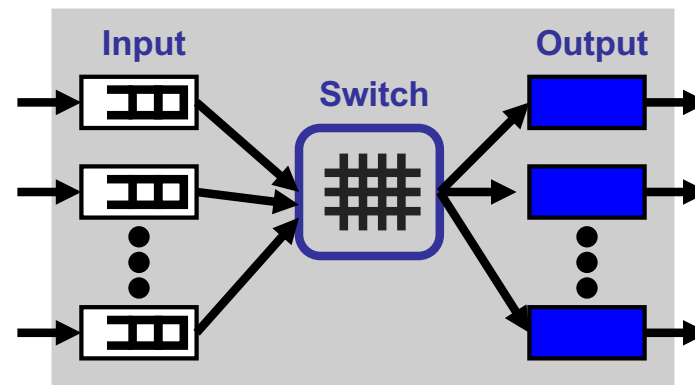
- ◆ N inputs may send to the same output
- ◆ Requires **speedup** of N
 - » Switch fabric must be N times faster than input line rate



Input queuing



- Input interfaces buffer packets
- Pro
 - ◆ Single congestion point
 - ◆ Simple to design algorithms
- Con
 - ◆ Must implement flow control
 - ◆ Low utilization due to Head-of-Line (HoL) Blocking

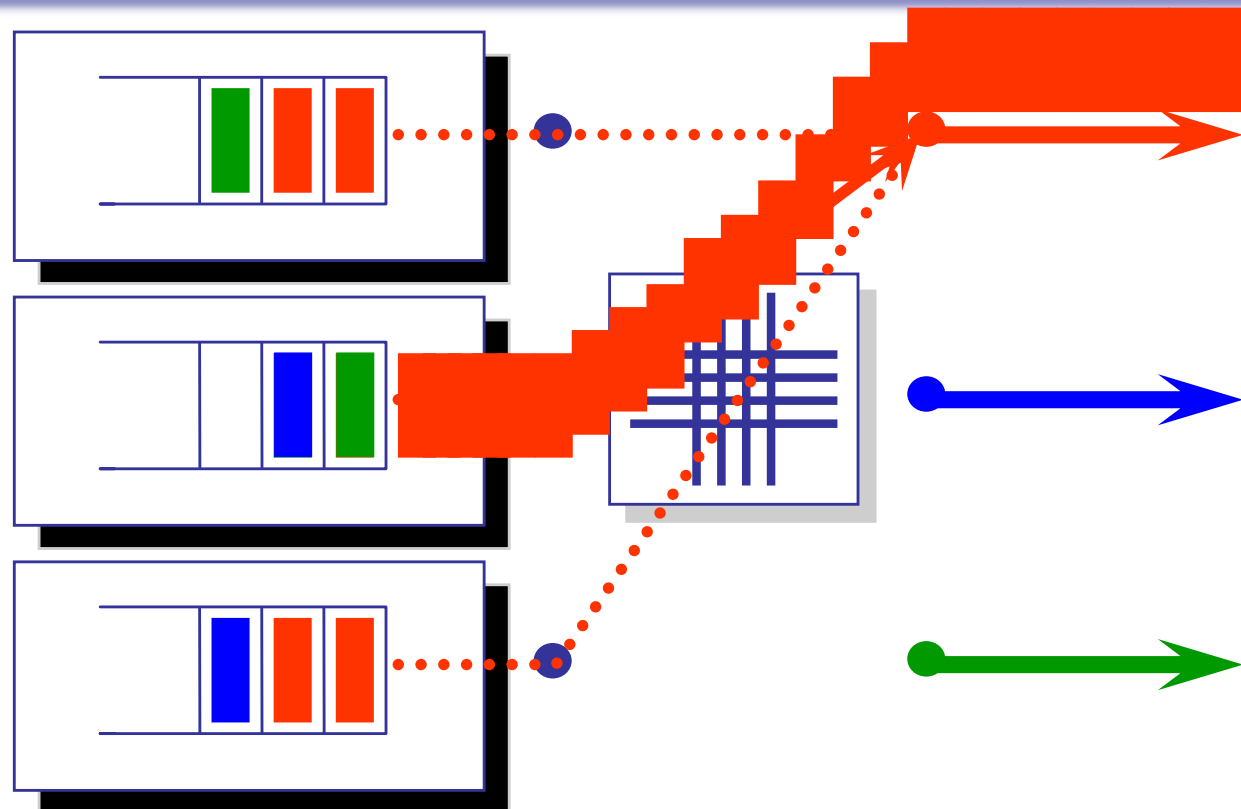




Head-of-Line Blocking

How many time units will it take to send the remainder of the packets?

- A. 3
- B. 4
- C. 5
- D. 8





IQ + Virtual Output Queuing

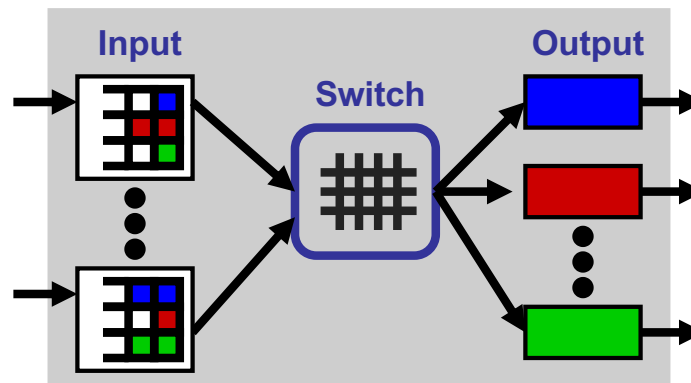
- Input interfaces buffer packets in per-output virtual queues

- Pro

- ◆ Solves blocking problem

- Con

- ◆ More resources per port
- ◆ Complex arbiter at switch
- ◆ Still limited by input/output contention (scheduler)

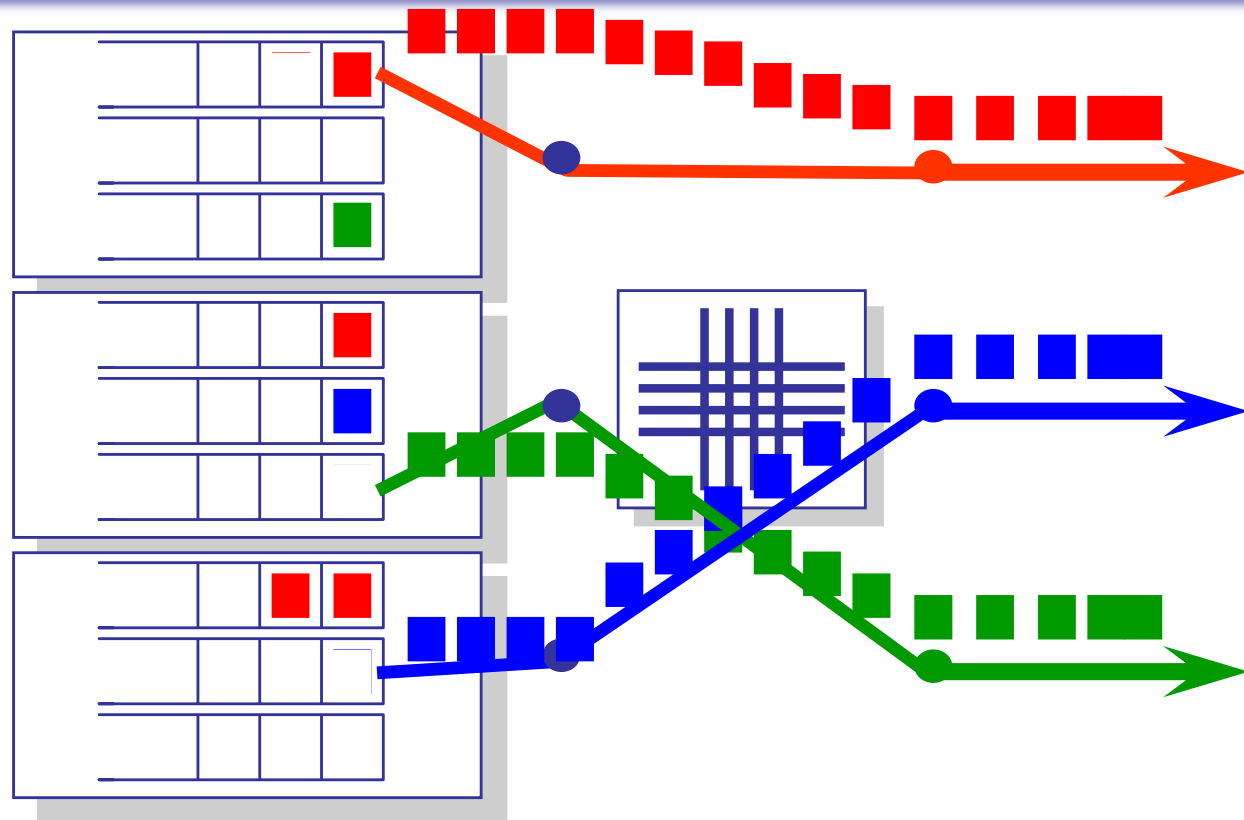




Virtual Output Queues

How many time units will it take to send the remainder of the packets?

- A. 2
- B. 3
- C. 4
- D. 5



Switch scheduling

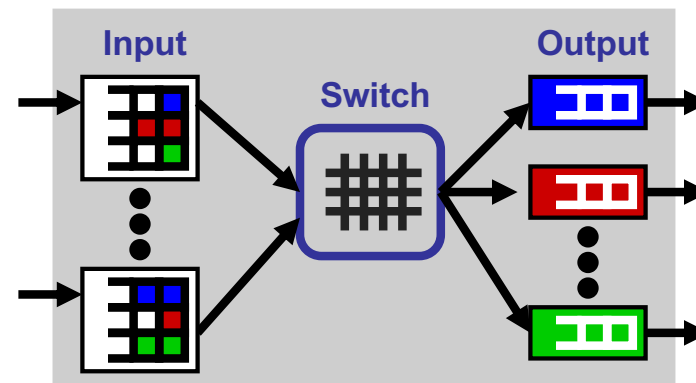


- Problem
 - ◆ Match inputs and outputs
 - ◆ Resolve contentions, no packet drops
 - ◆ Maximize throughput
 - ◆ Do it in constant time...
- If traffic is uniformly distributed its easy
 - ◆ Lots of algorithms (approximate matching)
- Seminal result (Dai et al, 2000)
 - ◆ Maximal size matching + *speedup* of two guarantees 100% utilization for most traffic assumptions



Typical high-performance router

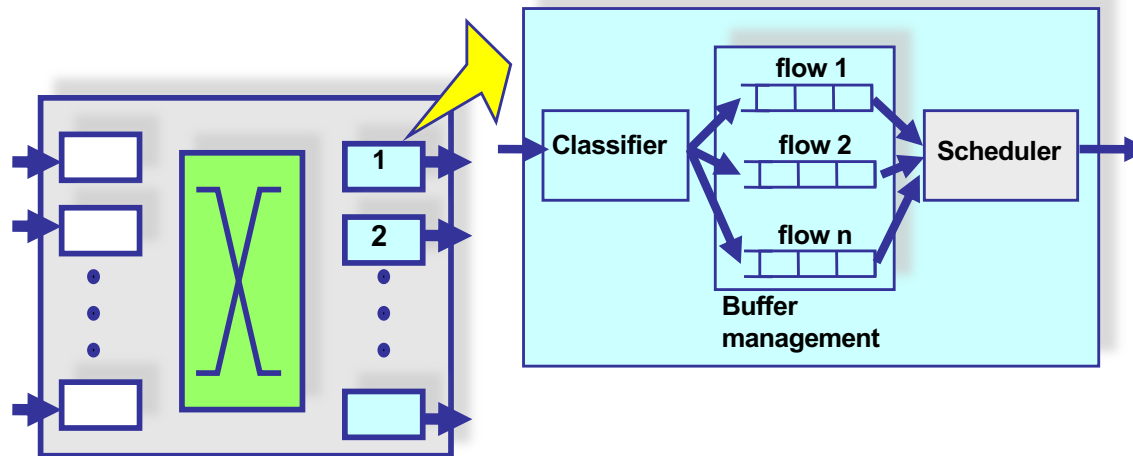
- IQ + VoQ + OQ
 - ◆ Speedup of 2
 - ◆ Central scheduler
 - ◆ Fixed-sized internal cells
- Pro
 - ◆ Can achieve utilization of 1
 - ◆ Can scale to > Tb/s
- Con
 - ◆ Multiple congestion points
 - ◆ Complexity





Key Router Challenges

- **Buffer management**: which packet to drop when?
 - ♦ We only have finite-length queues
- **Scheduling**: which packet to transmit next?





Basic Buffer Management

- FIFO + drop-tail
 - ♦ Simplest choice
 - ♦ Used widely in the Internet
- FIFO (first-in-first-out)
 - ♦ Implies single class of traffic
- Drop-tail
 - ♦ Arriving packets get dropped when queue is full regardless of flow or importance
- Important distinction:
 - ♦ FIFO: scheduling discipline
 - ♦ Drop-tail: drop policy (a.k.a. buffer management)



FIFO/Drop-Tail Problems

- Leaves responsibility of **congestion control** completely to the edges (e.g., TCP)
- Does not separate between different flows
- No policing: send more packets → get more service
- Synchronization: end hosts react to same events

Active Queue Management



- Design active router queue management to aid congestion control
- Why?
 - ◆ Router has unified view of queuing behavior
 - ◆ Routers see actual queue occupancy (end hosts have difficulty distinguishing between queuing delay and propagation delay)
 - ◆ Routers can decide on transient congestion, based on workload

Design Objectives



- Keep throughput high and delay low
 - ◆ High **power** (throughput/delay)
- Accommodate bursts
- Queue size should reflect ability to accept bursts rather than steady-state queuing
- Improve TCP performance with minimal hardware changes in router



Random Early Detection

- Detect incipient congestion
- *Assume* hosts respond to lost packets
- Avoid window synchronization
 - ◆ Randomly mark packets
- Avoid bias against bursty traffic

RED Algorithm



- Maintain running average of queue length in router
- If $\text{avg} < \text{min}_{\text{th}}$ do nothing
 - ◆ Low queuing, send packets through
- If $\text{avg} > \text{max}_{\text{th}}$, drop packet
 - ◆ Protection from misbehaving sources
- Else drop/mark packet in a manner proportional to queue length
 - ◆ Notify sources of incipient congestion
 - ◆ Dropping vs Marking tradeoff (Explicit Congestion Notification)

Is RED a scheduling discipline or a buffer management policy?

- A. Scheduling discipline**
- B. Buffer management policy**
- C. Both**
- D. Neither**

For next time...



- Read Ch. 6.2 in P&D
- Project 2a due Monday
- NO CLASS MONDAY (University holiday)