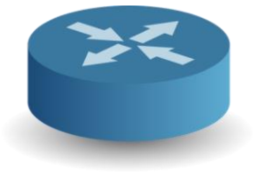


CMPN415 – CMP405B
Computer Networks

Part FOUR – 3rd lecture

Internetworking – Quality of Service

Most Important Slides

Quality of Service

Approaches to Achieve "*Good*" QoS

1. Over-provisioning
2. Buffering
3. Traffic Shaping
4. Packet Scheduling
5. Admission Control
6. Resource Reservation

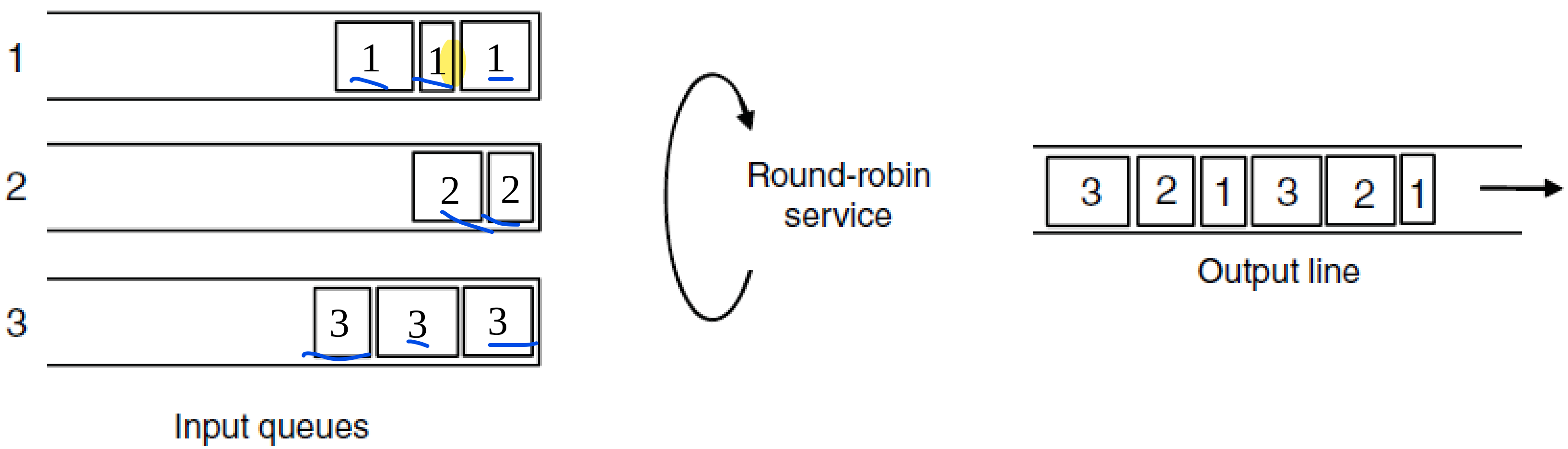
Usually more than one technique is used at the same time to satisfy the QoS requirements

4. Packet Scheduling

- Fluid Fair queuing (theoretical not applied)
  - Assign a queue to each flow
  - Assumes packet is infinitesimally divisible
  - Send part of each packet
  - All flows take same share of resources
- Fair queuing (output is Round Robin)
  - Assign a queue to each flow
  - Take one packet from each queue in round robin order
  - Problem: flows with larger packets dominate resources
  - All flows take same share of resources
- Weighted fair Queuing (Most used policy)
  - Assign a weight to each flow
  - Packets are scheduled such that flows with **higher weight get more resources**

Packet Scheduling
Fair Queuing

Packet scheduling divides router/link resources among traffic flows with alternatives to FIFO (First In First Out)



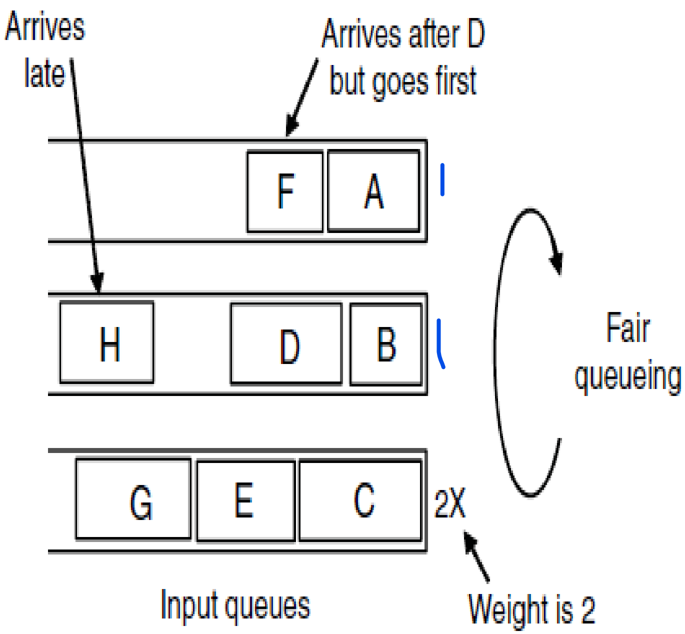
Example of round-robin queuing

Packet Scheduling: Weighted Fair Queuing

Fair Queueing approximates bit-level fairness with different packet sizes; weights change target levels

- Result is WFQ (Weighted Fair Queueing)

Virtual finish time is Calculated based on packets in same queue



Packet	Arrival time	Length	Finish time	Output order
A	0	8	8	1
B	5	6	11	3
C	5	10	10	2
D	8	9	20	7
E	8	8	14	4
F	10	6	16	5
G	11	10	19	6
H	20	8	28	8

WL
8
6
5
9
4
6
5
8

Packets may be sent out of arrival order

Finish virtual times determine transmission order

- Finish time is calculated from Weighted length
- Output order is based on Finish time

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5. Admission Control

Admission control takes a <u>traffic flow specification </u>and decides whether the network can carry it

- Sets up packet scheduling to meet QoS

Parameter	Unit
Token bucket rate	Bytes/sec
Token bucket size	Bytes
Peak data rate	Bytes/sec
Minimum packet size	Bytes
Maximum packet size	Bytes

Max. Rate for sender

Processing at router

Internetworking

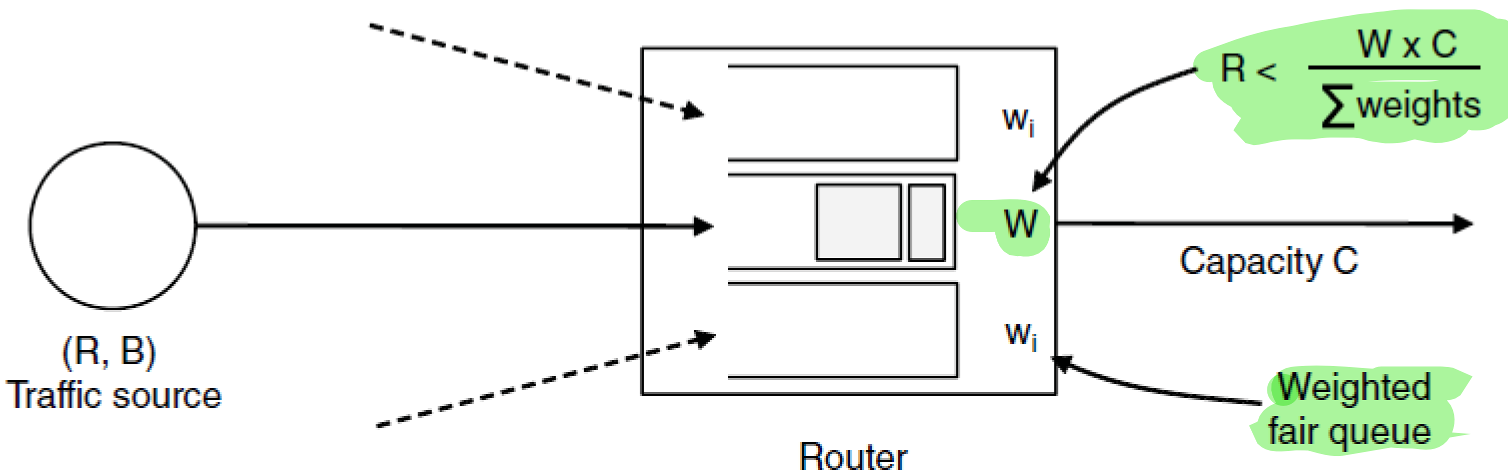
Example flow specification

Admission Control

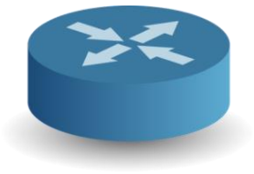
Construction to guarantee bandwidth B and delay D:

1. Shape traffic source to a (R, B) token bucket
2. Run WFQ with weight W / all weights > R/capacity

Holds for all traffic patterns, all topologies



if the flow has a rate of 1 Mbps and the router and output link have a capacity of 1 Gbps, the weight for the flow must be greater than 1/1000th of the total of the weights for all of the flows at that router for the output link.



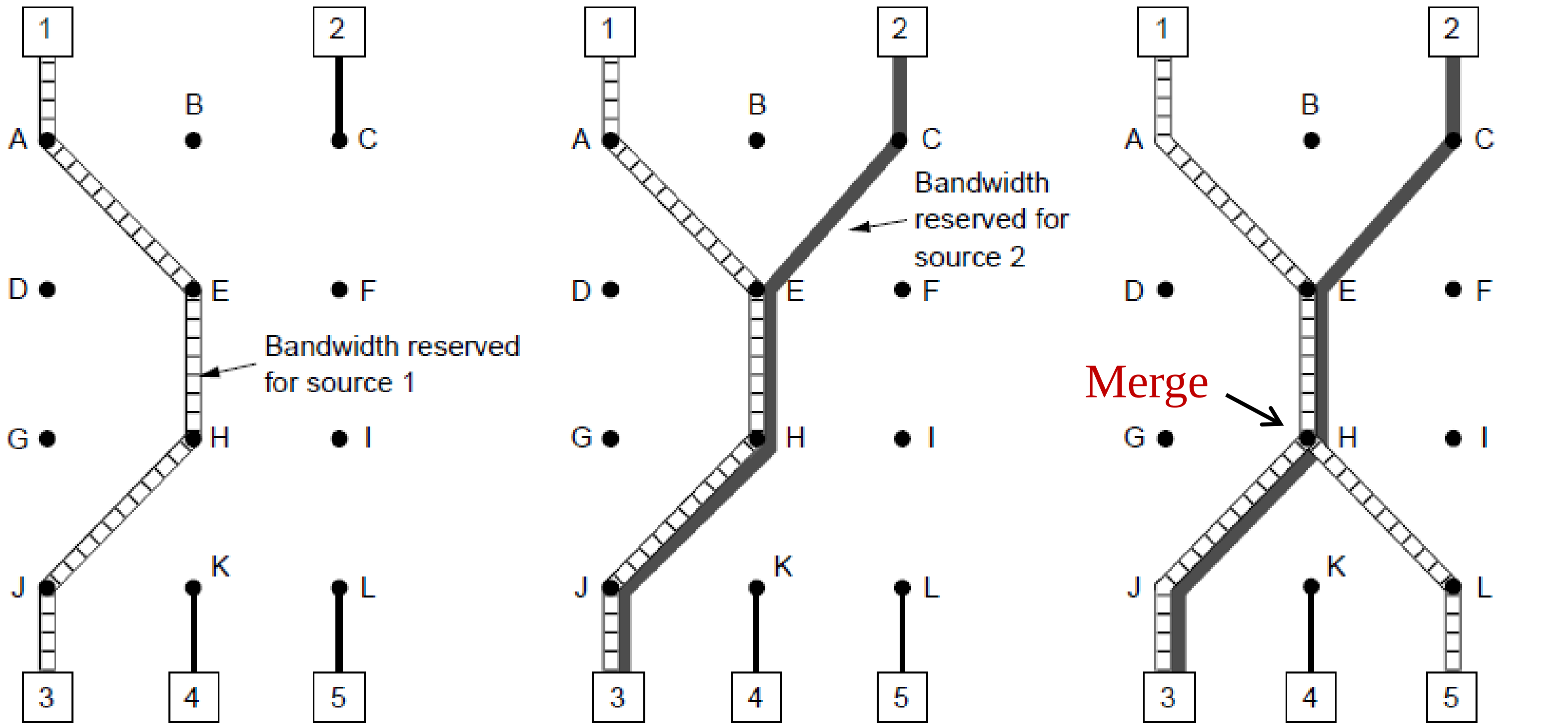
6. Resource Reservation Integrated Services

Design with QoS for each flow; handles multicast traffic.

Admission with **RSVP** (Resource reSerVation Protocol):

- Receiver sends a request back to the sender
- Each router along the way reserves resources
- Routers merge multiple requests for same flow
- Entire path is set up, or reservation not made

Integrated Services



R3 reserves flow from S1

R3 reserves flow from S2

R5 reserves flow from S1; merged with R3 at H

RSVP: disadvantages

- Not very scalable
  - Relies on specifying each flow separately
  - No flow aggregation
  - Problems when there are millions of flows
- State maintenance per router
  - Need to maintain state per flow
  - Complex if router crash
- Complex protocol
  - Complex end-to-end message exchange
  - Substantial implementation effort

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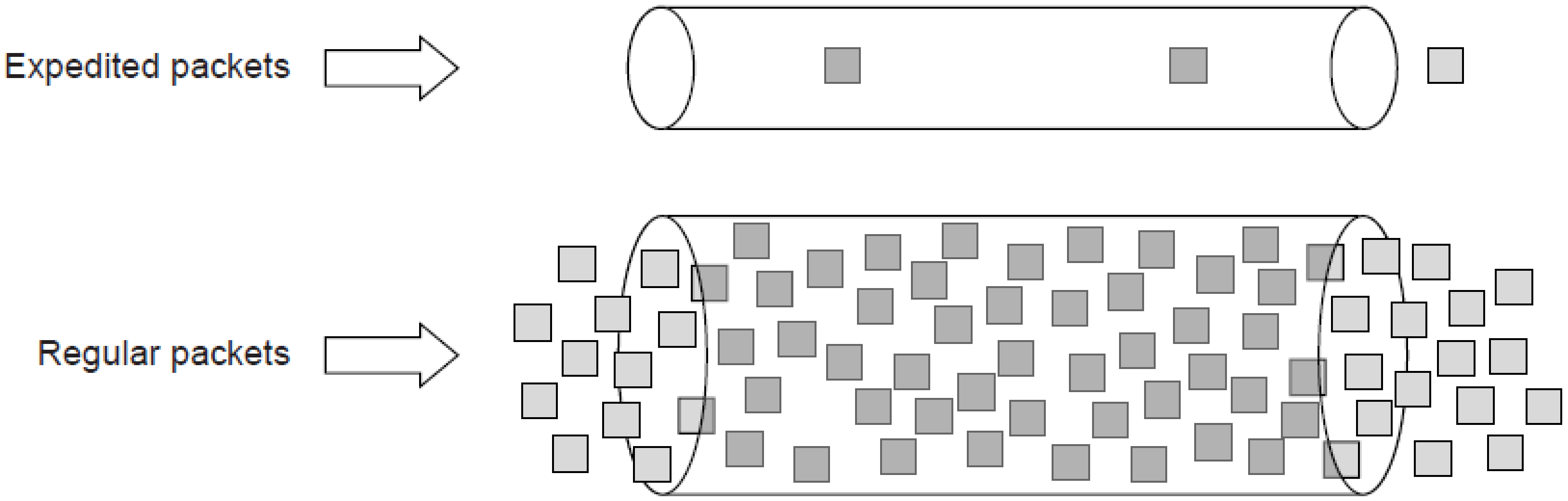
Differentiated Services

Design with classes of QoS; customers buy what they want

- **Expedited class:** is sent in preference to regular class
- **Regular Class**: Less expedited traffic but better quality for applications



Assured Forwarding (RFC2597)

Implementation of DiffServ:

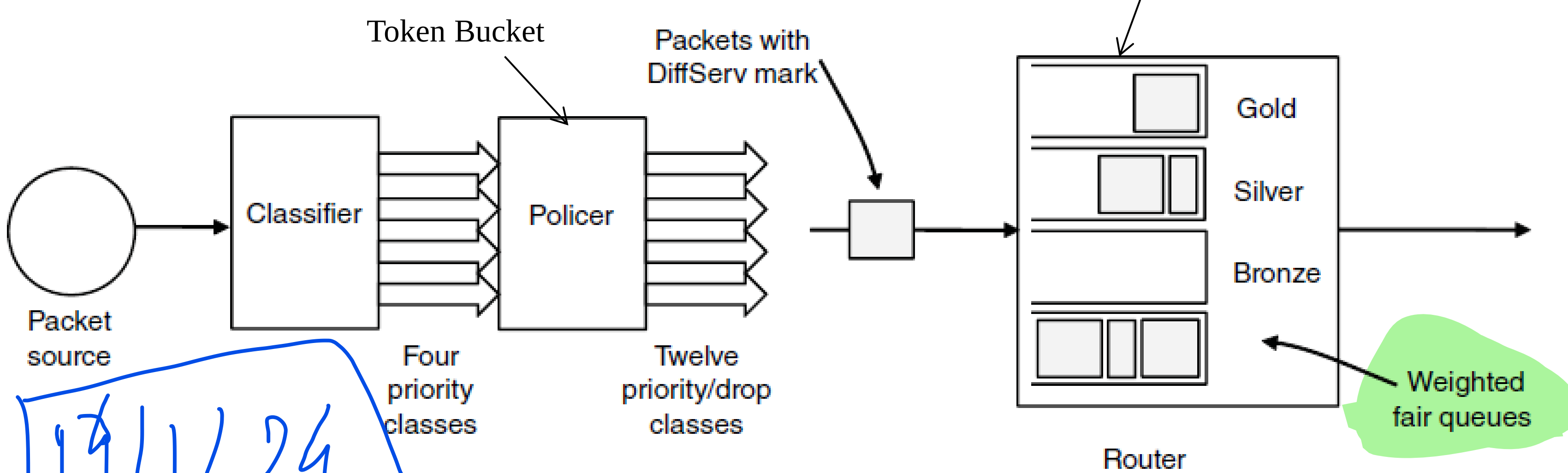
- 4 priority classes: each has its own resources
- 3 drop/discard probability in case of congestion: Low, medium, high

Total: 12 classes

Example of implementation

- Customers mark desired class on packet
- ISP shapes traffic to delay or drop packets
- Routers use WFQ to give different service levels

At Router: Higher discard class can be dropped using RED



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