Basics (cont.)

- Characteristics of data communication technologies
- OSI-Model
- Topologies
- Packet switching / Circuit switching
- Medium Access Control (MAC) mechanisms
- Coding
- Quality of Service (QoS)

The need for QoS

Convergence of media:

Congestion occurs due to increasing data rates and traffic bursts

➔ result: delays, jitter, data loss

➔ no serious effect for non-real time applications like ftp or e-mail

➔ but: limitation for real-time applications

➔ A challenge for IP networks!

What is QoS

- Quality of Service provides a certain level of reliability so that the service requirements of a transmission are met
- Ideal case:
  QoS provides dedicated bandwidth, controlled jitter and delay, and improves loss characteristics.

Quality Parameters

- Delay (latency)
  the total elapsed time for a packet to go from the sender to the receiver

- Delay variation (jitter)
  the variation in the arrival time between consecutive packets

- Loss ratio or reliability
  the average error rate or the ratio of the number of packets that arrive and are usable at the destination to the number of packets that either do not arrive or are unusable (e.g. packets that arrive too late)

Quality of Service Requirements

Service	Delay Latency	Delay variations (Jitter)	Reliability
Mail / File transfer	low	low	high
Database	low / medium	low	high
Video (MPEG)	high	medium	low
Telephony / Video Conference	high	high	low

QoS Approaches

- Resource Reservation (Integrated Services)
  Network resources are allocated according to the applications' QoS requests, and are subject to bandwidth policy.

- Prioritization (Differentiated Services, DiffServ)
  Network traffic is classified. To enable QoS, network elements give preferential treatment to classifications identified as having more demanding requirements.

Integrated Services (IntServ)

- standardized in RFC‘s 2210 - 2215
- provide special handling for real-time applications
- mechanisms to
  - identify traffic
  - handle traffic according to service level
- division of real-time traffic in two types
  - applications which can tolerate some amount of delay and jitter
  - applications which need strict bandwidth guarantee
- provide constraints on the delay, but does not attempt to minimize jitter
- use of the signaling protocol RSVP

IntServ Service Types

IntServ

Controlled-load Service

- equivalent to "best effort service under unloaded condition"
- routers use statistical approaches to decide whether the requested bandwidth is available

Guaranteed-load Service

- fixed boundaries on end-to-end queuing delays
- guarantees only possible for delays caused by queuing, not for the fixed delays (e.g. for transmission)

Resource Reservation Protocol (RSVP)

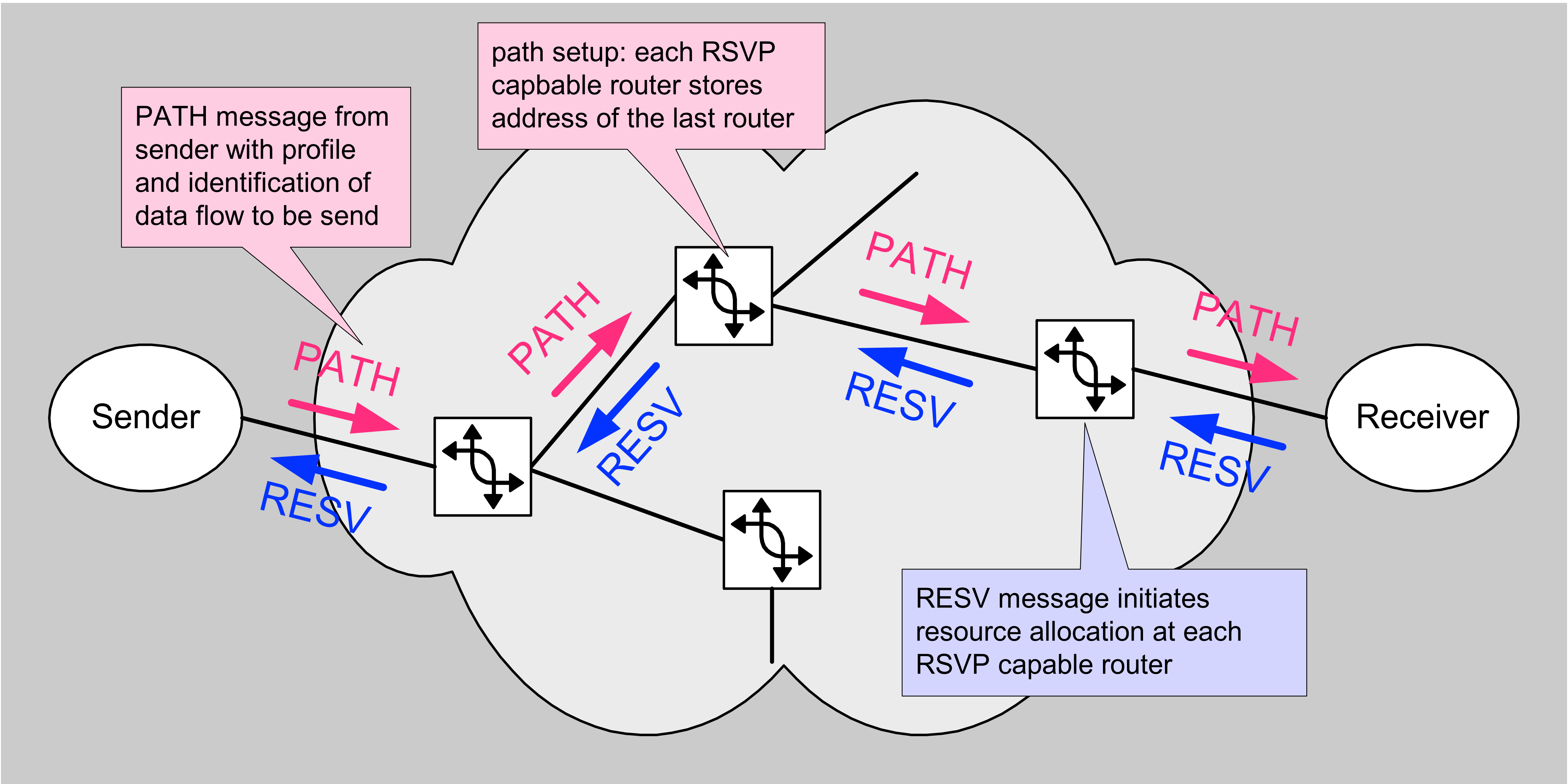
- RFC 2205

- signaling protocol that provides reservation setup and control
- includes periodic refresh messages to maintain the state along the reserved path(s)

- reservation of resources only in one direction
- usable for unicast and multicast transmissions

- relies on IP routing protocols

RSVP Reservation Set Up

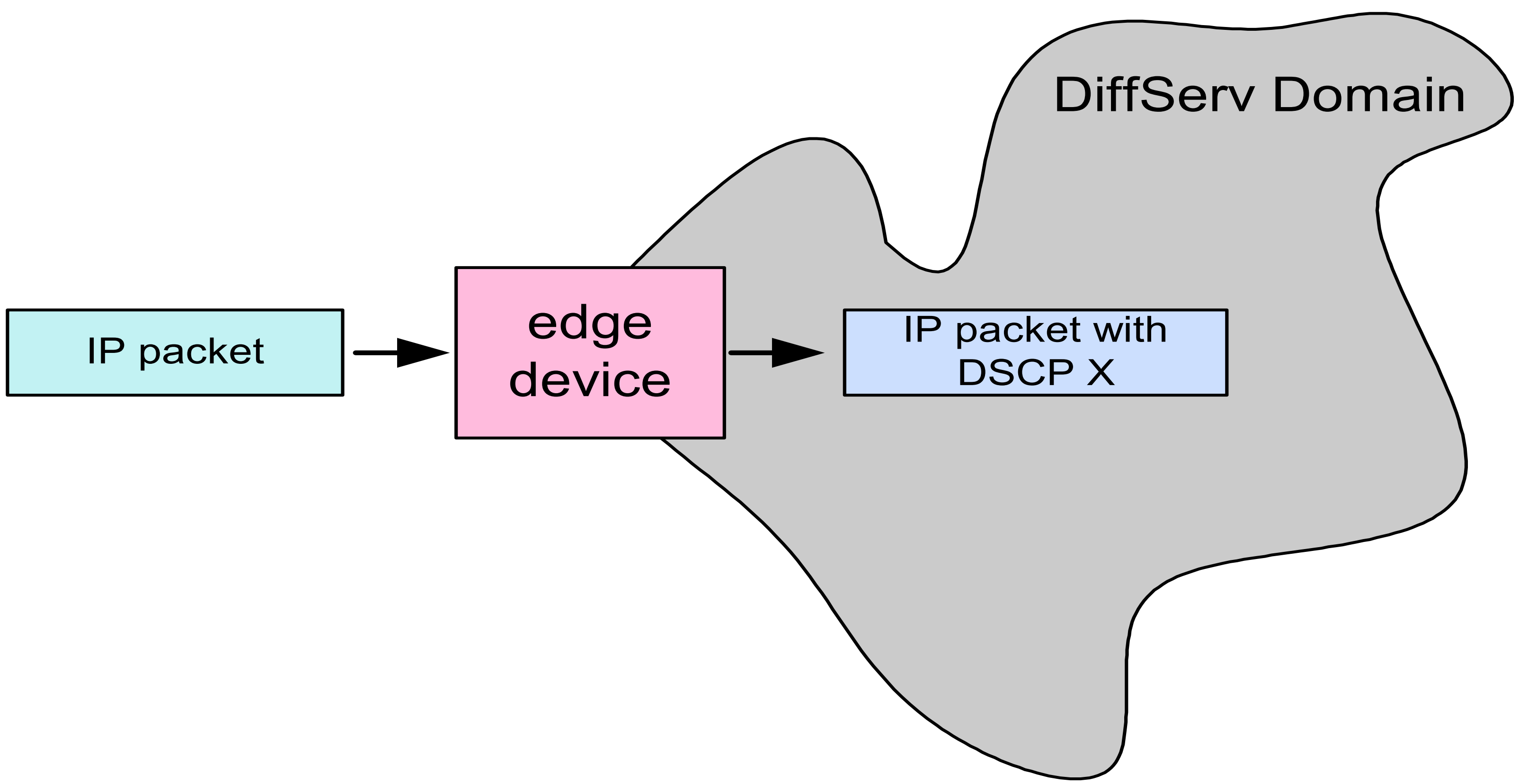


RSVP Issues

- RSVP involves many layers
- RSVP adds additional overhead to a data flow
  ➔ efficiency
- RSVP traffic can pass non-RSVP routers
  ➔ weak links with a ”best effort” service
- RSVP is not widely used because it is not supported on many of the applications and operating systems
- RSVP operates on the first-come, first-served basis. It is impossible to prioritize critical applications.
- RSVP requires nontrivial modifications to the network (applications and all routers should support RSVP for a good performance)

Differentiated Services (DiffServ) I

- packets entering a DiffServ domain are classified and marked
- packet marking is done by network edge devices
- resources are allocated for the different classes
- use of the IPv4 Type of Service (ToS) field which is for DiffServ renamed in Differentiated Services Codepoint (DSCP) field
- DSCP value specifies a drop-order



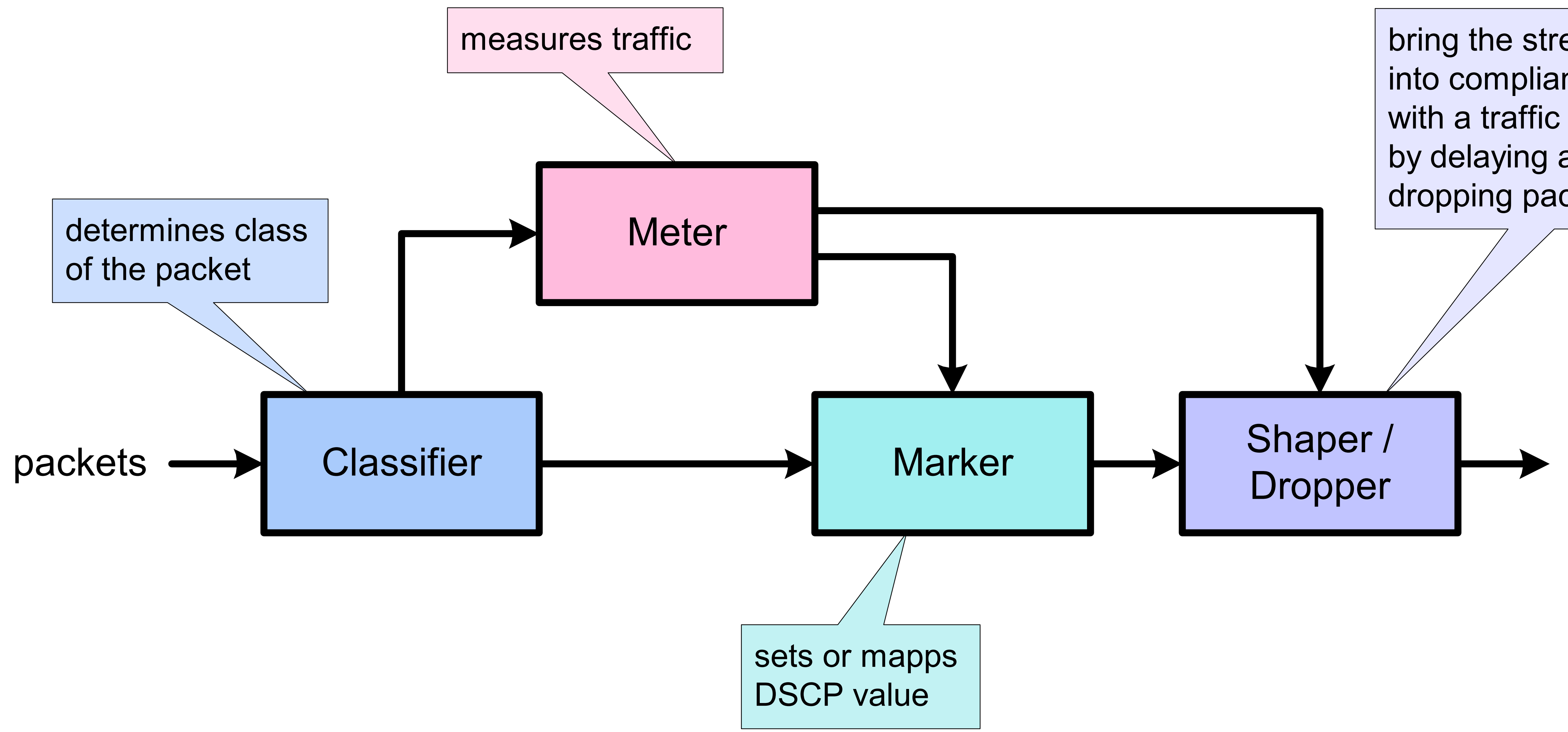
Differentiated Services (DiffServ) II

- each router treats a packet according to the DSCP value
- packets with different DSCP values receive different treatment by the routers (Per Hop Behavior - PHB)
- determination of the classes are based on the policy of the DiffServ domain
- service provider and user define a traffic profile in a contract called Service Level Agreement (SLA)
- the traffic profile describes temporal properties of a traffic stream such as rate and burst size

DiffServ Service Levels

Service Level	PHB	Description
premium	Expedited Forward (EF)	Has a single value (codepoint). EF minimizes delay and jitter and provides the highest level of quality of service. Any traffic that exceeds the defined traffic profile is discarded.
tiered	Assured Forward (AF)	Has four classes and three drop-precedences within each class (together 12 codepoints). Excess traffic is not delivered with as high probability as the traffic within the profile, which means it may be demoted but not necessarily dropped.
best effort	Default Forward (DF)	

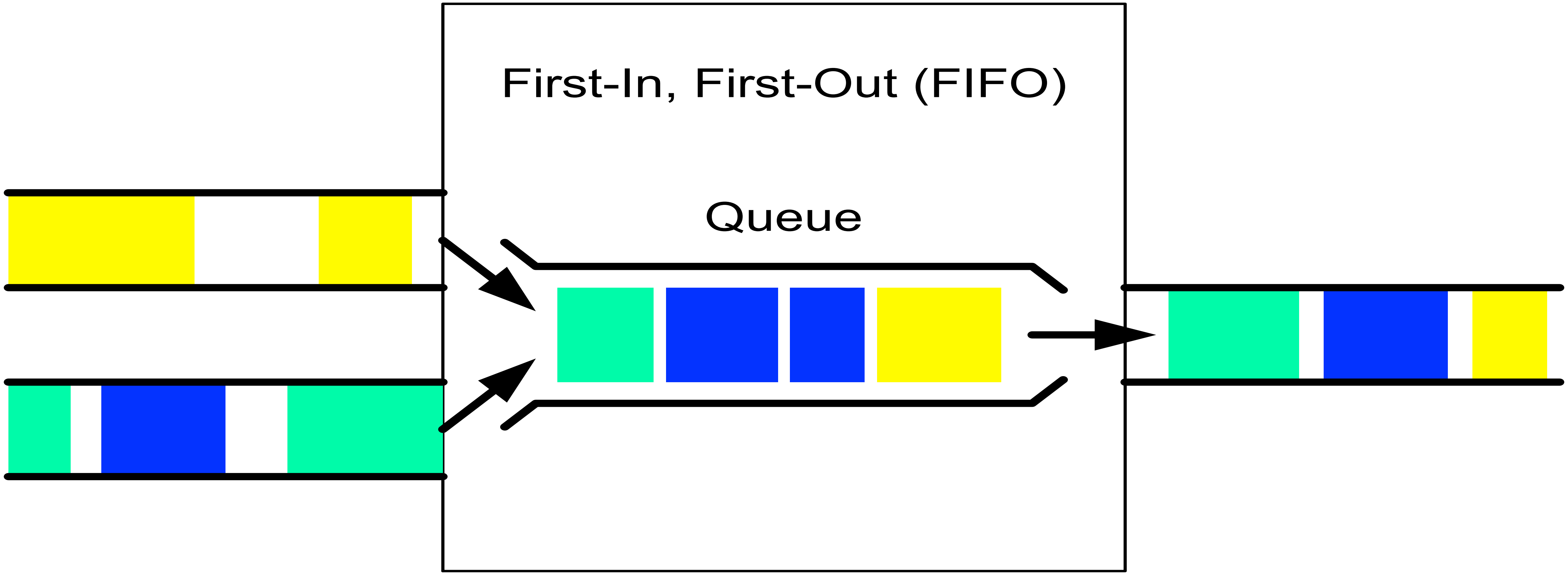
Elements of a DiffServ Router



Bandwidth Managers

- At the moment the traffic is classified independently of the current condition of the network
- Bandwidth Managers are planned/available
- they determine dynamically the status and the availability of network resources
- this information is delivered to the classifiers

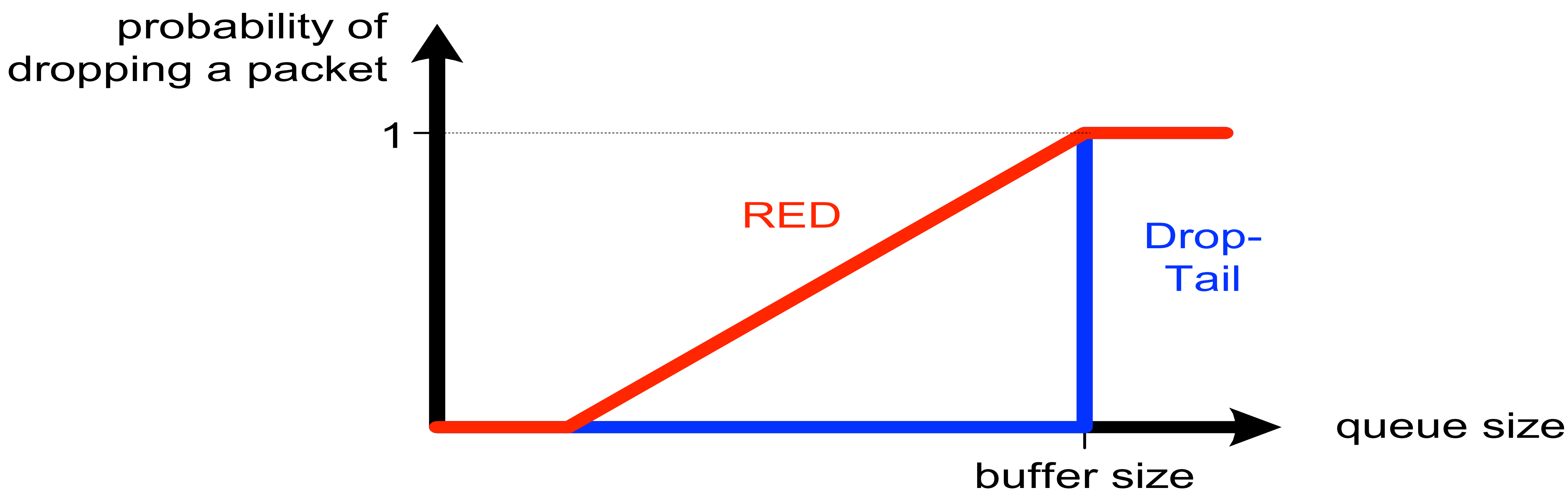
Queuing and Scheduling



- Non-DiffServ Routers employ FIFO scheduling and a drop-on-overflow buffer management.
- When a buffer overflow occurs packets of all connections may be affected.

Queue Management: Random Early Discard (RED)

- RED drops packets before a buffer overflow occurs
- the TCP connections to which the packets belong are slowed down
- the average of the traffic is kept below the critical point

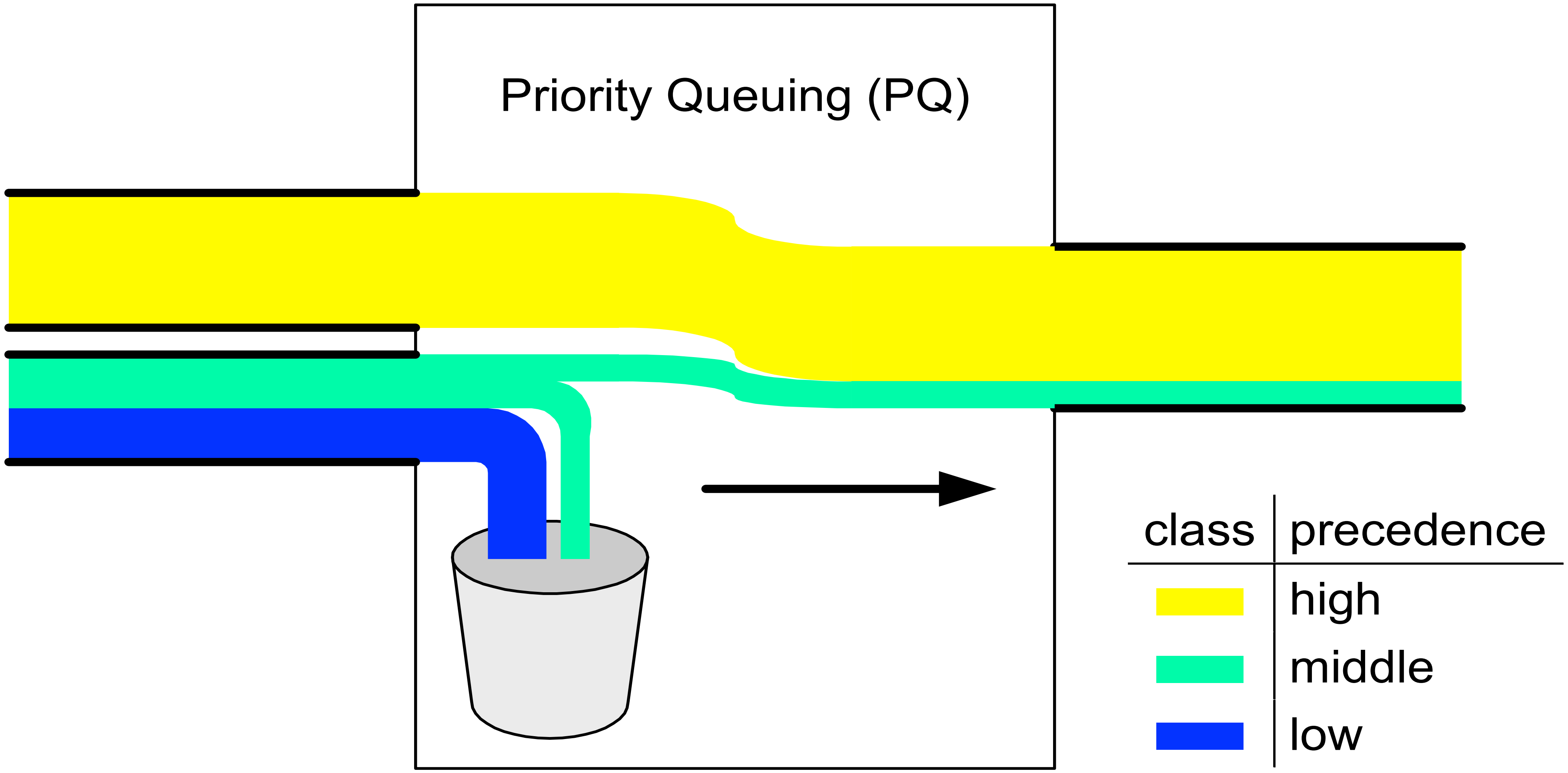


Queue Management: Random Early Discard (RED) cont.

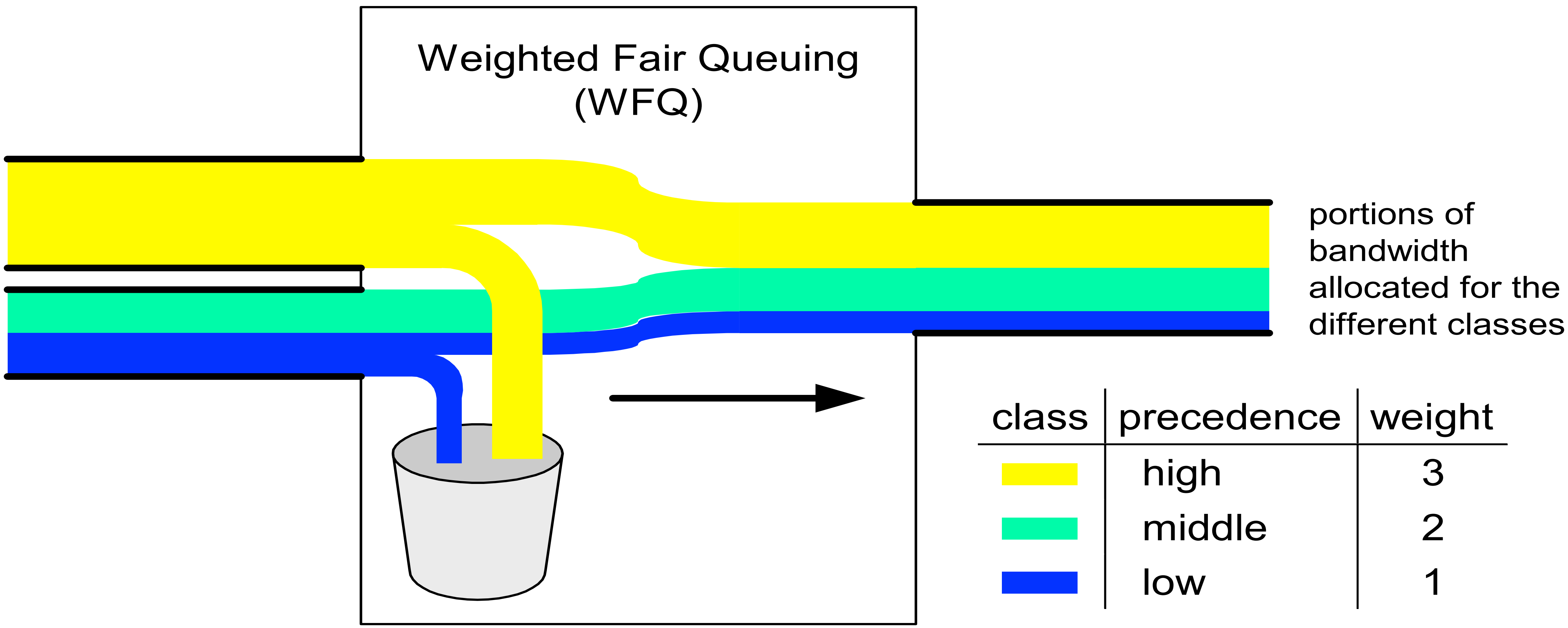
- Weighted RED combines the capabilities of the RED algorithm with IP precedence.
- It discards rather packets of lower-priority traffic than of high-priority traffic.

Priority Queuing (PQ)

Arriving packets are placed into the queue according to the packet priority
This algorithm gives higher-priority queues absolute preferential treatment over low-priority queues



Weighted Fair Queuing (WFQ)



Weighted Fair Queuing (WFQ) cont.

- For each class a weight is specified and a portion of the output bandwidth is allocated in proportion to the weight
- In times of congestion the classes are restricted to their portion of bandwidth
- When a class is not using its allocated bandwidth, the excess bandwidth is shared among the other classes

Different Bandwidth Management Algorithms

Level of QoS	Description	activated by: network elements	activated by: applications
most	provisioned resources end-to-end (e.g. private, low-traffic network)	+	
↑	RSVP – IntServ Guaranteed-load	+	+
	RSVP – IntServ Controlled-load	+	+
	Multi-Protocol Label Switching (MPLS)	+	
	DiffServ using Bandwidth Manager applied on LANs	+	+
	DiffServ applied at network core ingress	+	
	fair queuing applied by network elements (e.g. RED, WFQ)	+	
least	Best effort service		