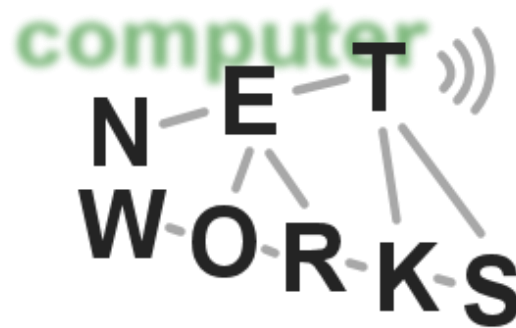# Quality of Service

## Computer Networks, Winter 2010/2011

Chapter 6 outline

- 6.1 Providing multiple classes of service
- 6.2 Differentiated Services
- 6.3 Providing QoS guarantees
- 6.4 Integrated Services
- 6.5 Resource Reservation Protocol
- 6.6 Next Steps in Signaling
- 6.7 Multiprotocol Label Switching

Providing Multiple Classes of Service

o thus far: making the best of best effort service

  o one-size fits all service model

o alternative: multiple classes of service

  o partition traffic into classes

  o network treats different classes of traffic differently (analogy: VIP service vs regular service)

o granularity: differential service among multiple classes, not among individual connections
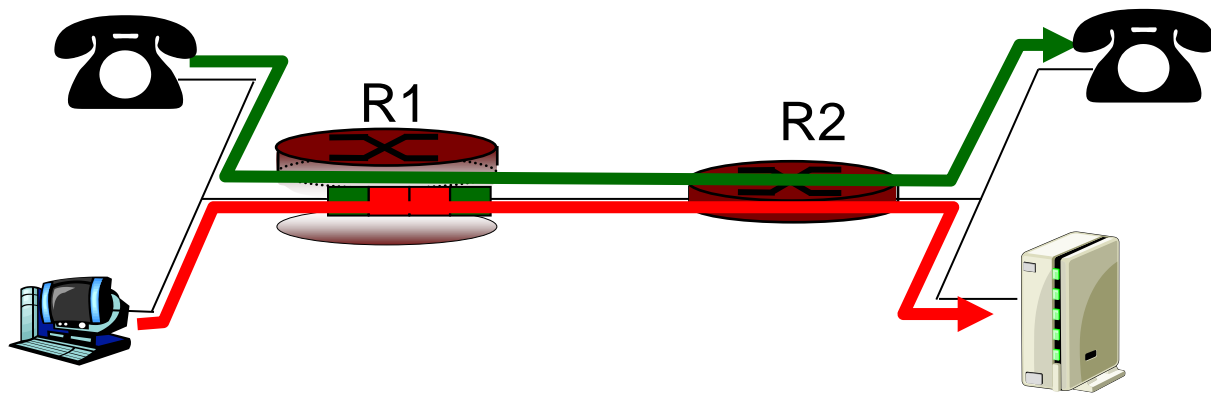

o history: ToS bits
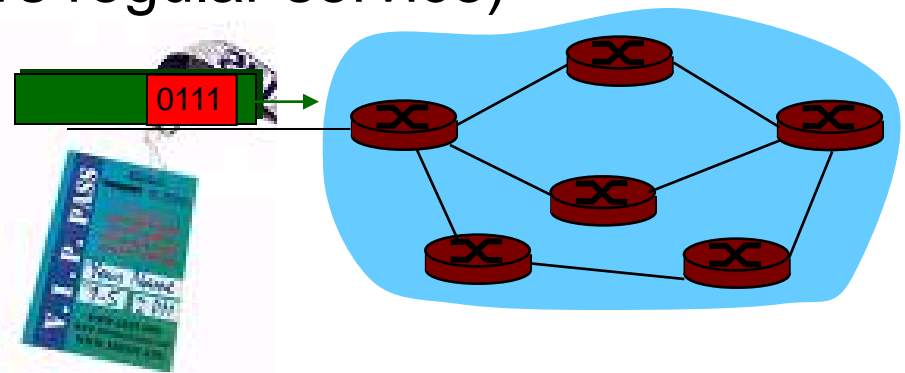
Multiple classes of service: scenario
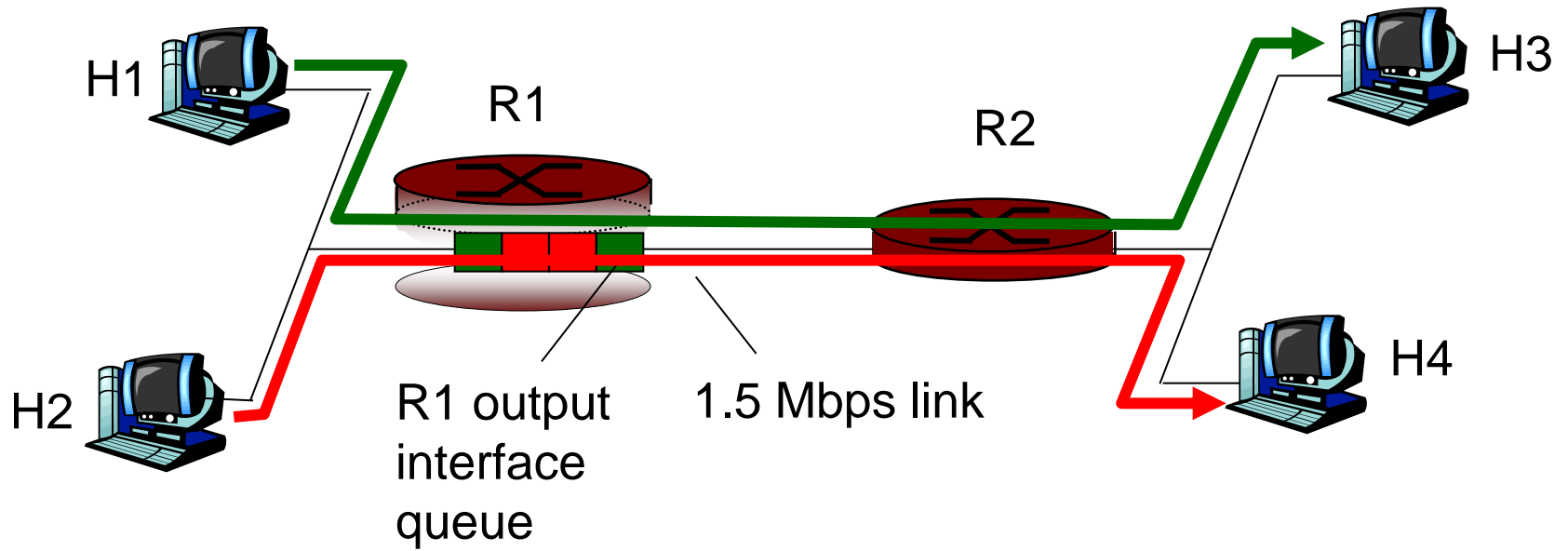
Scenario 1: mixed FTP and audio

○ Example: 1Mbps IP phone, FTP share 1.5 Mbps link.
  ○ bursts of FTP can congest router, cause audio loss
 ○ want to give priority to audio over FTP

R1

R2

Principle 1

packet marking needed for router to distinguish between different classes; and new router policy to treat packets accordingly

Principles for QOS Guarantees (more)

o what if applications misbehave (audio sends higher than declared rate)

  o policing: force source adherence to bandwidth allocations

o marking and policing at network edge:

  o similar to ATM UNI (User Network Interface)

1 Mbps phone

R1

R2

1.5 Mbps link

packet marking and policing
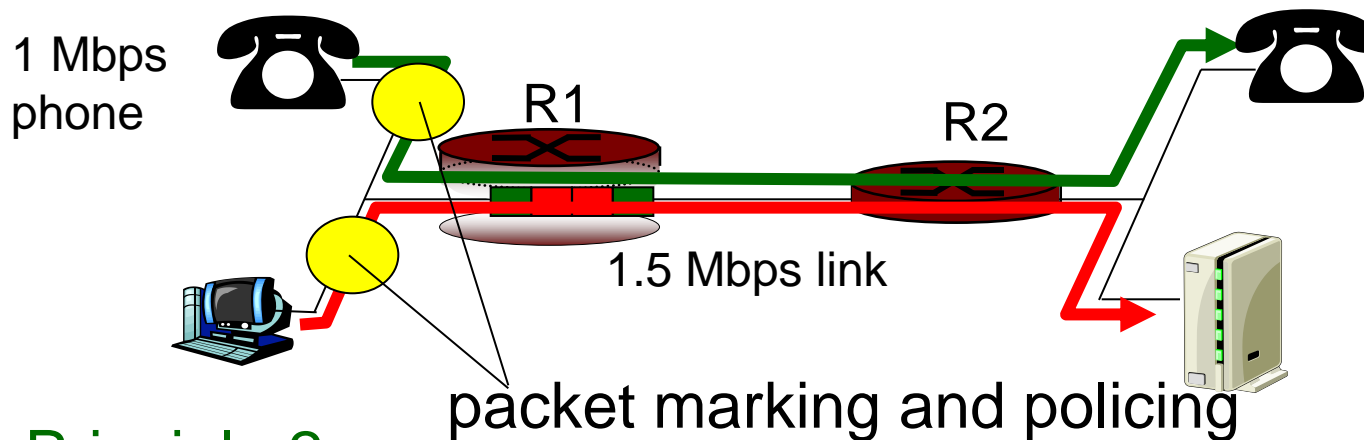
Principle 2

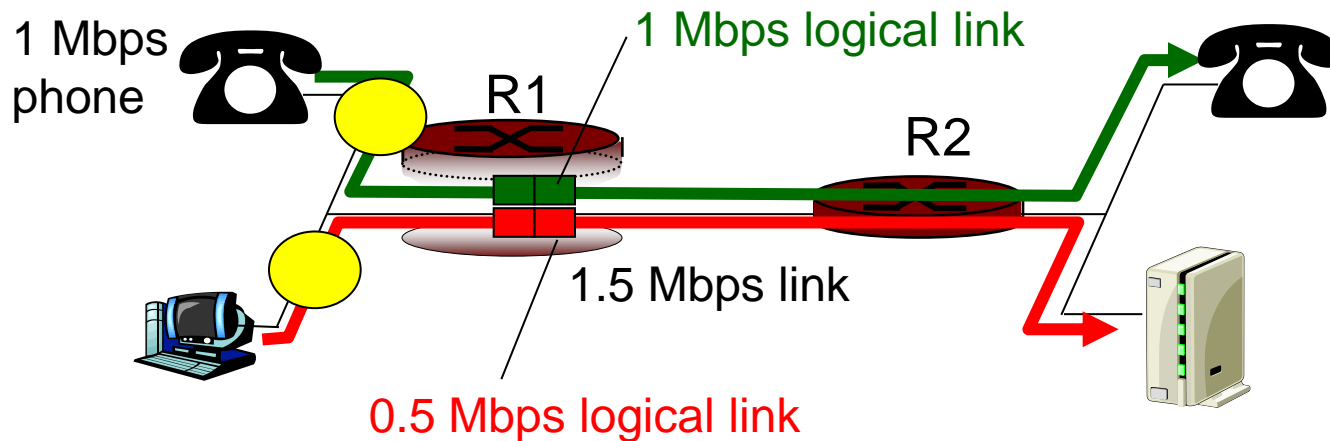provide protection (*isolation*) for one class from others

Principles for QOS Guarantees (more)

○ Allocating fixed (non-sharable) bandwidth to flow: inefficient use of bandwidth if flows doesn't use its allocation


1 Mbps phone
1 Mbps logical link
R1
R2
1.5 Mbps link
0.5 Mbps logical link

Principle 3

While providing isolation, it is desirable to use resources as efficiently as possible

Scheduling And Policing Mechanisms

o scheduling: choose next packet to send on link

o FIFO (first in first out) scheduling: send in order of arrival to queue

 o real-world example?

 o discard policy: if packet arrives to full queue: who to discard?

  • Tail drop: drop arriving packet

  • priority: drop/remove on priority basis

  • random: drop/remove randomly

arrivals   departures

queue   link
(waiting area)   (server)
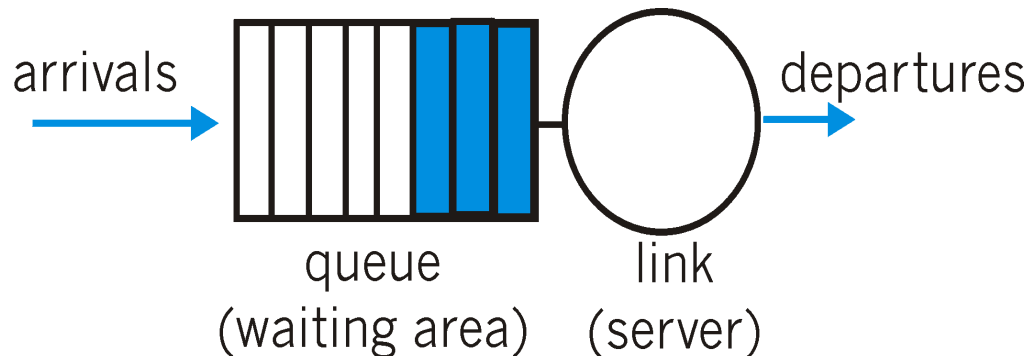
Scheduling Policies: more

o Priority scheduling: transmit highest priority queued packet

o multiple classes, with different priorities

  o class may depend on marking or other header info, e.g. IP source/dest, port numbers, etc..

  o Real world example?
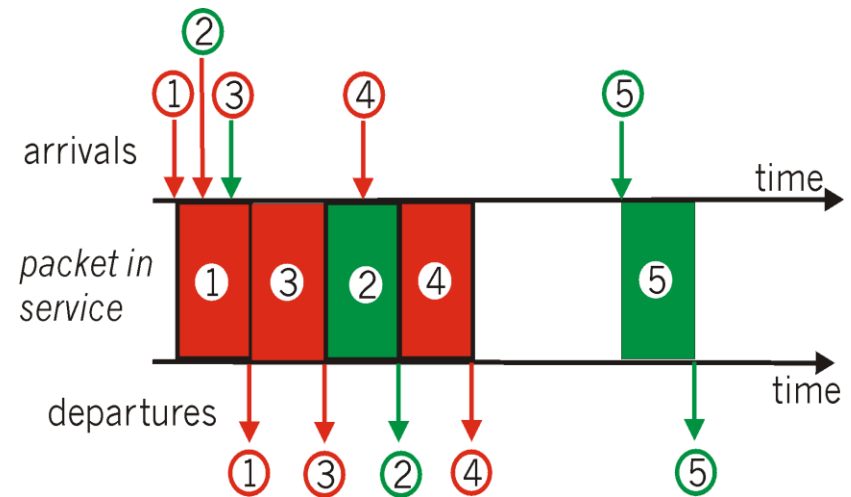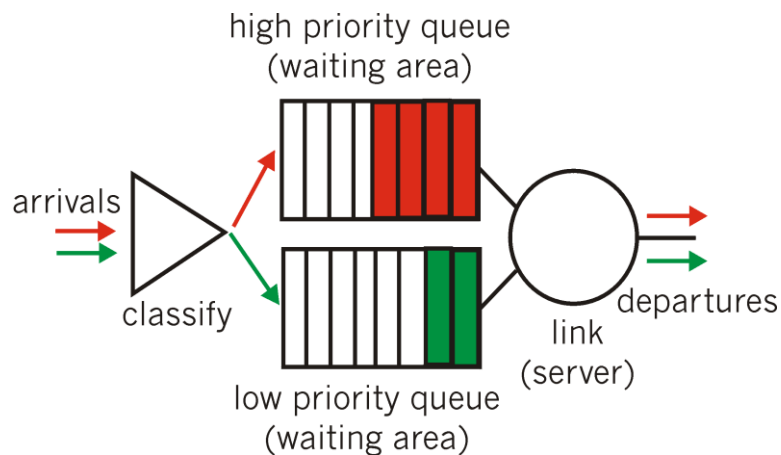
Scheduling Policies: still more

o round robin scheduling:

o multiple classes

o cyclically scan class queues, serving one from each class (if available)

o real world example?
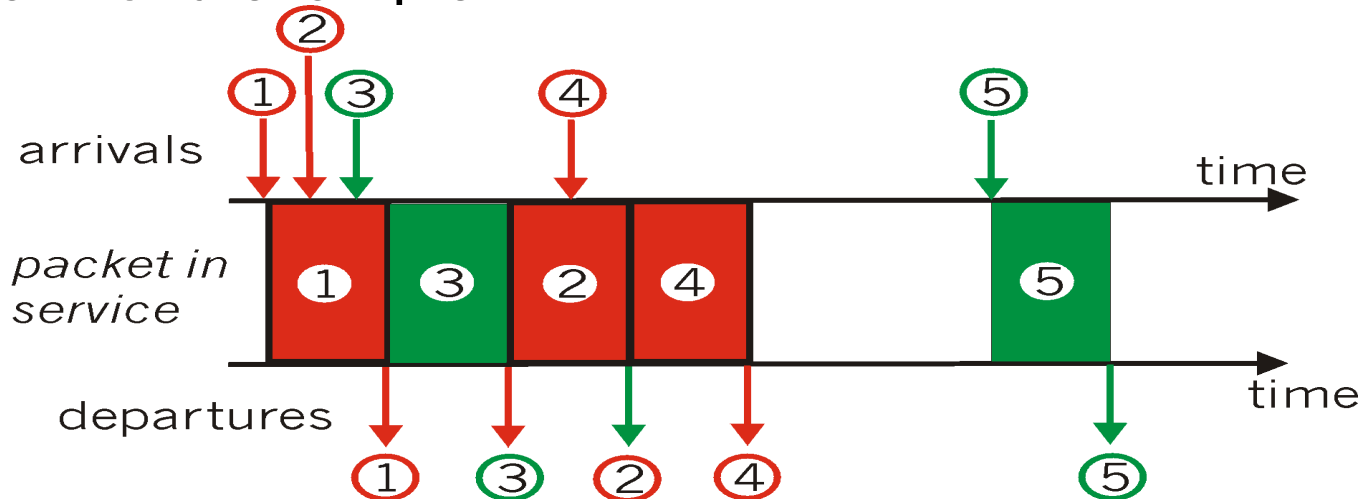
Scheduling Policies: still more

o Weighted Fair Queuing:
  - o generalized Round Robin
  - o each class gets weighted amount of service in each cycle
  - o real-world example?
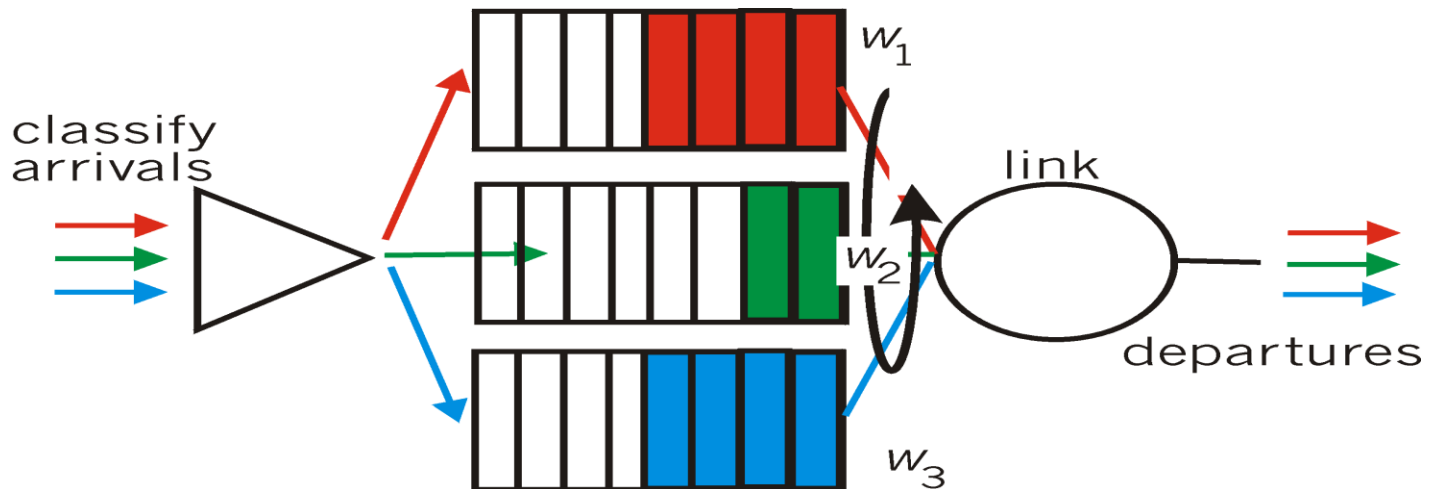
Policing Mechanisms

o Goal: limit traffic to not exceed declared parameters

o Three common-used criteria:

o (Long term) Average Rate: how many pkts can be sent per unit time (in the long run)

  o crucial question: what is the interval length: 100 packets per sec or 6000 packets per min have same average!

o Peak Rate: e.g., 6000 pkts per min. (ppm) avg.; 1500 ppm peak rate

o (Max.) Burst Size: max. number of pkts sent consecutively (with no intervening idle)

Policing Mechanisms

o Token Bucket: limit input to specified Burst Size and Average Rate.
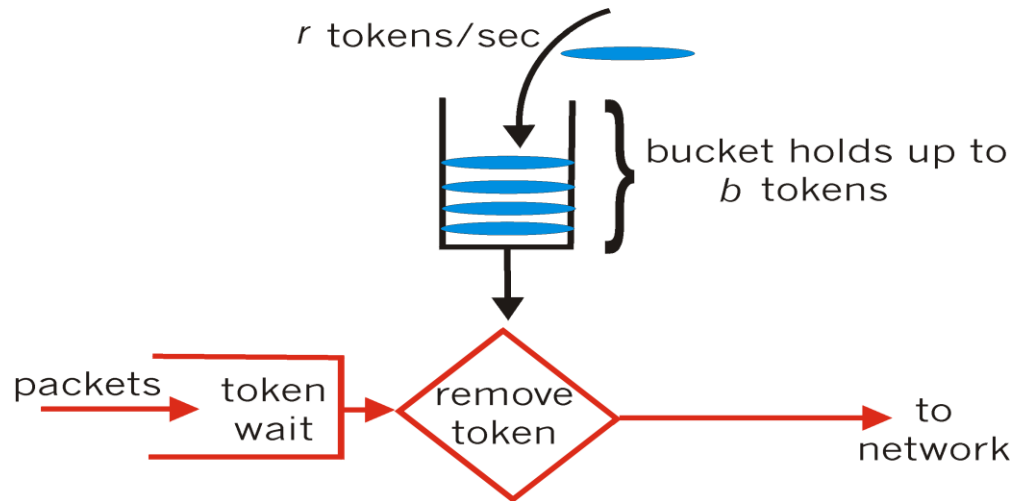
o bucket can hold b tokens

o tokens generated at rate r token/sec unless bucket full

o over interval of length t: number of packets admitted less than or equal to (r t + b).

Policing Mechanisms (more)

o token bucket, WFQ combine to provide guaranteed upper bound on delay, i.e., QoS guarantee!
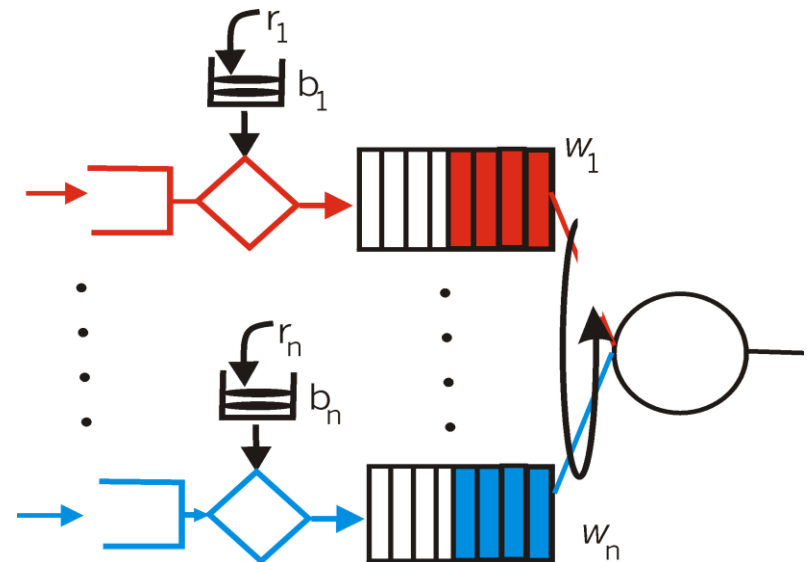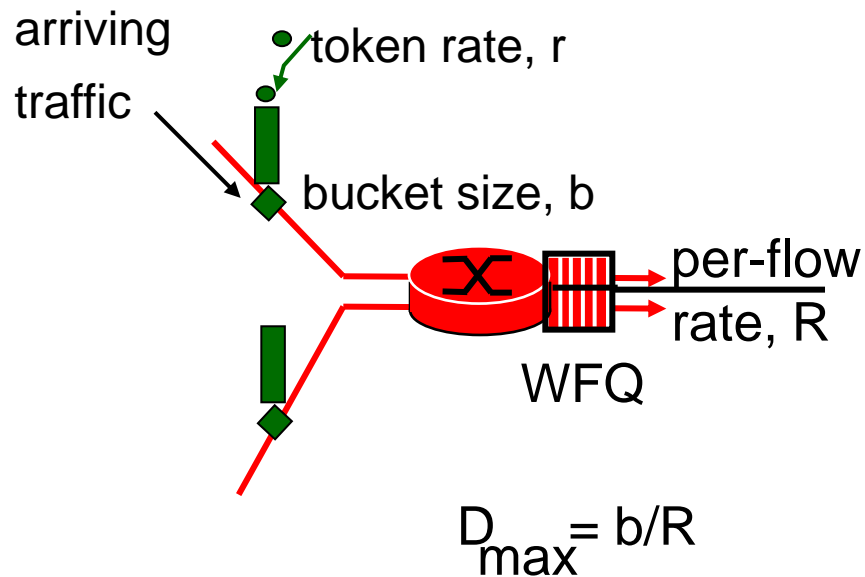
arriving traffic

token rate, r

bucket size, b

per-flow rate, R

WFQ

$$D_{max} = b/R$$

r_1

b_1

w_1

r_n

b_n

w_n

Chapter 6 outline

IETF Differentiated Services

o want "qualitative" service classes

   o "behaves like a wire"

   o relative service distinction: Platinum, Gold, Silver

o scalability: simple functions in network core, relatively complex functions at edge routers (or hosts)

   o signaling, maintaining per-flow router state difficult with large number of flows

o don't define define service classes, provide functional components to build service classes

Diffserv Architecture

Edge router:

o per-flow traffic management

o marks packets as in-profile and out-profile

Core router:

o per class traffic management

o buffering and scheduling based on marking at edge

o preference given to in-profile packets

marking

ling

r

b
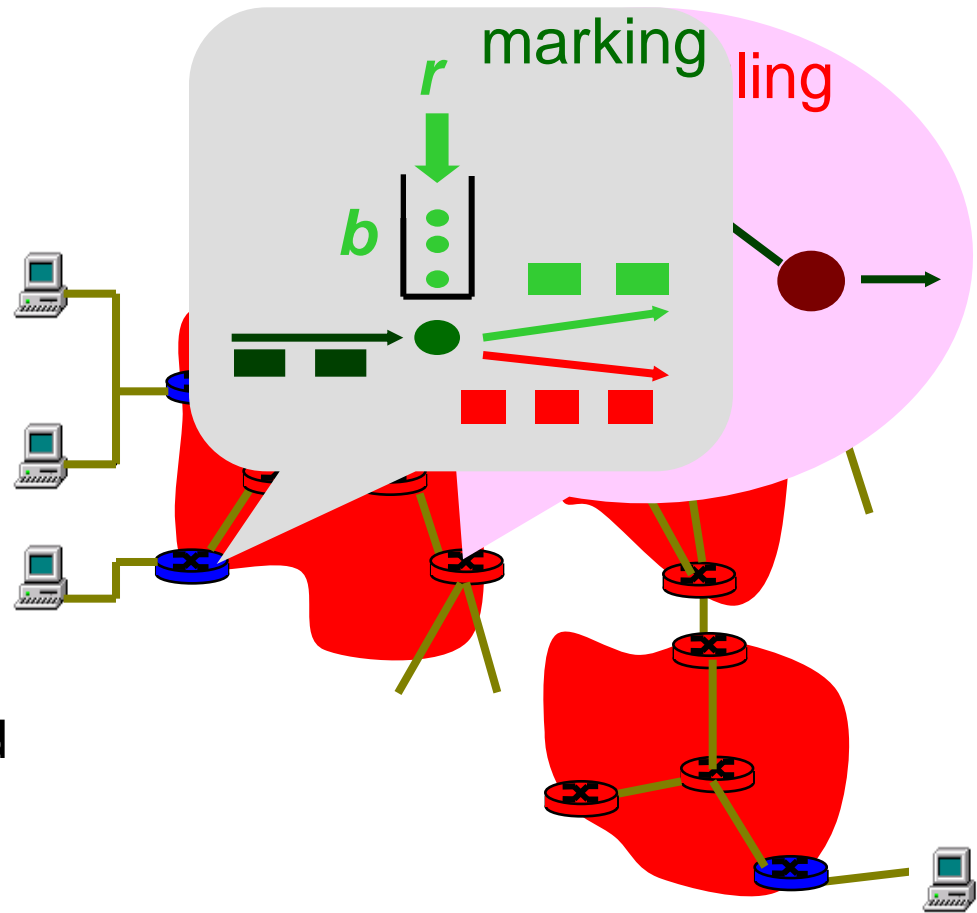
Edge-router Packet Marking

○ **profile:** pre-negotiated rate A, bucket size B

○ packet marking at edge based on per-flow profile

Rate A

B

User packets
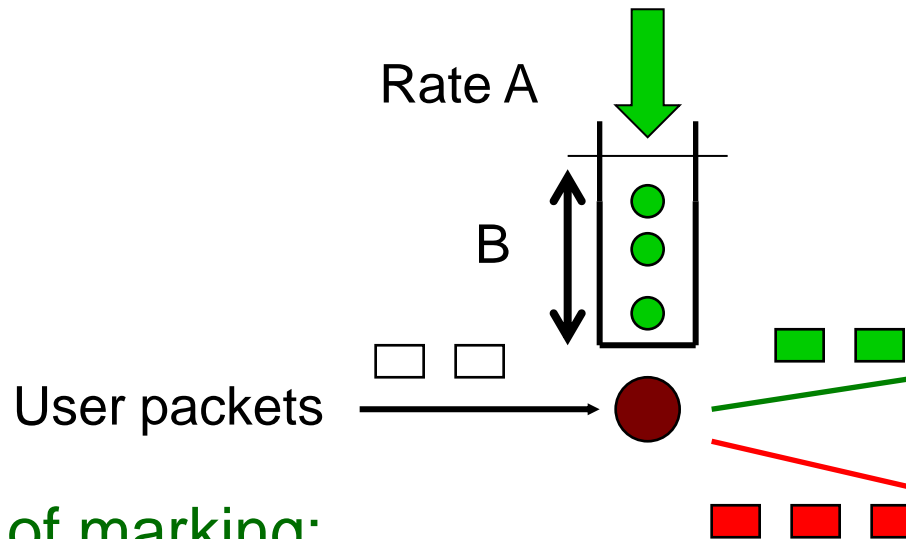
Possible usage of marking:

○ class-based marking: packets of different classes marked differently

○ intra-class marking: conforming portion of flow marked differently than non-conforming one

Classification and Conditioning

o Packet is marked in the Type of Service (TOS) in IPv4, and Traffic Class in IPv6

o 6 bits used for Differentiated Service Code Point (DSCP) and determine PHB that the packet will receive

o 2 bits are currently unused

```
0                               7
┌────┬────┬────┬────┬────┬────┬────┬────┐
│         DSCP          │   CU    │
└────┴────┴────┴────┴────┴────┴────┴────┘
```

Classification and Conditioning

o may be desirable to limit traffic injection rate of some class:

  o user declares traffic profile (e.g., rate, burst size)
  o traffic metered, shaped if non-conforming
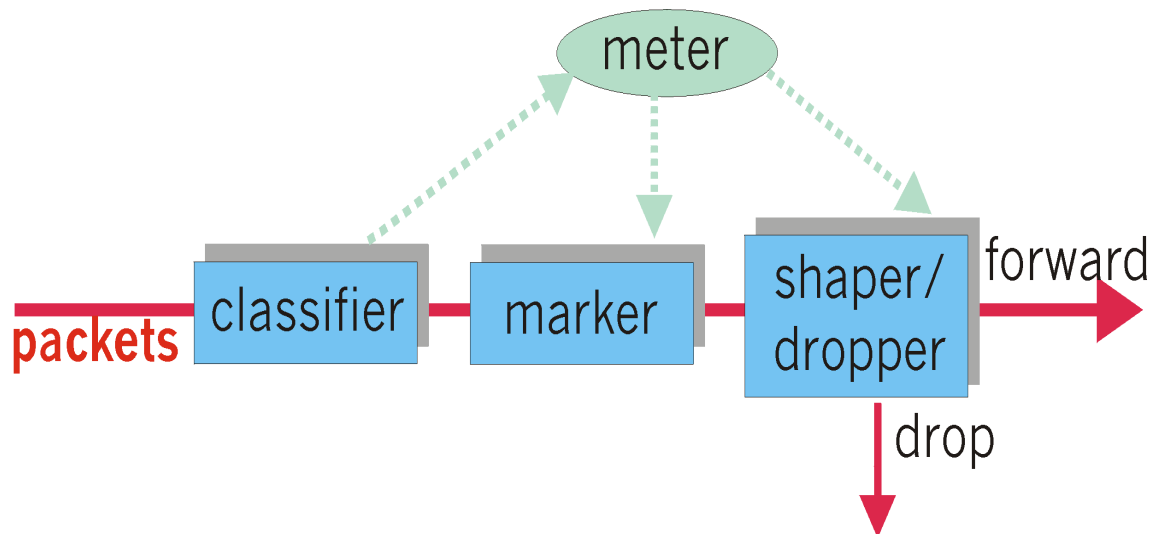
Forwarding (PHB)

o PHB result in a different observable (measurable) forwarding performance behavior

o PHB does not specify what mechanisms to use to ensure required PHB performance behavior

o Examples:

　　o Class A gets x% of outgoing link bandwidth over time intervals of a specified length

　　o Class A packets leave first before packets from class B

Forwarding (PHB)

o PHBs being developed:

o Expedited Forwarding: pkt departure rate of a class equals or exceeds specified rate

    o logical link with a minimum guaranteed rate

o Assured Forwarding: 4 classes of traffic

    o each guaranteed minimum amount of bandwidth

    o each with three drop preference partitions

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Principles for QOS Guarantees (more)

○ Basic fact of life: can not support traffic demands beyond link capacity

1 Mbps phone

R1

R2

1 Mbps phone

1.5 Mbps link
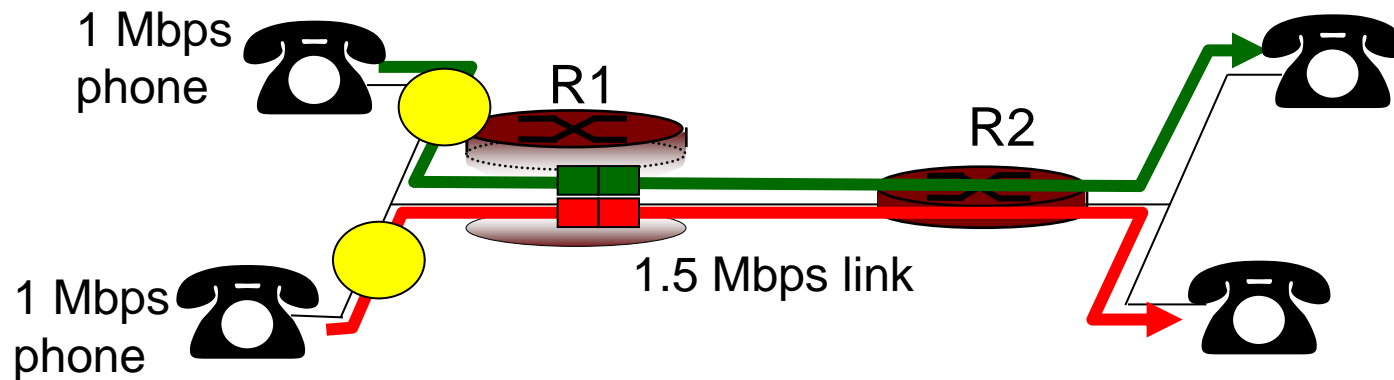
Principle 4

Call Admission: flow declares its needs, network may block call (e.g., busy signal) if it cannot meet needs

QoS guarantee scenario

- Resource reservation
    - call setup, signaling (RSVP)
    - traffic, QoS declaration
    - per-element admission control

request/
reply
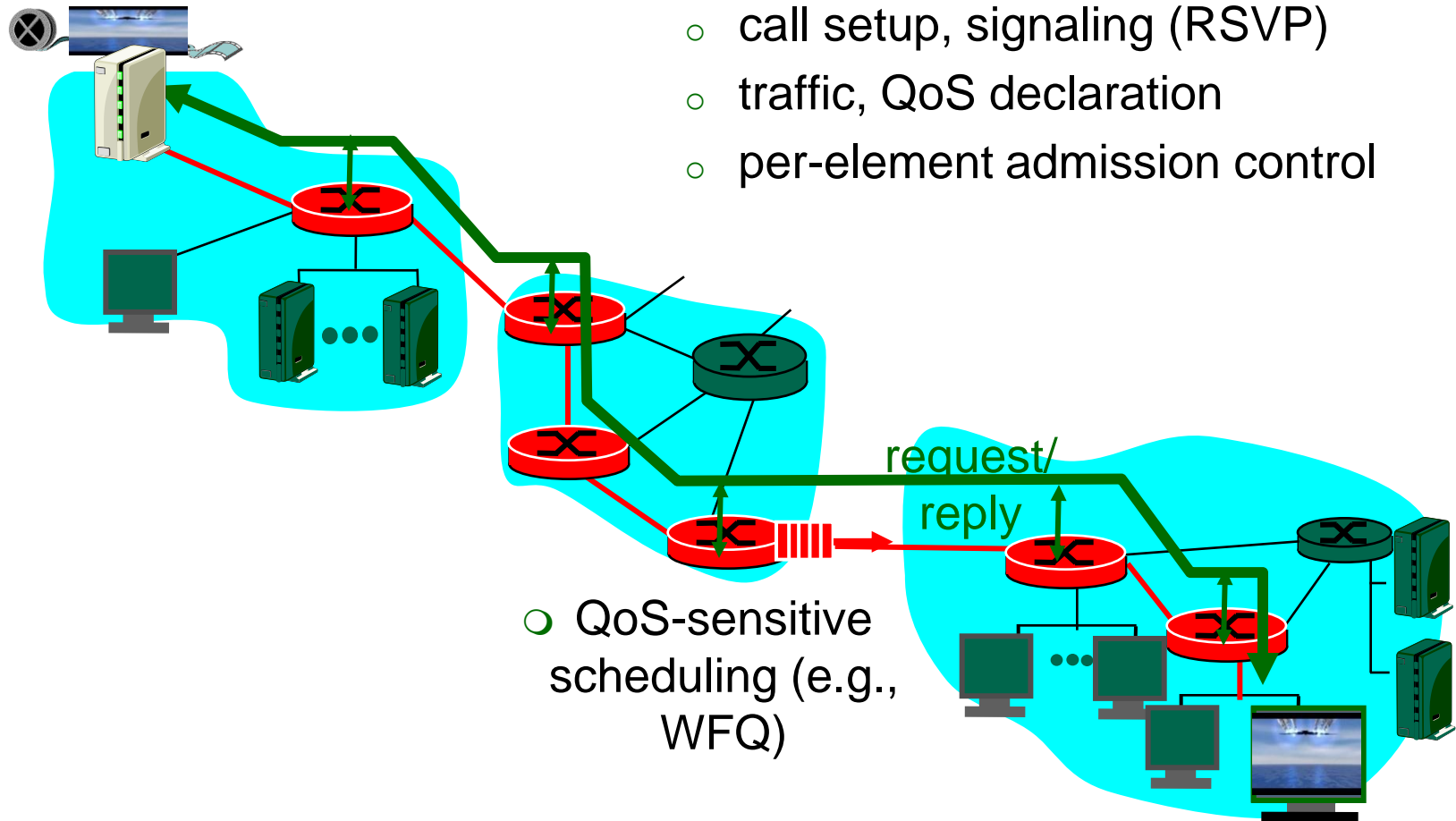
- QoS-sensitive scheduling (e.g., WFQ)

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IETF Integrated Services

o architecture for providing QOS guarantees in IP networks for individual application sessions

o resource reservation: routers maintain state info (a la VC) of allocated resources, QoS req's

o admit/deny new call setup requests:

Question: can newly arriving flow be admitted with performance guarantees while not violated QoS guarantees made to already admitted flows?

Call Admission

Arriving session must :

o declare its QOS requirement

    o R-spec: defines the QOS being requested

o characterize traffic it will send into network

    o T-spec: defines traffic characteristics

o signaling protocol: needed to carry R-spec and T-spec to routers (where reservation is required)

    o RSVP

Intserv QoS: Service models [rfc2211, rfc 2212]

- Guaranteed service:
  - worst case traffic arrival: leaky-bucket-policed source
  - simple (mathematically provable) bound on delay [Parekh 1992, Cruz 1988]

- Controlled load service:
  - "a quality of service closely approximating the QoS that same flow would receive from an unloaded network element."

token rate, r

arriving

traffic

bucket size, b

per-flow rate, R

WFQ
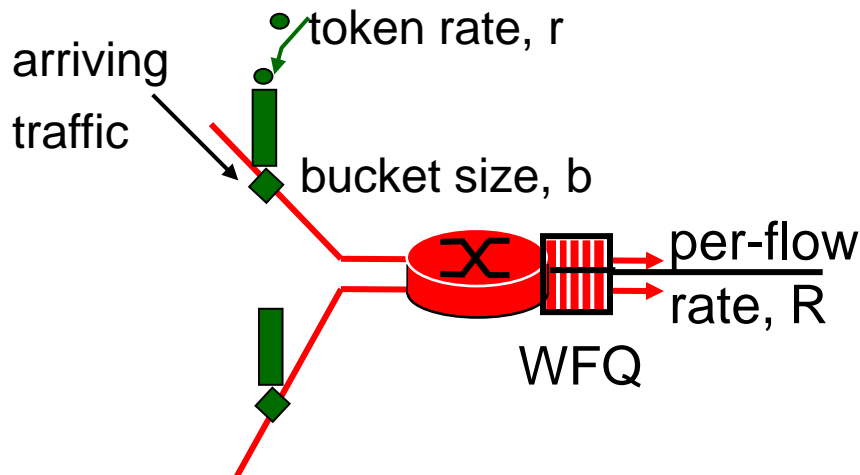
$D_{max} = b/R$

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Signaling in the Internet

connectionless
(stateless) forwarding   best effort   no network
by IP routers   **+**   service   **=**   signaling protocols
in initial IP design

o New requirement: reserve resources along end-to-end path (end system, routers) for QoS for multimedia applications

o RSVP: Resource Reservation Protocol [RFC 2205]

  o " … allow users to communicate requirements to network in robust and efficient way." i.e., signaling!

o earlier Internet Signaling protocol: ST-II [RFC 1819]

RSVP Design Goals

1. accommodate heterogeneous receivers (different bandwidth along paths)

2. accommodate different applications with different resource requirements

3. make multicast a first class service, with adaptation to multicast group membership

4. leverage existing multicast/unicast routing, with adaptation to changes in underlying unicast, multicast routes

5. control protocol overhead to grow (at worst) linear in # receivers

6. modular design for heterogeneous underlying technologies

RSVP: does not…

o specify how resources are to be reserved

   o rather: a mechanism for communicating needs

o determine routes packets will take

   o that's the job of routing protocols

   o signaling decoupled from routing

o interact with forwarding of packets

   o separation of control (signaling) and data (forwarding) planes

RSVP: overview of operation

- senders, receiver join a multicast group
  - done outside of RSVP
  - senders need not join group
- sender-to-network signaling
  - *path message:* make sender presence known to routers
  - path teardown: delete sender's path state from routers
- receiver-to-network signaling
  - *reservation message:* reserve resources from sender(s) to receiver
  - reservation teardown: remove receiver reservations
- network-to-end-system signaling
  - path error
  - reservation error

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Next Steps in Signaling (NSIS)

o RSVP not widely used for resource reservation

- o But used for MPLS path setup
- o Design heavily biased by multicast needs
- o Limited ability signaling delivery any size of signaling & over congested situation
- o Marginal and after-the-fact security
- o Limited support for IP mobility

NSIS (cont'd)

o Thus, IETF NSIS working group developing new framework for general state management protocol

  o resource reservation

  o NAT and firewall control

  o traffic and QoS measurement

  o MPLS and lambda path setup

o Split into two components:

  o NSIS Signaling Layer Protocol (NSLP)

  o NSIS Transport Layer Protocol (NTLP)

NSIS (cont'd)

o On-path vs. off-path

  o off-path → bandwidth brokers

o Discovery of next NTLP or NSLP hop

  o use router alert option

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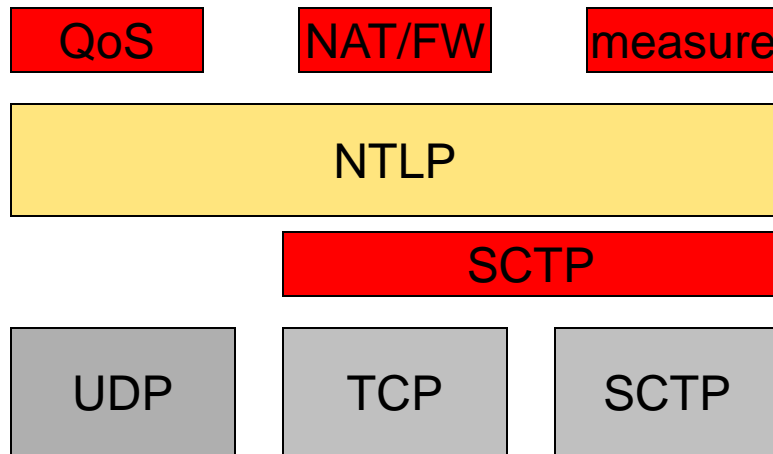- 6.7 Multiprotocol Label Switching

Multiprotocol Label Switching (MPLS)

- o *Original motivation*: improve forwarding speed of IP routers.

- o MPLS introduces a **fixed-length label** between layer-2 (i.e. PPP or Ethernet) header and layer-3 (i.e. IP) header.

PPP or Ethernet header	MPLS header	IP header	....

Label	QoS (Exp)	S	TTL
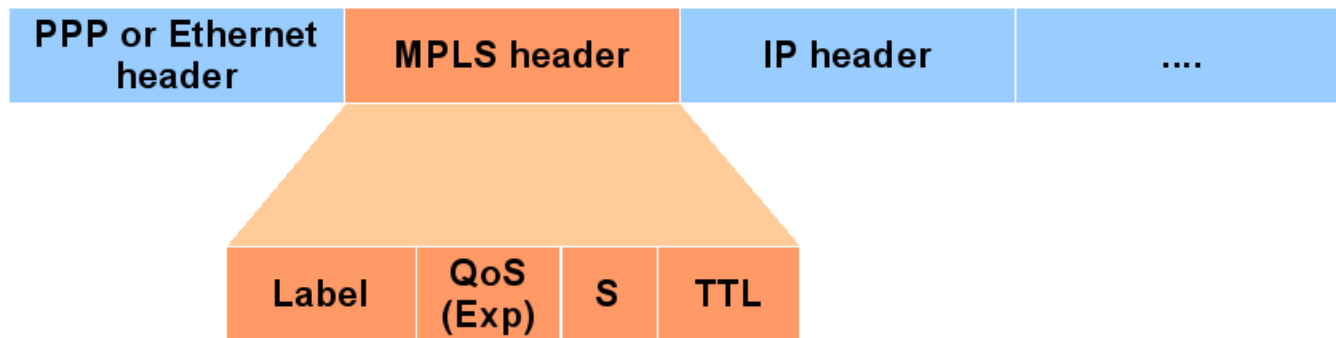
Introduction to MPLS

o **Conventional IP (Layer-3) forwarding:**
Each router analyzes the incoming packet's header and independently chooses a next hop. Routing algorithm and adequate speed are prerequisite.

o **MPLS (Layer-2.5) forwarding:**
All forwarding is driven by the labels, no header analysis needed. Once a packet enters a network, it's assigned a label. Each router forwards packets according to their labels.

IP Forwarding

o **Longest-prefix match** based on packet's destination IP address

NIF node forwarding Engine

IP Forwarding (cont'd)

Address Prefix and mask	Next-Hop	Interface
171.68.10/24	171.68.9.1	Serial1
...	...	...

0   1

Rtr-A   171.68.10/24

IP packet
D=171.68.10.23

IP packet
D=171.68.10.12

Router-A forwards packets with different
destination addresses using the same
route, same next-hop and same interface
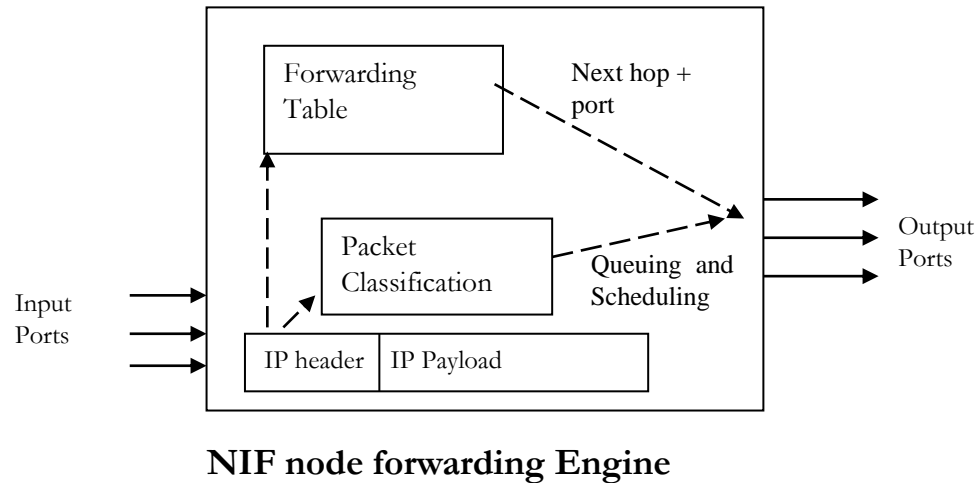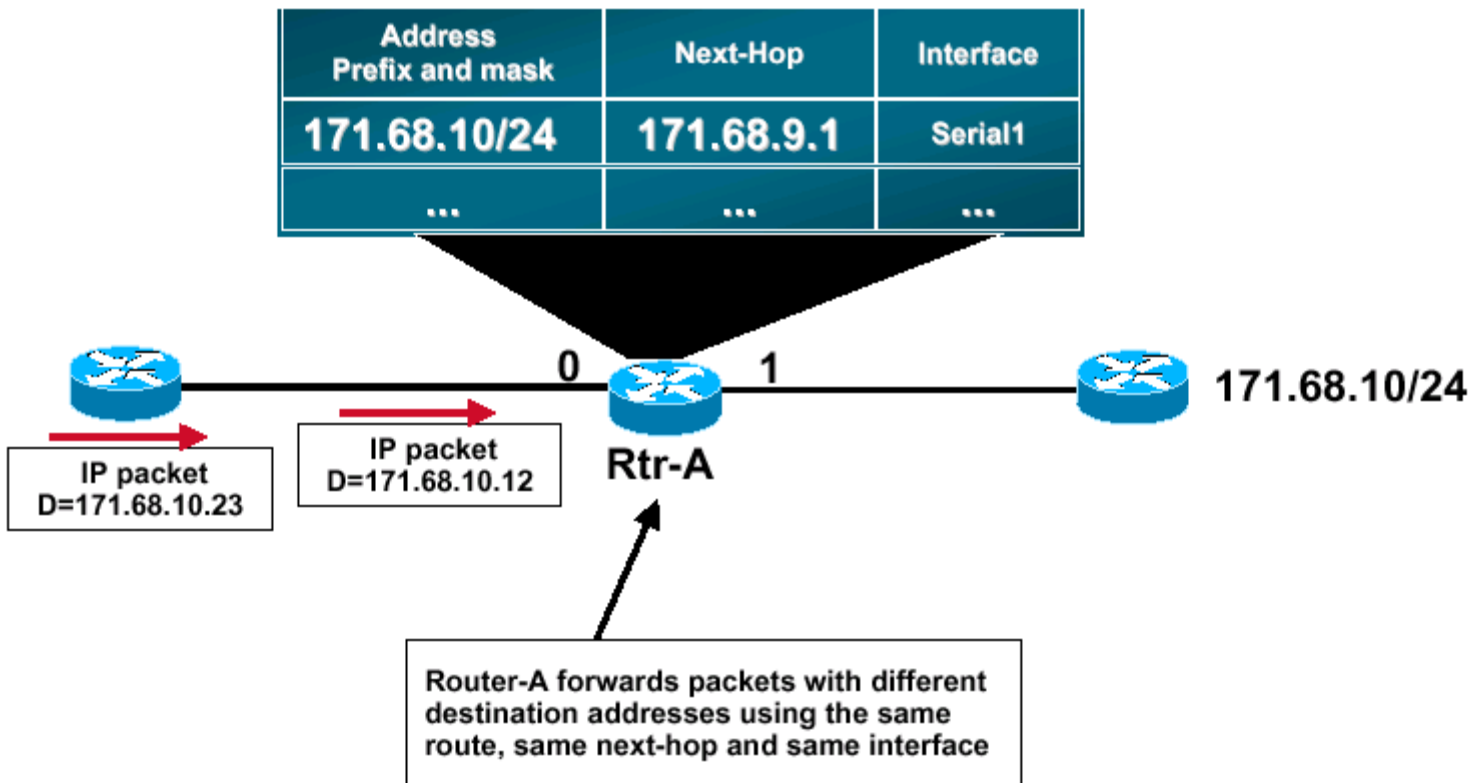
MPLS forwarding

In I/F	In Lab	Address Prefix	Out I/F	Out Lab
4	x	171.68.10	3	5
...	...	...	...	...

In I/F	In Lab	Address Prefix	Out I/F	Out Lab
0	5	171.68.10	1	3
...	...	...	...	...

3

4

Rtr-B

Label = 5

IP packet
D=171.68.10.12

0   1

Rtr-A

171.68.10/24

Label = 3

IP packet
D=171.68.10.12

IP packet
D=171.68.10.12

Router-B classify the IP packet into a FEC
and assign the corresponding label.

Router-A forwards labelled packets
by looking at the label value
against the label table. No packet
classification into FEC is done.
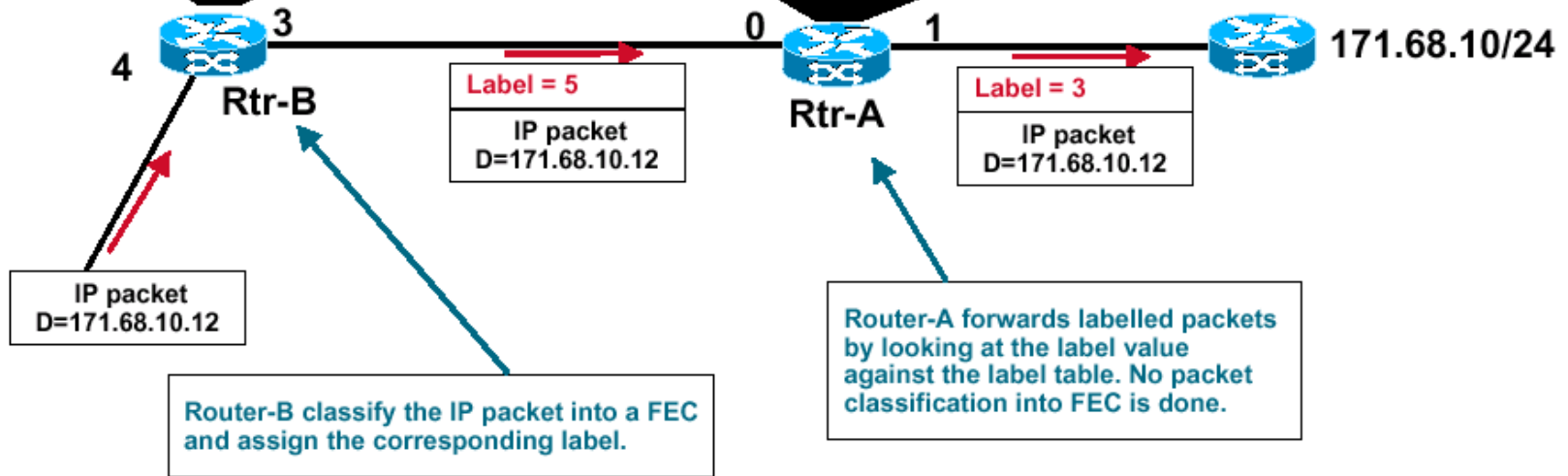
**FEC:
Forwarding
Equivalence
Class**

MPLS Network

Access A1

R1

IP backbone

R6

Access A3

R3

R2

Access A2

R4

R5

Destination D

———— Desired route from Ax to D

– – – – – Actual route from Ax to D
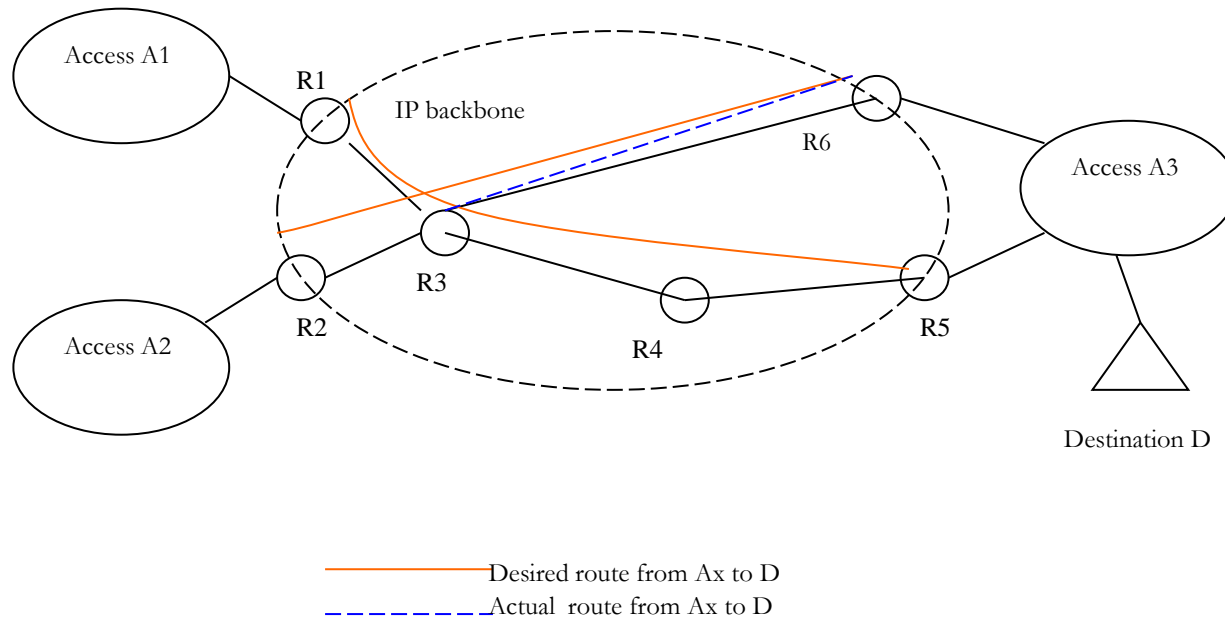
Traffic Engineering to override shortest path route

MPLS Advantages

o Router can use any information in determining label assignment, not limited to packet header.

o How to distribute labels may become more and more complicated, without any impact on the routers that merely forward labeled packets.

o A label can be used to represent a pre-chosen route so that the identity of explicit route need not be carried with the packet.

o Mutiprotocol: its techniques are applicable to ANY network layer protocol.

MPLS Applications

- Extensive traffic engineering and management.

- Out-of-band control.

- Quality of Service.

- Traffic separation: Virtual Private Networks.

Summary

o Principles

  o classify multimedia applications

  o identify network services applications need

  o making the best of best effort service

o Protocols and Architectures

  o specific protocols for best-effort

  o mechanisms for providing QoS

  o architectures for QoS

    • multiple classes of service

    • QoS guarantees, admission control

Thank you

Any questions?