Computer Networks
COL 334/672

Data Plane

Slides adapted from KR

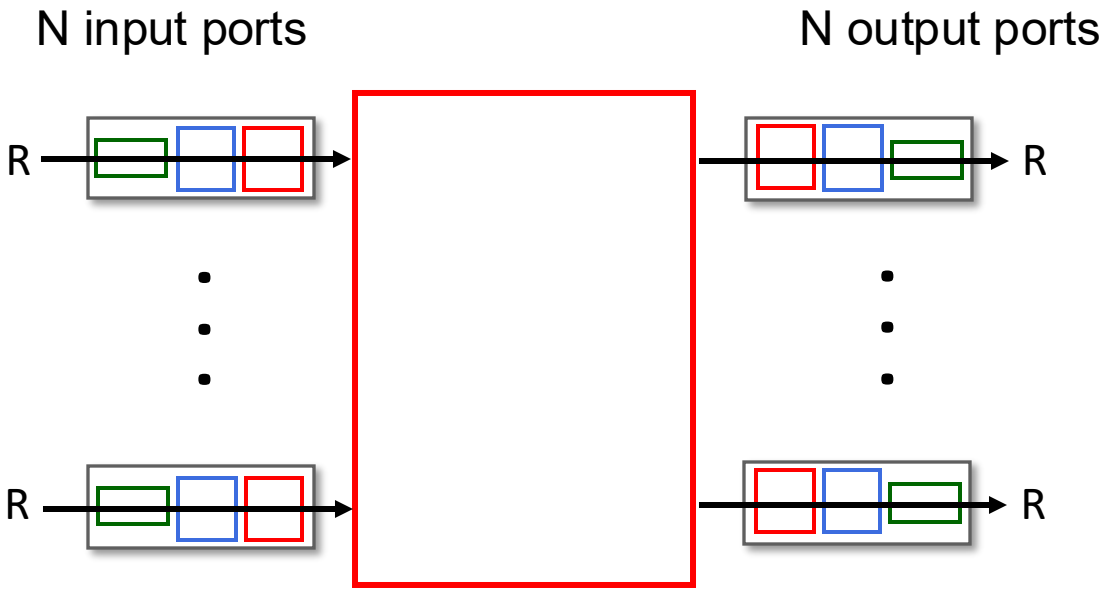
Sem 1, 2025-26

Today's Class: Data Plane Functions

- IP lookup
- **Switching**
- Queuing
- Scheduling

Switching

- Transfer packets from input port to appropriate output port
- Switching rate depends on switching fabric and switching algorithm at the router
- Switching hardware
  - Switching via CPU
  - Switching via a bus
  - Interconnection network

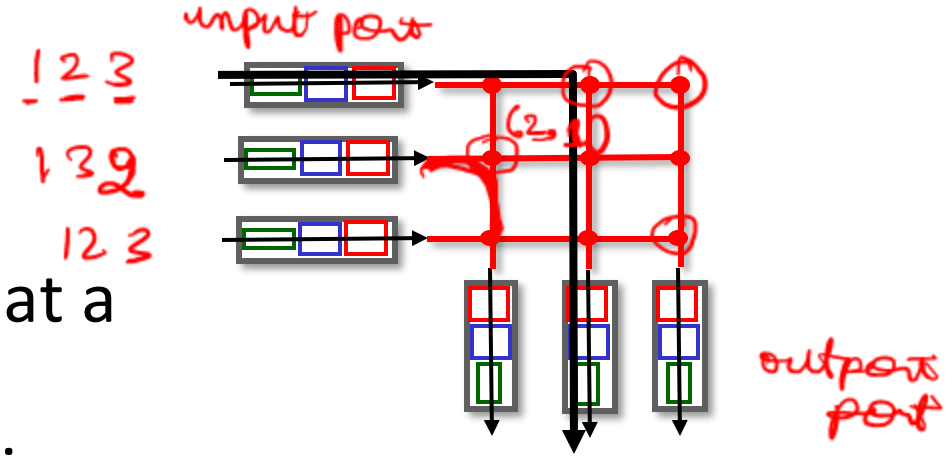


crossbar switch

Switching via interconnection network

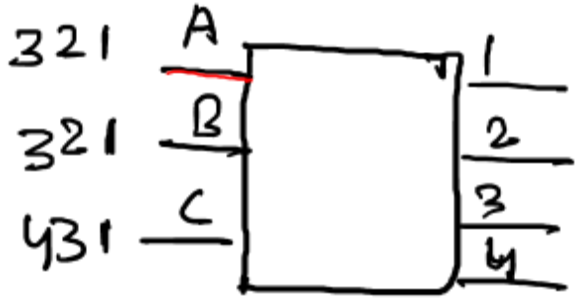
- Grid of N inputs, N outputs
- How it works:
  - Each input can connect to one output at a time and vice-versa
  - Multiple input-output pairs can be active at the same time
- How to decide which input-output should be connected at each timeslot

Switching algorithm

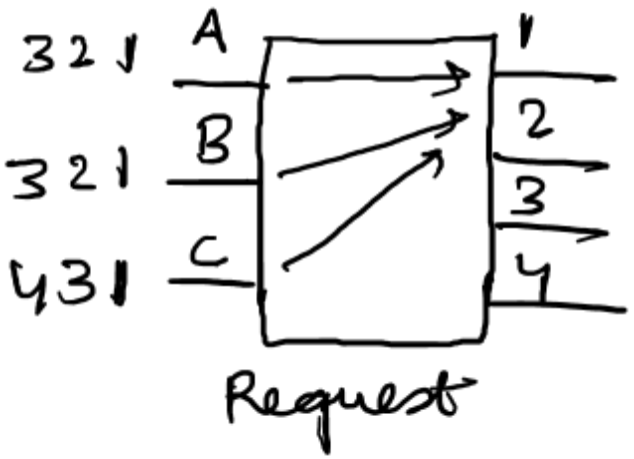


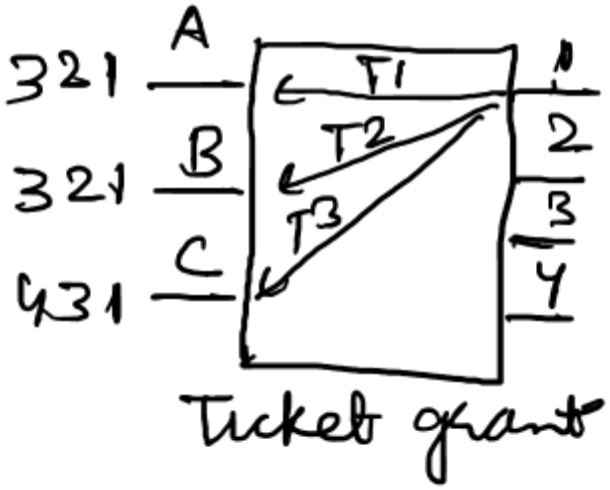
Switching algorithm

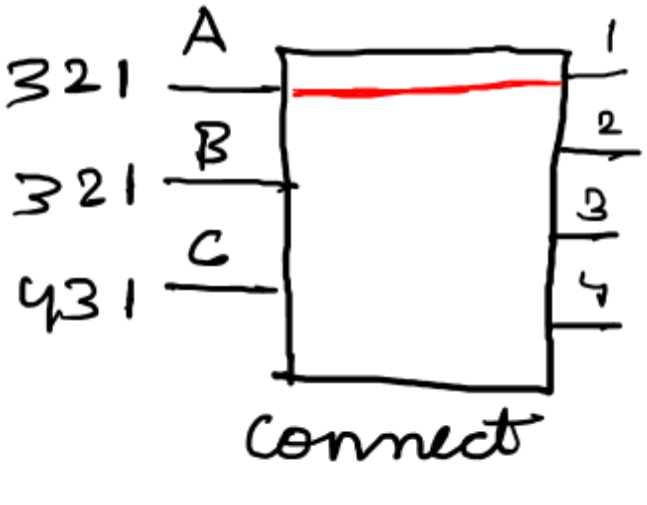
- Take a ticket mechanism: Use a simple ticket number mechanism for scheduling packets waiting at input port



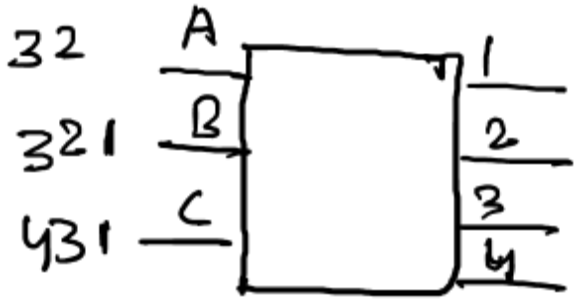
Round 1

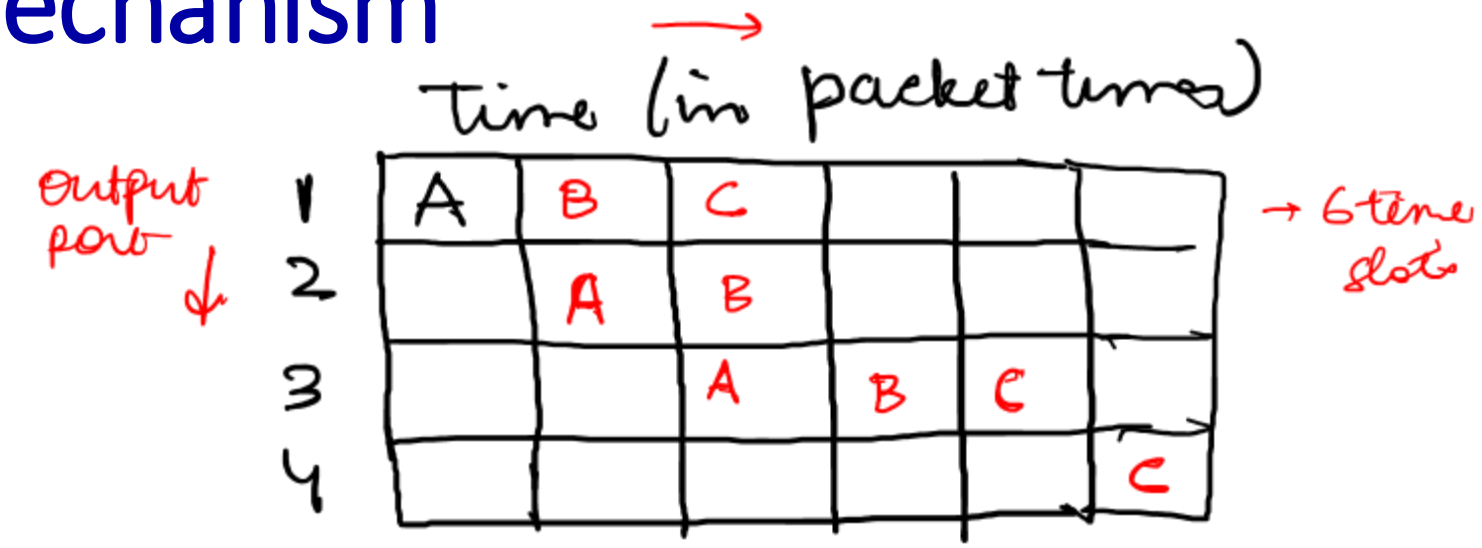




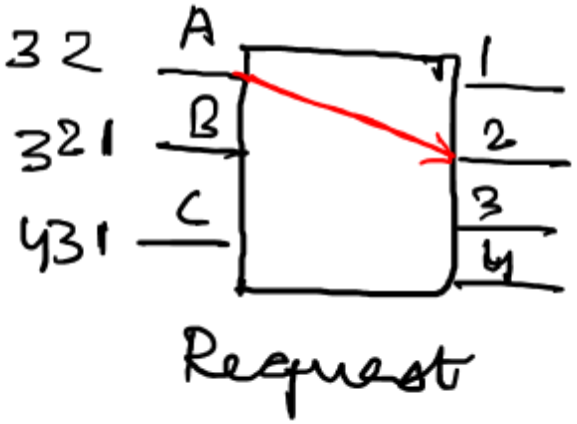


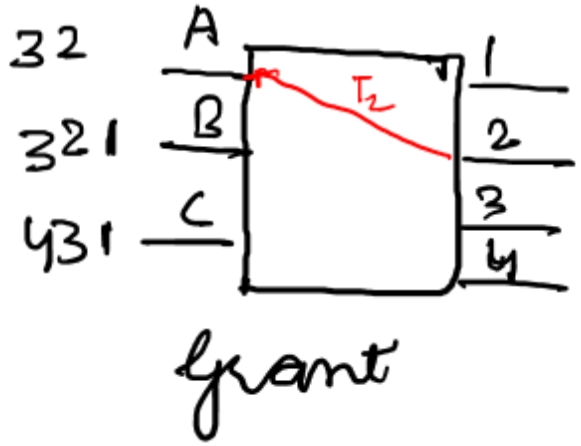
Take a Ticket Mechanism

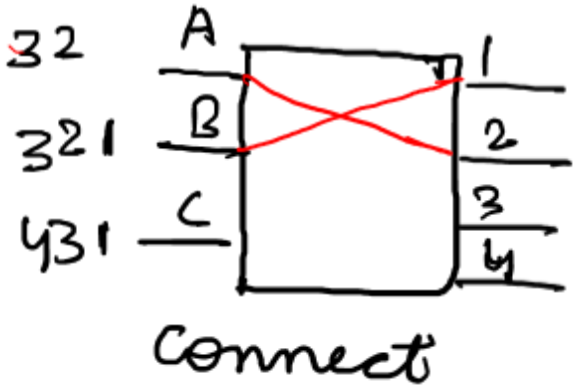




Round 2



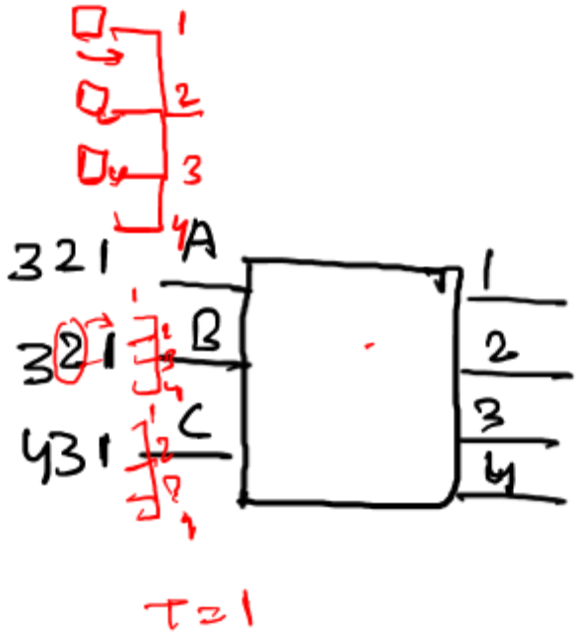




Can we do better?

Input port queuing

- Head-of-Line (HOL) blocking: datagram at front of queue prevents others in queue from moving forward
- Use virtual output queuing

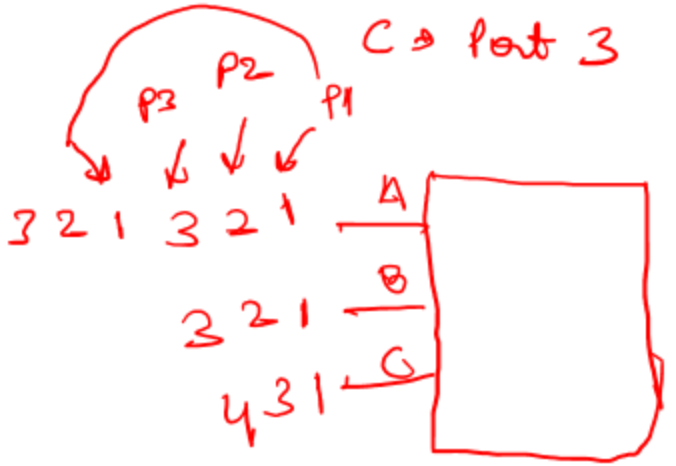


→ Having separate physical queues is cumbersome.

→ Instead keep n pointer, one for each output port.

→ The pointer points to the 1st packet in the queue for that output port

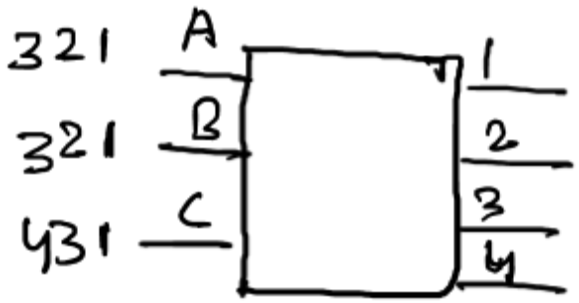
A = Port 1
B → Port 2
C → Port 3

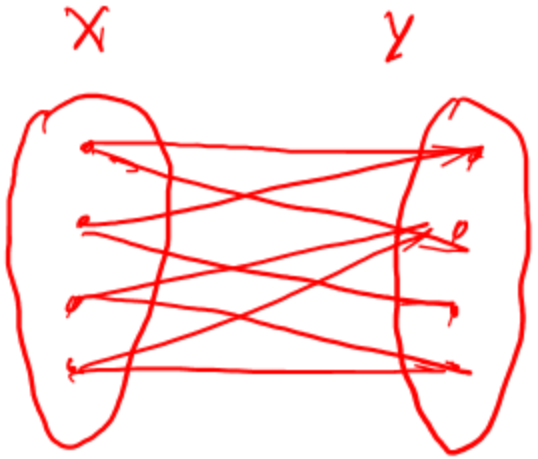


When we use Virtual Output Queuing

- Switching problem reduces to maximum bipartite matching problem
- Known algorithms to solve it optimally
  - However, too slow! $O(n^3)$
  - Approximation algorithms: E.g., Parallel Iterative Match $O(n)$

iSlip





Bipartite graph ←

Edge b/w X & Y only

Maximum BP: largest # of edges

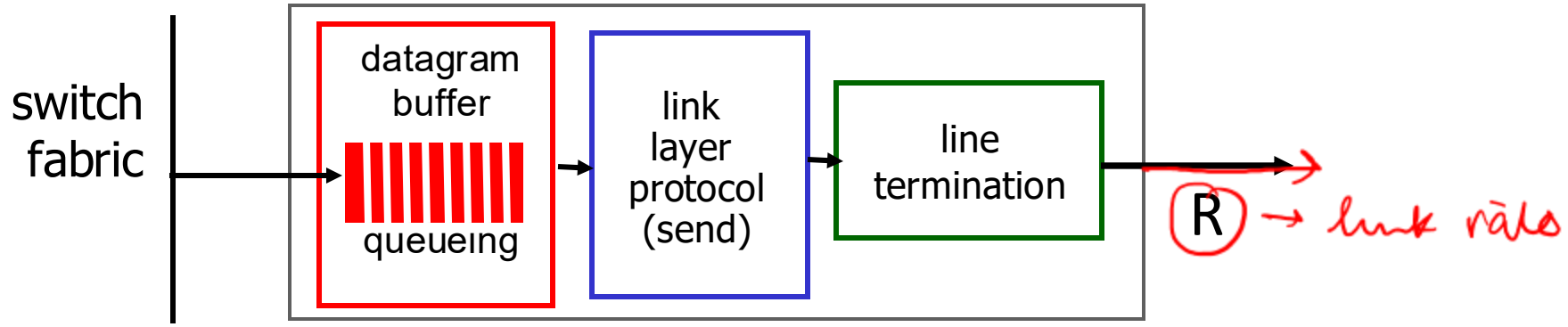
Bipartite matching: set of edges in the graph such that no two edges share a vertex

Data Plane Functions

- Prefix lookup
- Switching
- **Queuing**
- Scheduling

Output port queuing

if arrival rate > R ; packets need to be queued



- *Buffering* required when datagrams arrive from fabric faster than link transmission rate, otherwise datagrams will get lost

How large should be that buffer?

① circuit space is limited

How much buffering?

- Why not simply use large buffers?
- ② but *too* much buffering can increase delays (particularly in home routers)
  - long RTTs: poor performance for real-time apps, sluggish TCP response

Bandwidth-delay product

- RFC 3439 rule of thumb: average buffering equal to "typical" RTT (say 250 msec) times link capacity C
  - e.g., C = 10 Gbps link: 2.5 Gbit buffer

C x 250 ms

Updated rule of thumb: $\frac{C \times RTT}{\sqrt{n}}$; n is no of flows

queuing delay will increase

1 Bufferbloat [Video conferencing, gaming, Trading

Trade-off :

Smaller buffer : higher pkt drops

larger buffer ; Bufferbloat

Data Plane Functions

- Prefix lookup
- Switching
- Queuing
- **Scheduling**

Packet Scheduling: FCFS

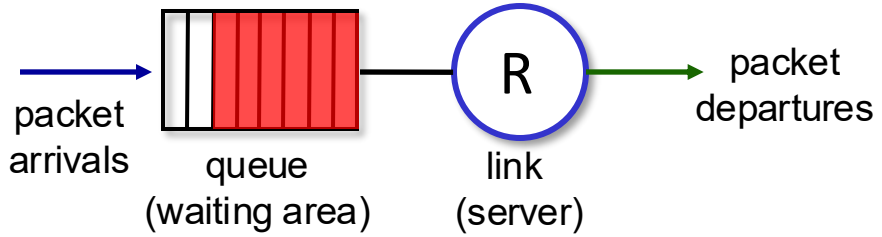
packet scheduling: deciding which packet to send next on link

Can you think of some queuing policies?

FCFS: packets transmitted in order of arrival to output port

- also known as: First-in-first-out (FIFO)

Abstraction: queue

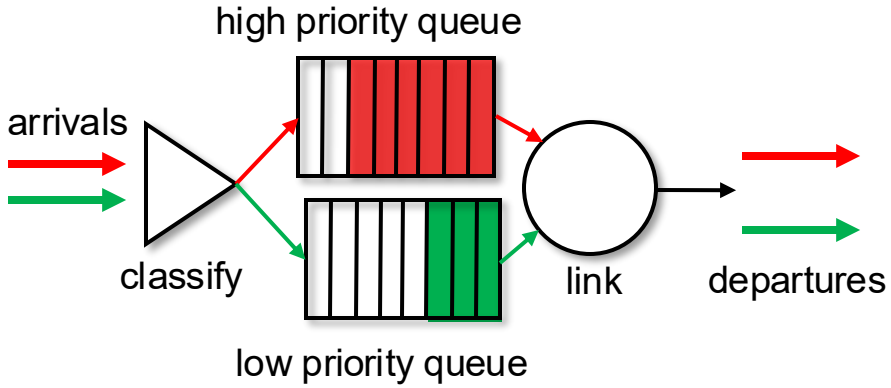


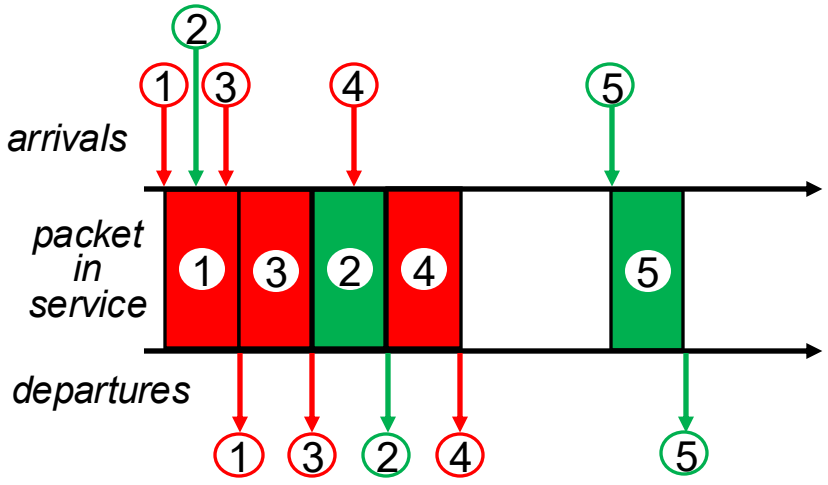
Scheduling policies: priority

Pre-emptive
Non pre-emptive
} will study in → OS too

Priority scheduling:

- arriving traffic classified, queued by class
  - any header fields can be used for classification
- send packet from highest priority queue that has buffered packets
  - FCFS within priority class

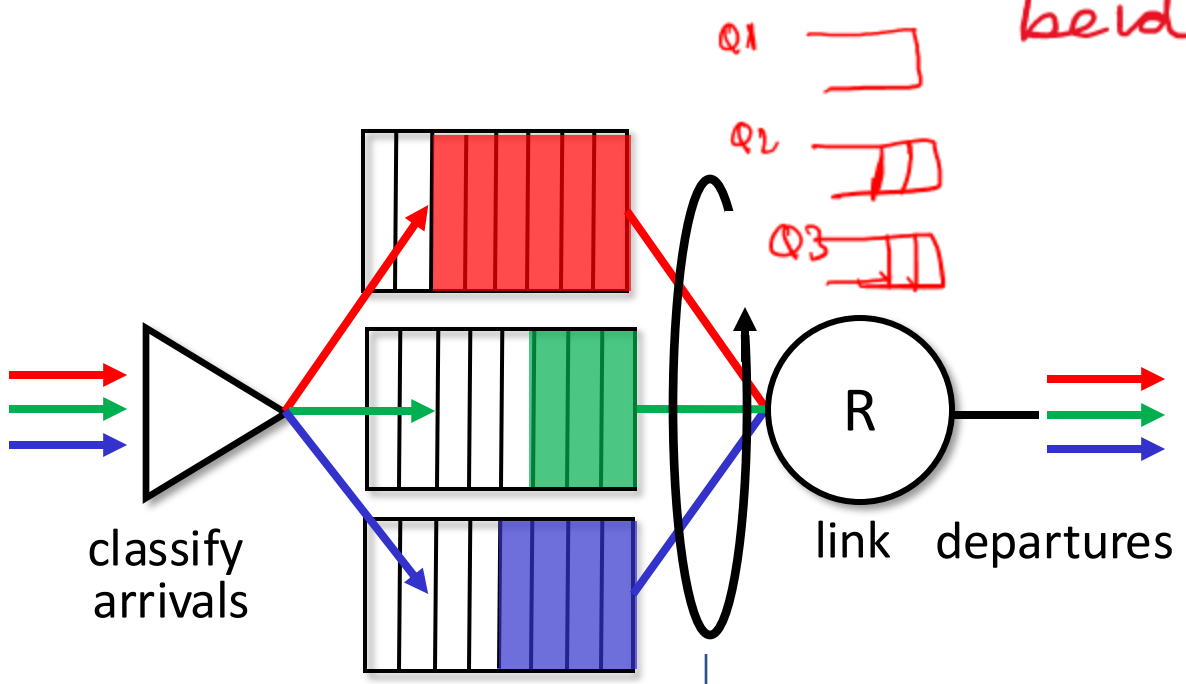




Scheduling policies: round robin

Round Robin (RR) scheduling:

- arriving traffic classified, queued by class
  - any header fields can be used for classification
- server cyclically, repeatedly scans class queues, sending one complete packet from each class (if available) in turn



Scheduling policies: weighted fair queueing

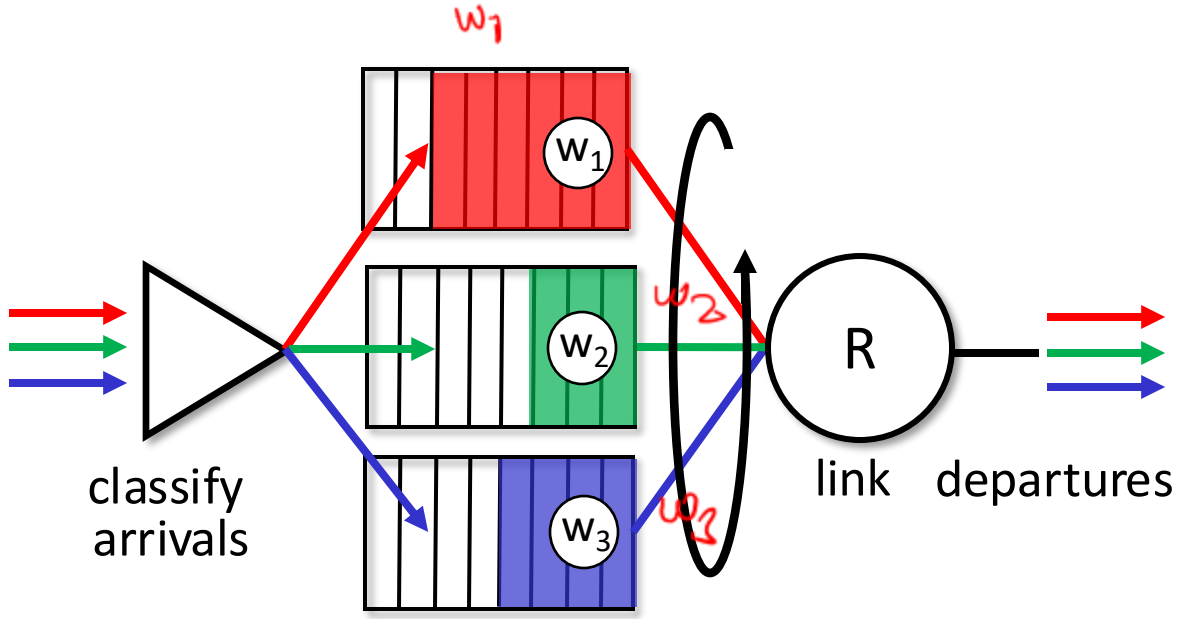
$w_i = 1$ for RR.

Weighted Fair Queuing (WFQ):

- generalized Round Robin
- each class, *i*, has weight, w_i, and gets weighted amount of service in each cycle:

$$\frac{w_i}{\sum_j w_j}$$

- minimum bandwidth guarantee (per-traffic-class)



What about net neutrality?

Sidebar: Network Neutrality

What is network neutrality?

Internet service providers (ISPs) must treat all Internet communications equally regardless of content, website, platform, application, type of equipment

Different countries have different "takes" on network neutrality

Network Neutrality: India

ISPs Perspective

In February 2012, at the World Mobile Congress held in Barcelona, the CEO of Bharti Airtel, Sunil Bharti Mittal suggested that services like YouTube should pay an interconnect charge to network operators, saying that if telecom operators are building highways for data then there should be a tax on the highway.[14] In July 2012, Bharti Airtel's Director of Network Services, Jagbir Singh suggested that large Internet companies like Facebook and Google should share revenues with telecom companies. According to him, Internet companies were making big profits from small investments, whereas the telecom companies were actually investing in building networks. He also suggested that the telecom regulator should establish interconnection charges for data services, similar to those applied to voice calls.[15] In August 2012, *The Hindu* reported that according to data from M-Lab, You Broadband, Airtel, and BSNL were throttling BitTorrent traffic.[16]

Facebook Free Basics

Facebook's proposed Free Basics is a new avatar of its internet.org initiative which allows customers to access a slew of apps for free. However, activists are pushing back this initiative arguing that with Free Basics, Facebook would become a gatekeeper, deciding who would not be on the Free Basics platform and in the process, make or break fortunes of several startups.[60] As a result, Facebook has challenged the TRAI after releasing its Free Basics zero-rating app "which provides access to a host of Internet services like Wikipedia, the BBC, health sites and weather reports, and, of course, Facebook. The services are lightweight versions of the originals that load quickly and perform well on less robust 2G and 3G networks."[61] The TRAI blocked Free Basics on the basis that although the service is free, there are specific sites that cannot be accessed unless the consumer pays. Zuckerberg countered this argument by releasing a statement saying, "It's not an equal Internet if the majority of people can't participate."[61] Towards the

Summary

- Control plane functions
  - Inter-domain vs intra-domain routing
- Data plane functions
  - Prefix lookup
  - Switching
  - Buffering
  - Scheduling ..
- Next: We will meet the IPv4 and IPv6 packets