Quality of Service

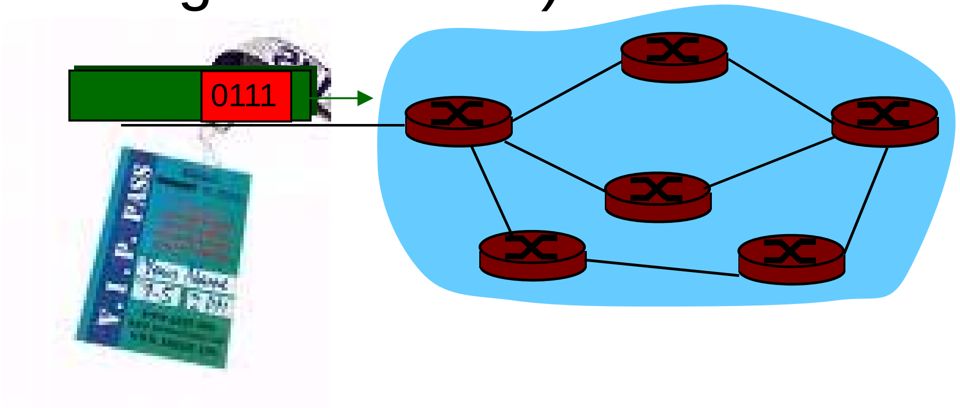
Computer Networks, Winter 2014/2015

Chapter 6 outline

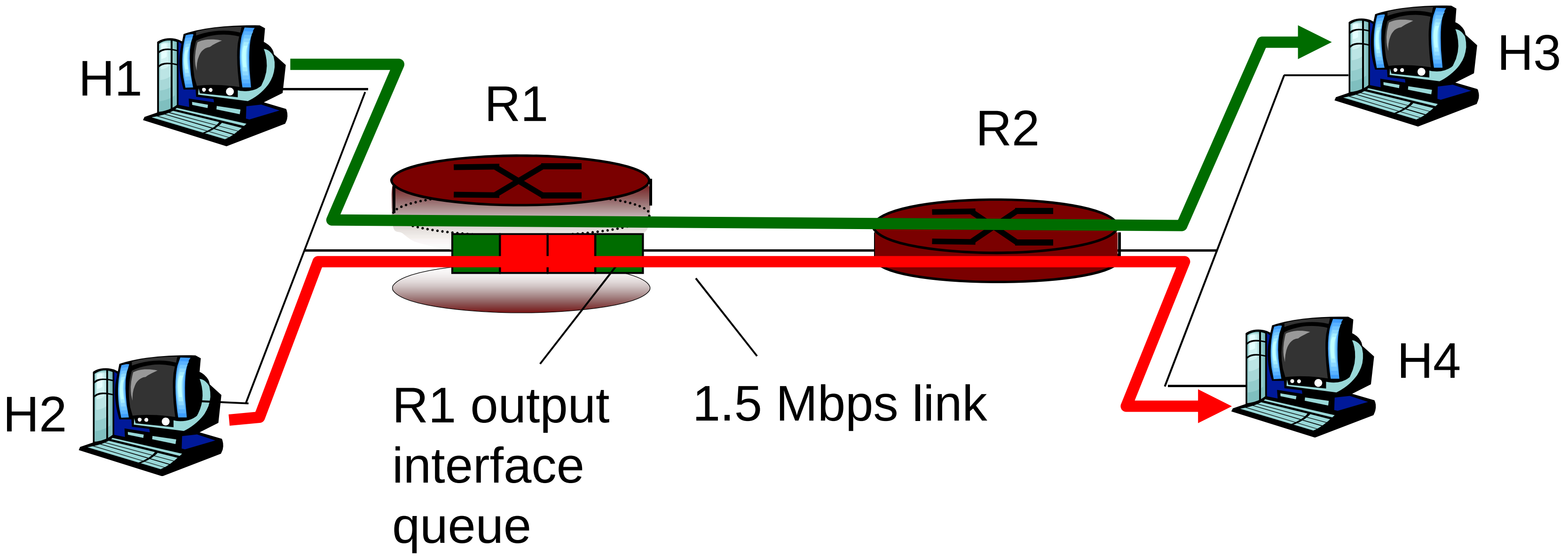
- 6.1 Providing multiple classes of service
- 6.2 Differentiated Services
- 6.3 Providing QoS guarantees
- 6.4 Integrated Services
- 6.5 Resource Reservation Protocol
- 6.6 Next Steps in Signaling
- 6.7 Multiprotocol Label Switching

Providing Multiple Classes of Service

- thus far: making the best of best effort service
  - one-size fits all service model
- alternative: multiple classes of service
  - partition traffic into classes
  - network treats different classes of traffic differently (analogy: VIP service vs regular service)
- granularity: differential service among multiple classes, not among individual connections
- history: ToS bits

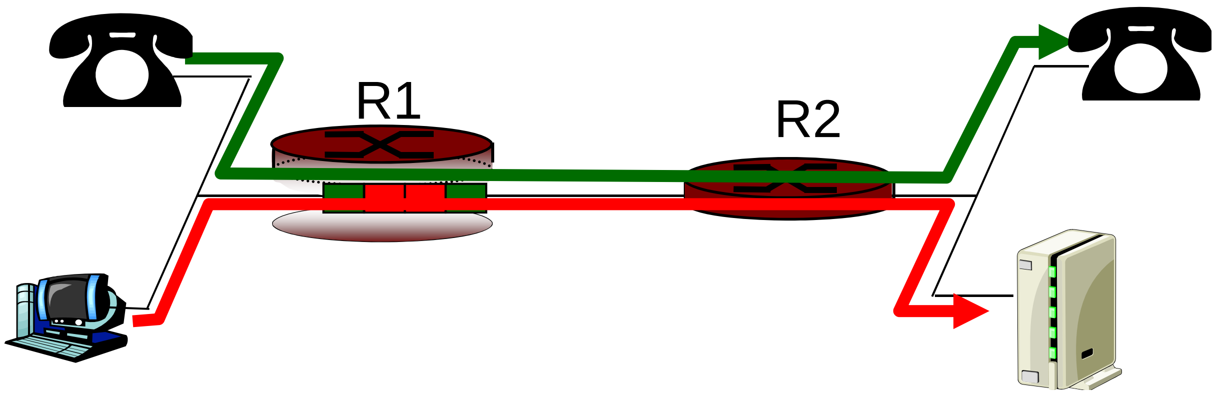


Multiple classes of service: scenario



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

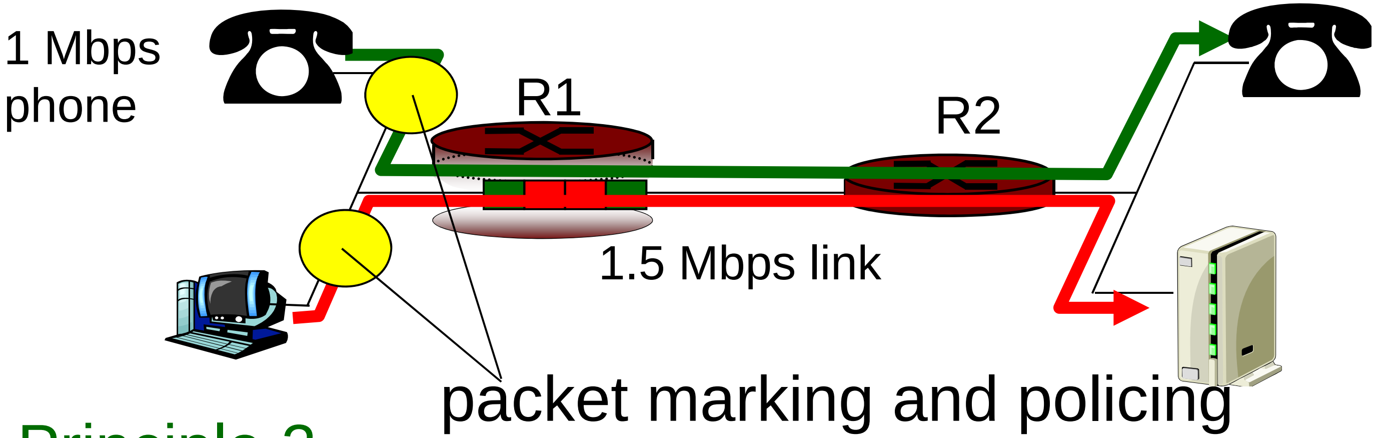


Principle 1

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

Principles for QOS Guarantees (more)

- what if applications misbehave (audio sends higher than declared rate)
  - policing: force source adherence to bandwidth allocations
- marking and policing at network edge:
  - similar to ATM UNI (User Network Interface)

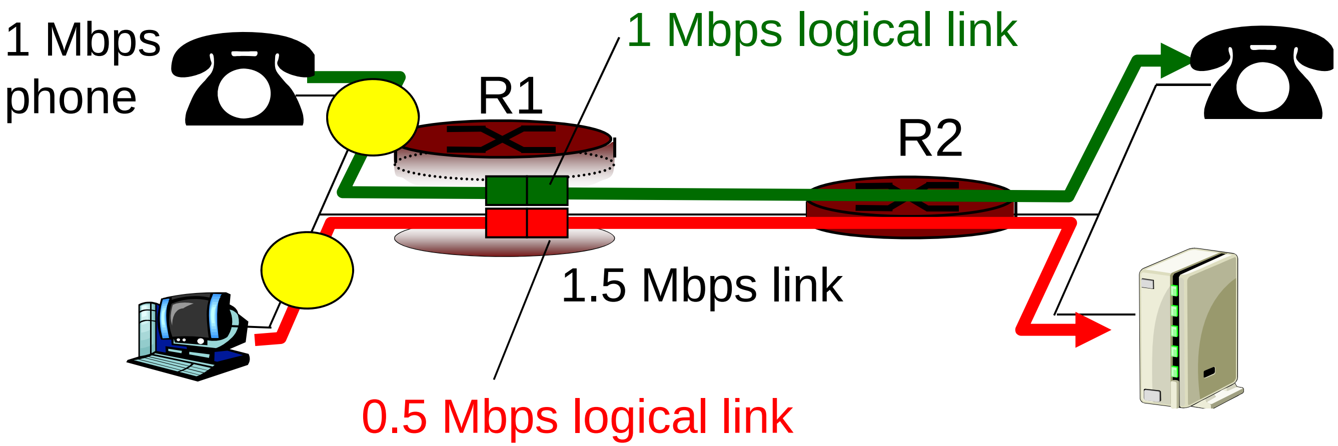


Principle 2

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

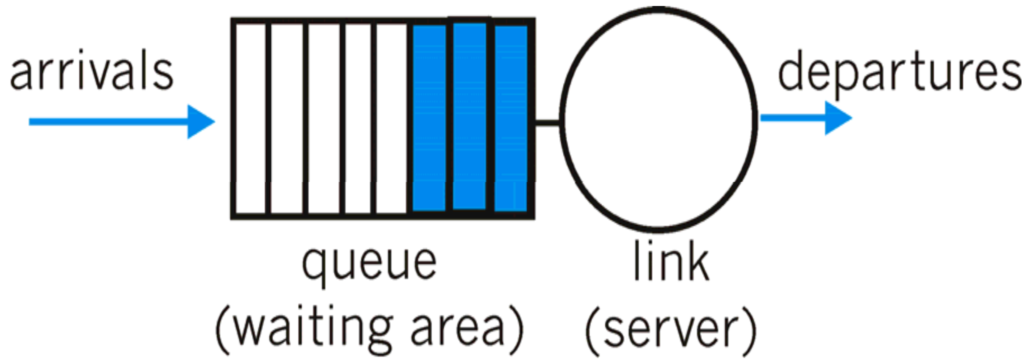


Principle 3

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

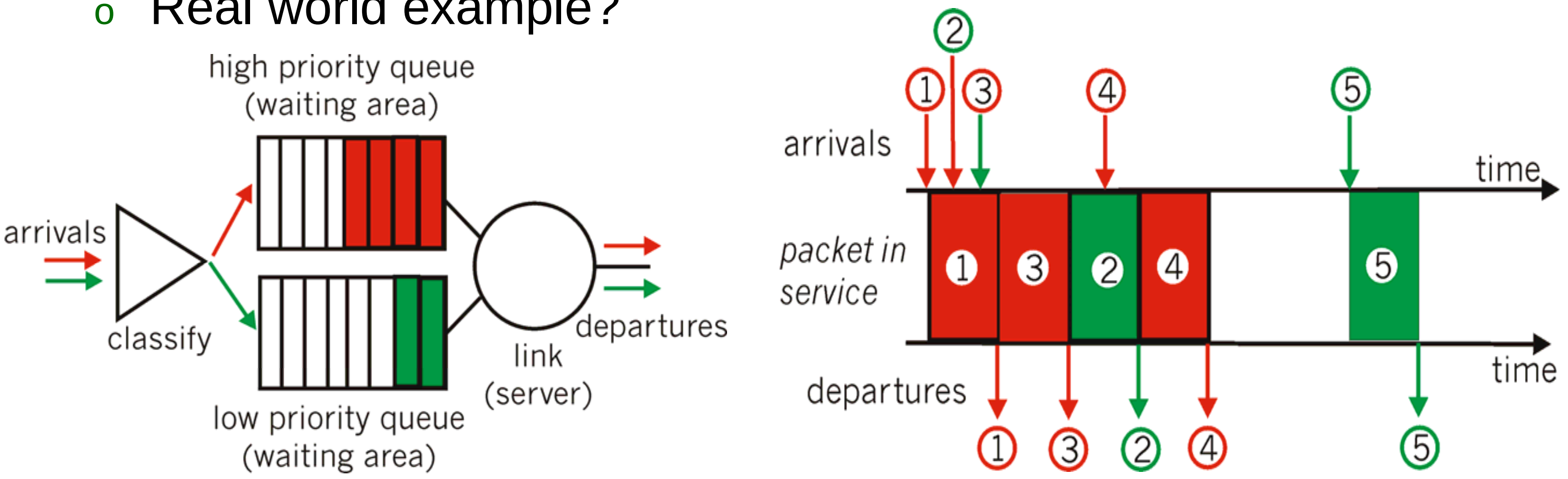
Scheduling And Policing Mechanisms

- scheduling: choose next packet to send on link
- FIFO (first in first out) scheduling: send in order of arrival to queue
  - real-world example?
  - 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



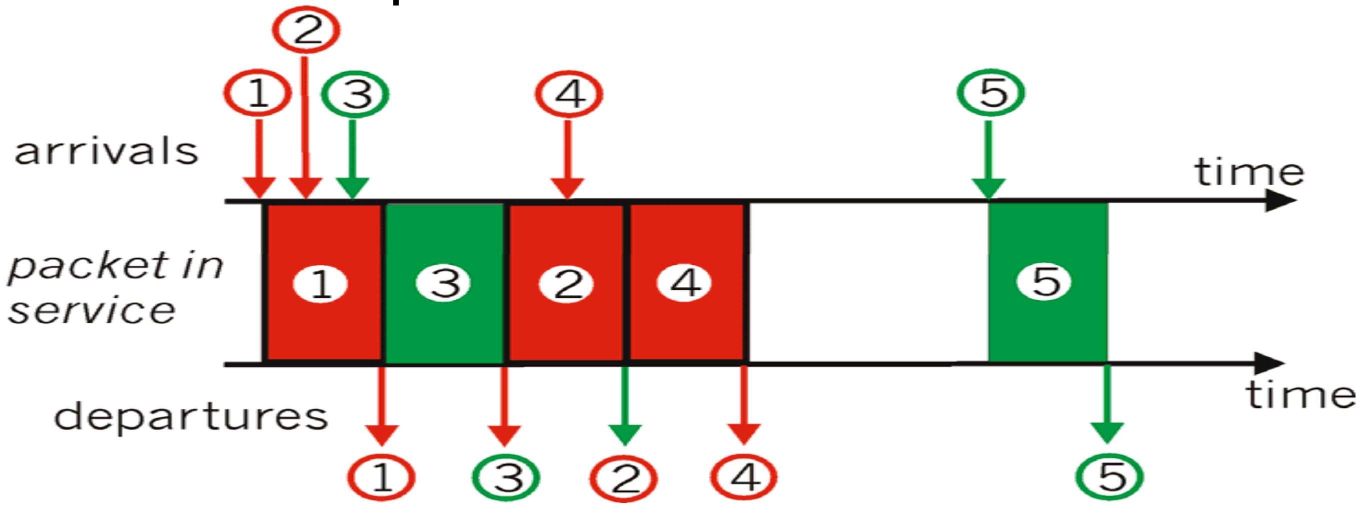
Scheduling Policies: more

- Priority scheduling: transmit highest priority queued packet
- multiple classes, with different priorities
  - class may depend on marking or other header info, e.g. IP source/dest, port numbers, etc..
  - Real world example?



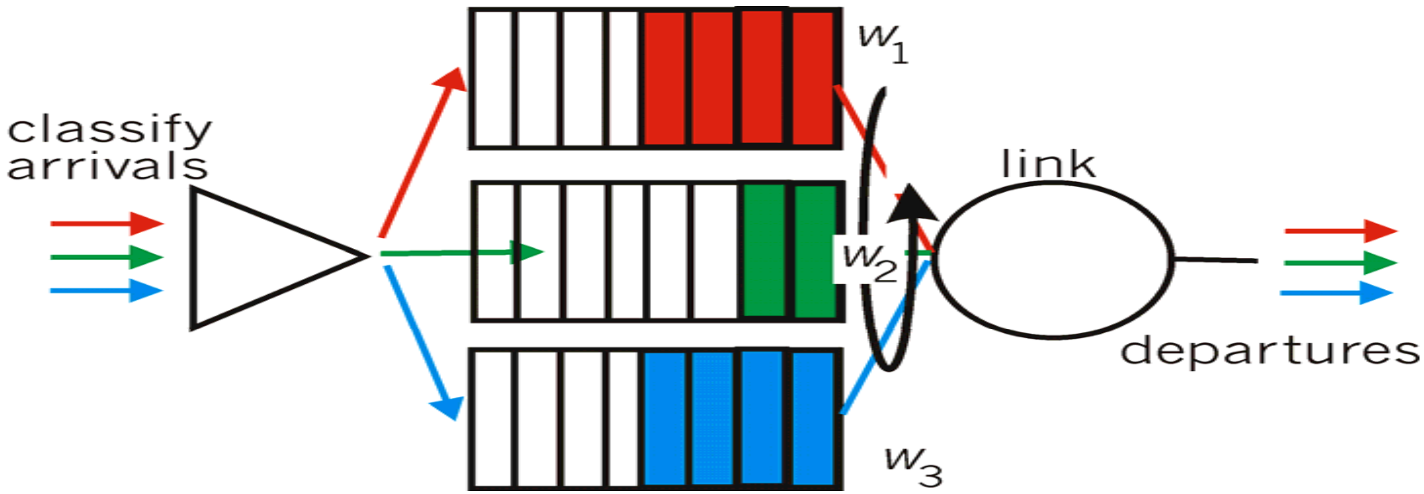
Scheduling Policies: still more

- round robin scheduling:
- multiple classes
- cyclically scan class queues, serving one from each class (if available)
- real world example?



Scheduling Policies: still more

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

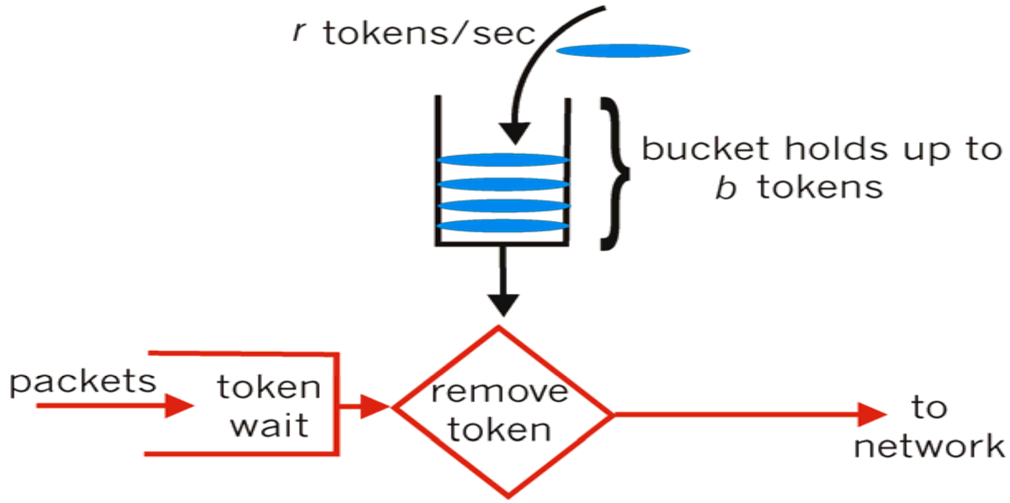


Policing Mechanisms

- Goal: limit traffic to not exceed declared parameters
- Three common-used criteria:
- (Long term) Average Rate: how many pkts can be sent per unit time (in the long run)
  - crucial question: what is the interval length: 100 packets per sec or 6000 packets per min have same average!
- Peak Rate: e.g., 6000 pkts per min. (ppm) avg.; 1500 ppm peak rate
- (Max.) Burst Size: max. number of pkts sent consecutively (with no intervening idle)

Policing Mechanisms

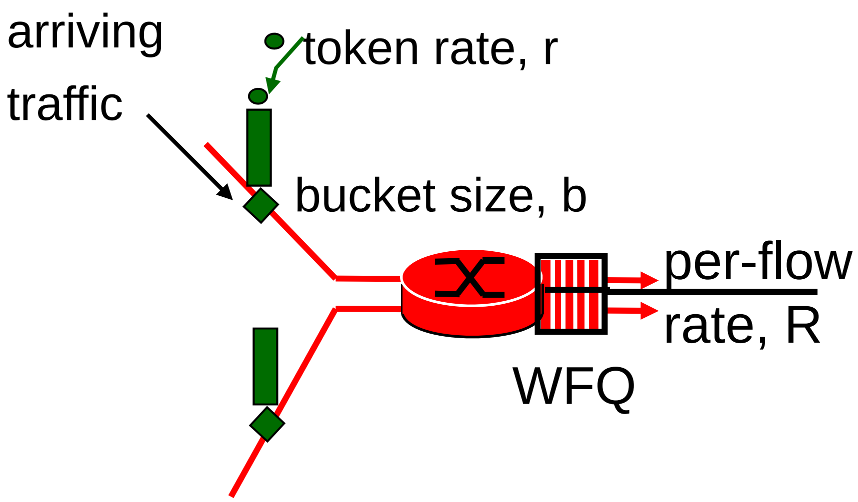
- Token Bucket: limit input to specified Burst Size and Average Rate.



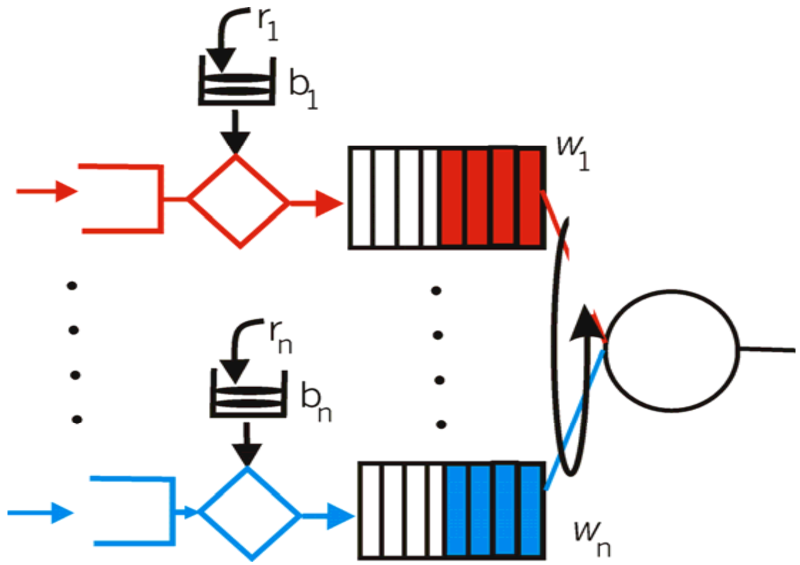
- bucket can hold b tokens
- tokens generated at rate r token/sec unless bucket full
- over interval of length t: number of packets admitted less than or equal to (r t + b).

Policing Mechanisms (more)

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



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



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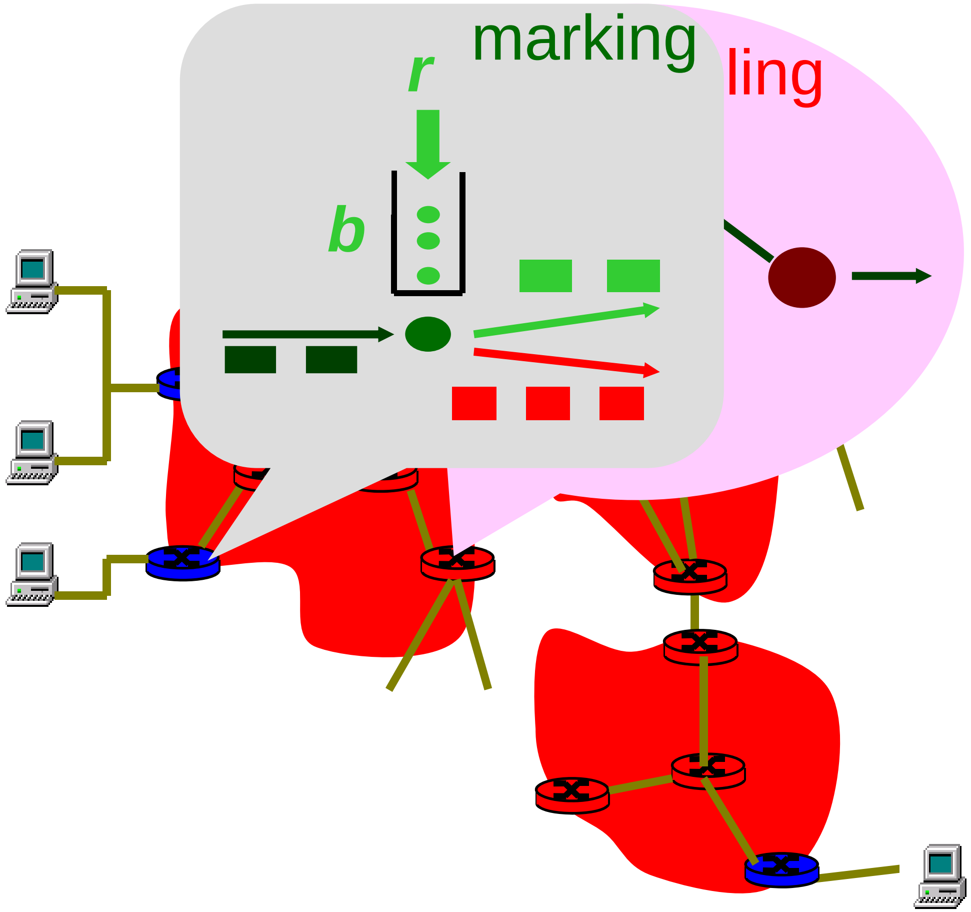
IETF Differentiated Services

- want "qualitative" service classes
  - "behaves like a wire"
  - relative service distinction: Platinum, Gold, Silver
- scalability: simple functions in network core, relatively complex functions at edge routers (or hosts)
  - signaling, maintaining per-flow router state difficult with large number of flows
- don't define define service classes, provide functional components to build service classes

Diffserv Architecture

Edge router:

- per-flow traffic management
- marks packets as in-profile and out-profile

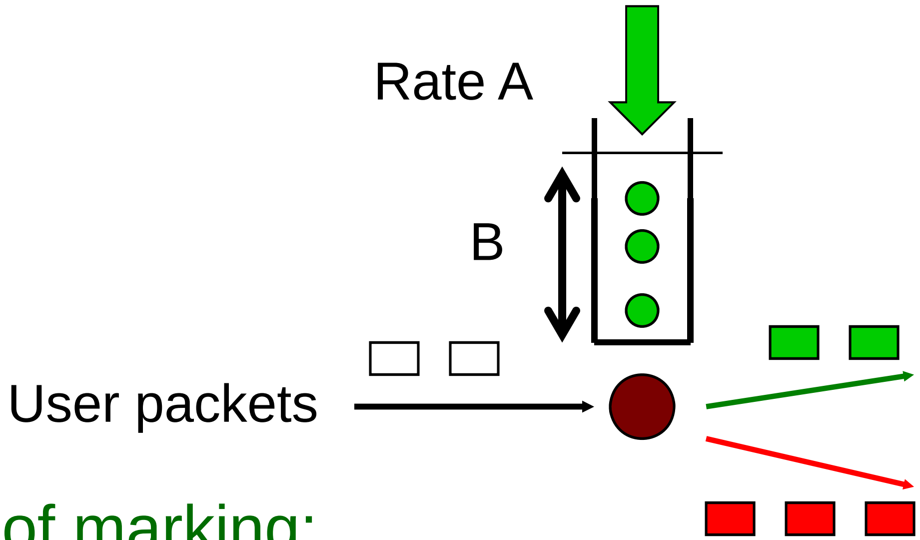


Core router:

- per class traffic management
- buffering and scheduling based on marking at edge
- preference given to in-profile packets

Edge-router Packet Marking

- profile: pre-negotiated rate A, bucket size B
- packet marking at edge based on per-flow profile

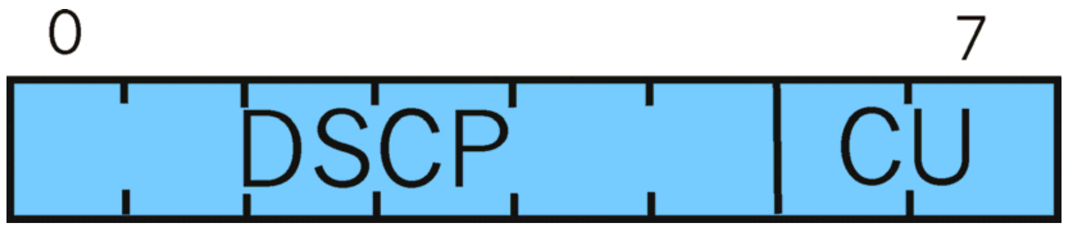


Possible usage of marking:

- class-based marking: packets of different classes marked differently
- intra-class marking: conforming portion of flow marked differently than non-conforming one

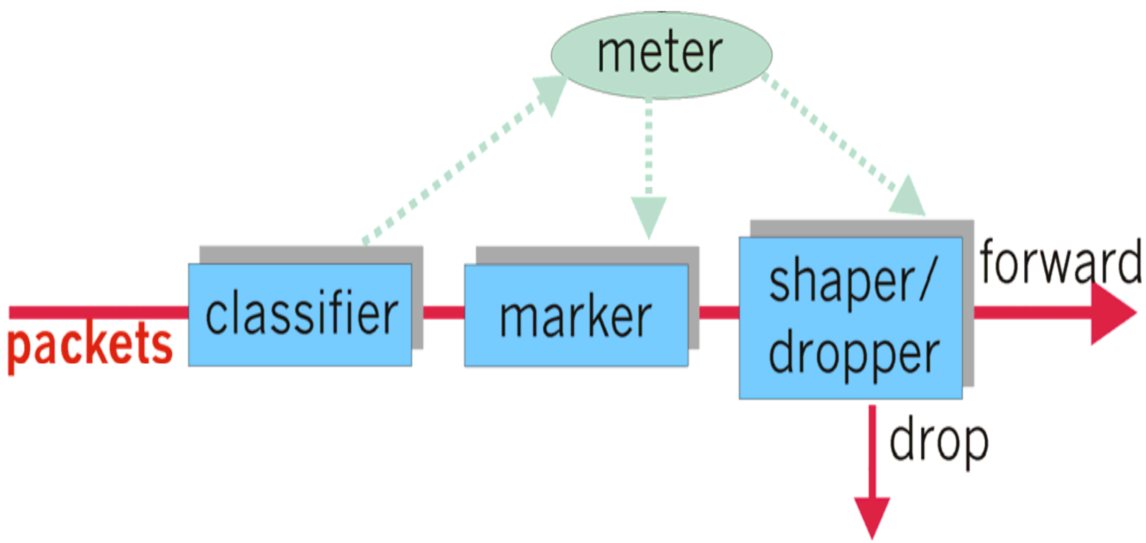
Classification and Conditioning

- Packet is marked in the Type of Service (TOS) in IPv4, and Traffic Class in IPv6
- 6 bits used for Differentiated Service Code Point (DSCP) and determine PHB that the packet will receive
- 2 bits are currently unused



Classification and Conditioning

- may be desirable to limit traffic injection rate of some class:
  - user declares traffic profile (e.g., rate, burst size)
  - traffic metered, shaped if non-conforming



Forwarding (PHB)

- PHB result in a different observable (measurable) forwarding performance behavior
- PHB does not specify what mechanisms to use to ensure required PHB performance behavior
- Examples:
  - Class A gets x% of outgoing link bandwidth over time intervals of a specified length
  - Class A packets leave first before packets from class B

Forwarding (PHB)

- PHBs being developed:
- Expedited Forwarding: pkt departure rate of a class equals or exceeds specified rate
  - logical link with a minimum guaranteed rate
- Assured Forwarding: 4 classes of traffic
  - each guaranteed minimum amount of bandwidth
  - each with three drop preference partitions

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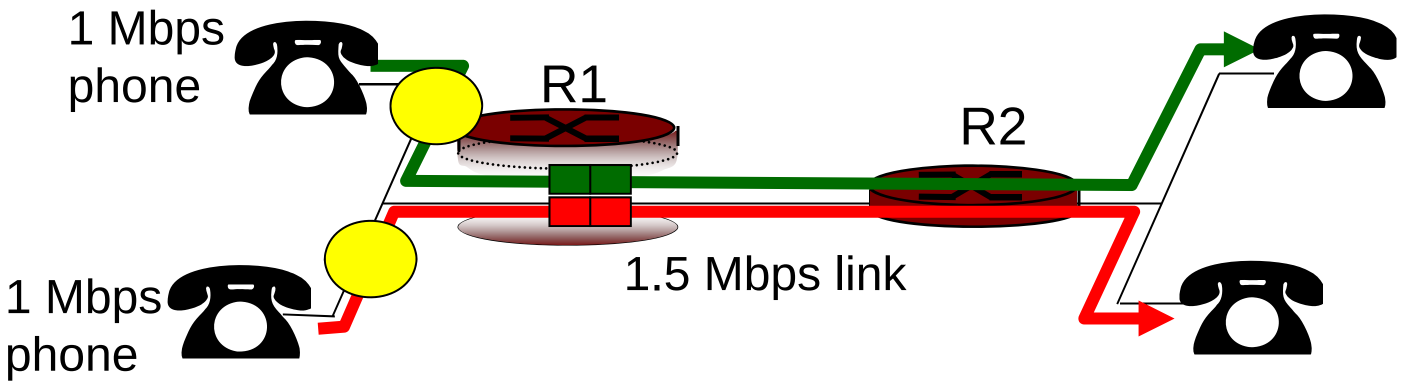
Principles for QOS Guarantees (more)

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

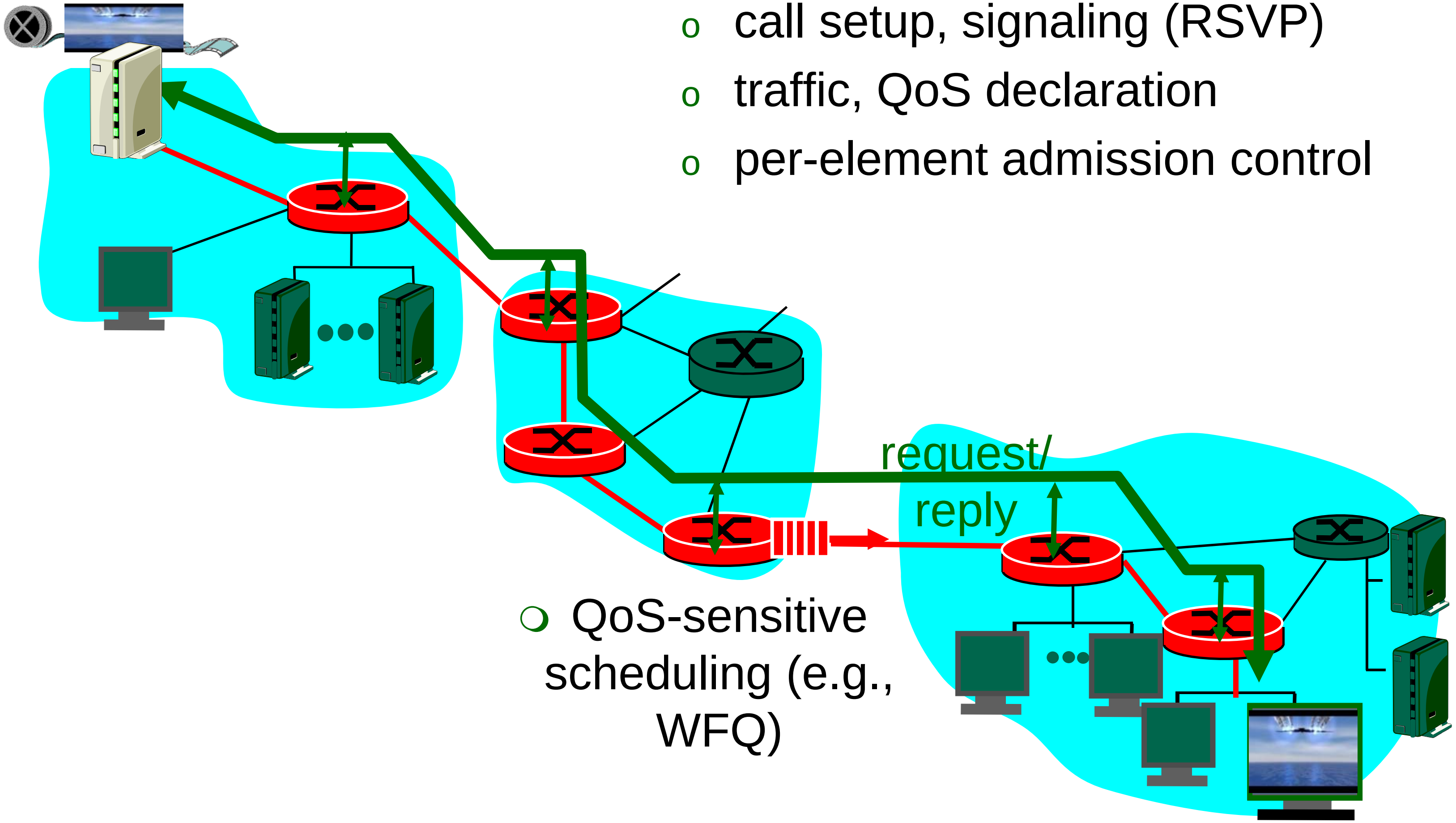


Principle 4

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



- QoS-sensitive scheduling (e.g., WFQ)

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IETF Integrated Services

- architecture for providing QOS guarantees in IP networks for individual application sessions
- resource reservation: routers maintain state info (a la VC) of allocated resources, QoS req's
- 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?

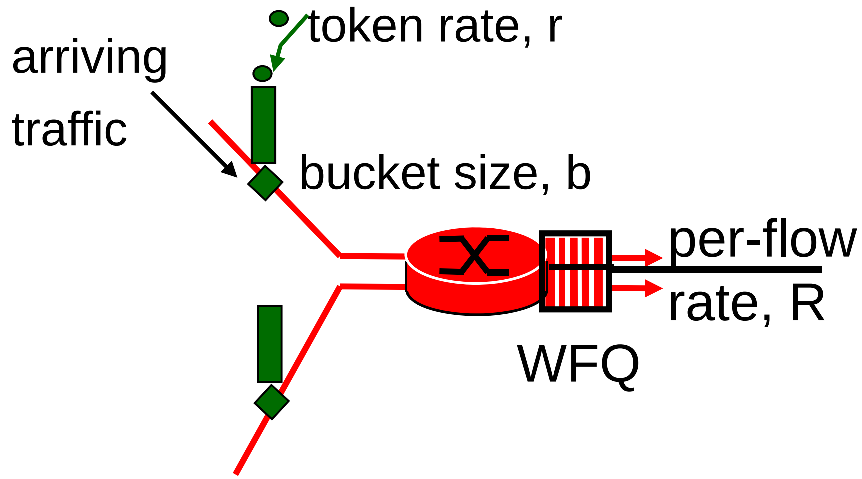
Call Admission

Arriving session must :

- declare its QOS requirement
  - R-spec: defines the QOS being requested
- characterize traffic it will send into network
  - T-spec: defines traffic characteristics
- signaling protocol: needed to carry R-spec and T-spec to routers (where reservation is required)
  - 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."



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

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Signaling in the Internet

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

- New requirement: reserve resources along end-to-end path (end system, routers) for QoS for multimedia applications
- RSVP: Resource Reservation Protocol [RFC 2205]
  - " … allow users to communicate requirements to network in robust and efficient way." i.e., signaling!
- 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…

- specify how resources are to be reserved
  - rather: a mechanism for communicating needs
- determine routes packets will take
  - that's the job of routing protocols
  - signaling decoupled from routing
- interact with forwarding of packets
  - 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)

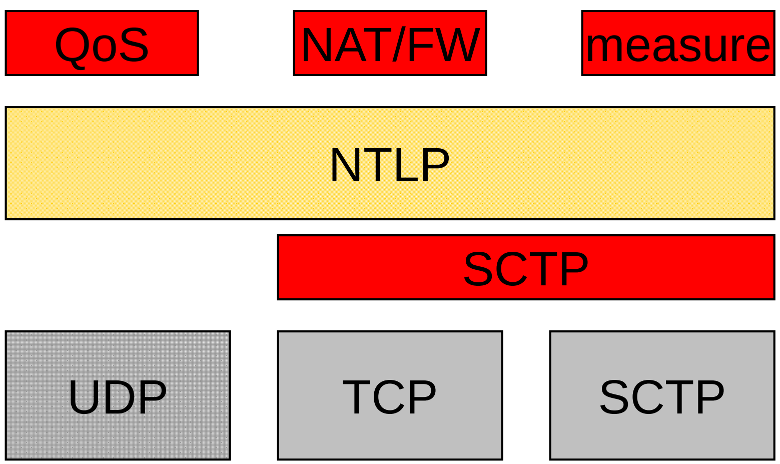
- RSVP not widely used for resource reservation
  - But used for MPLS path setup
  - Design heavily biased by multicast needs
  - Limited ability signaling delivery any size of signaling & over congested situation
  - Marginal and after-the-fact security
  - Limited support for IP mobility

NSIS (cont'd)

- Thus, IETF NSIS working group developing new framework for general state management protocol
  - resource reservation
  - NAT and firewall control
  - traffic and QoS measurement
  - MPLS and lambda path setup
- Split into two components:
  - NSIS Signaling Layer Protocol (NSLP)
  - NSIS Transport Layer Protocol (NTLP)

NSIS (cont'd)

- On-path vs. off-path
  - off-path → bandwidth brokers
- Discovery of next NTLP or NSLP hop
  - use router alert option



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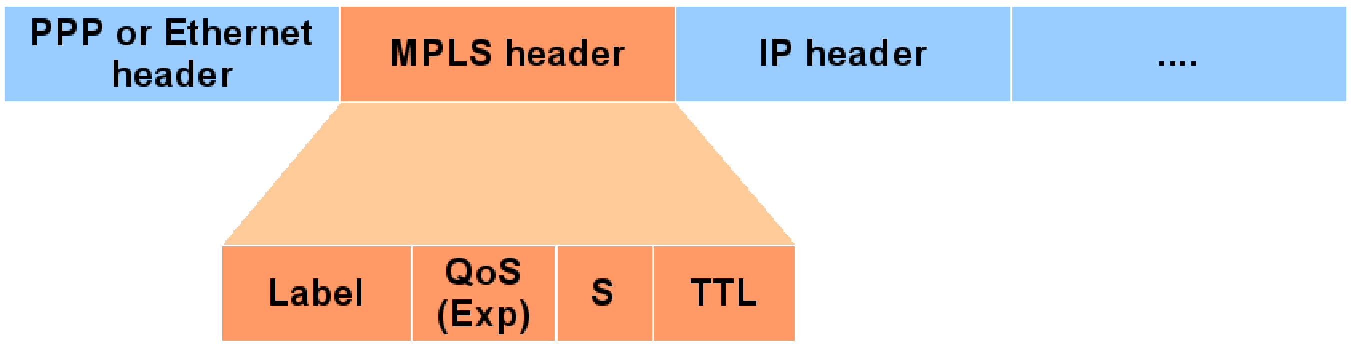
Multiprotocol Label Switching (MPLS)

- *Original motivation*: improve forwarding speed of IP routers.
- MPLS introduces a **fixed-length label** between layer-2 (i.e. PPP or Ethernet) header and layer-3 (i.e. IP) header.

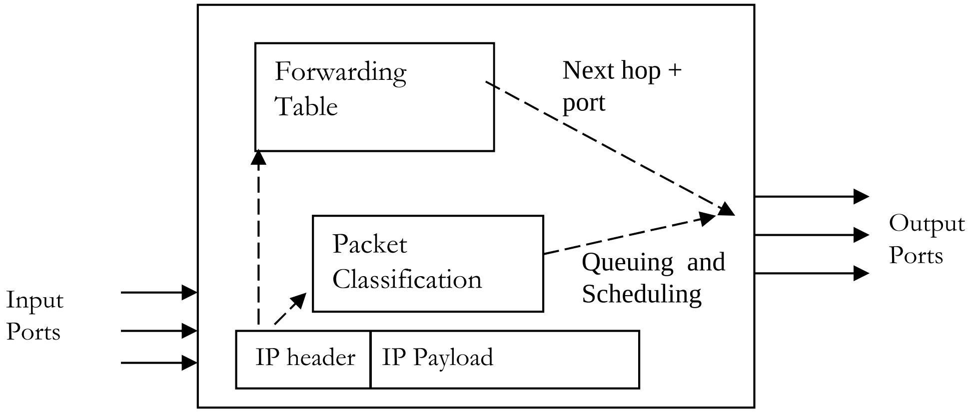


Introduction to MPLS

- **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.
- **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.

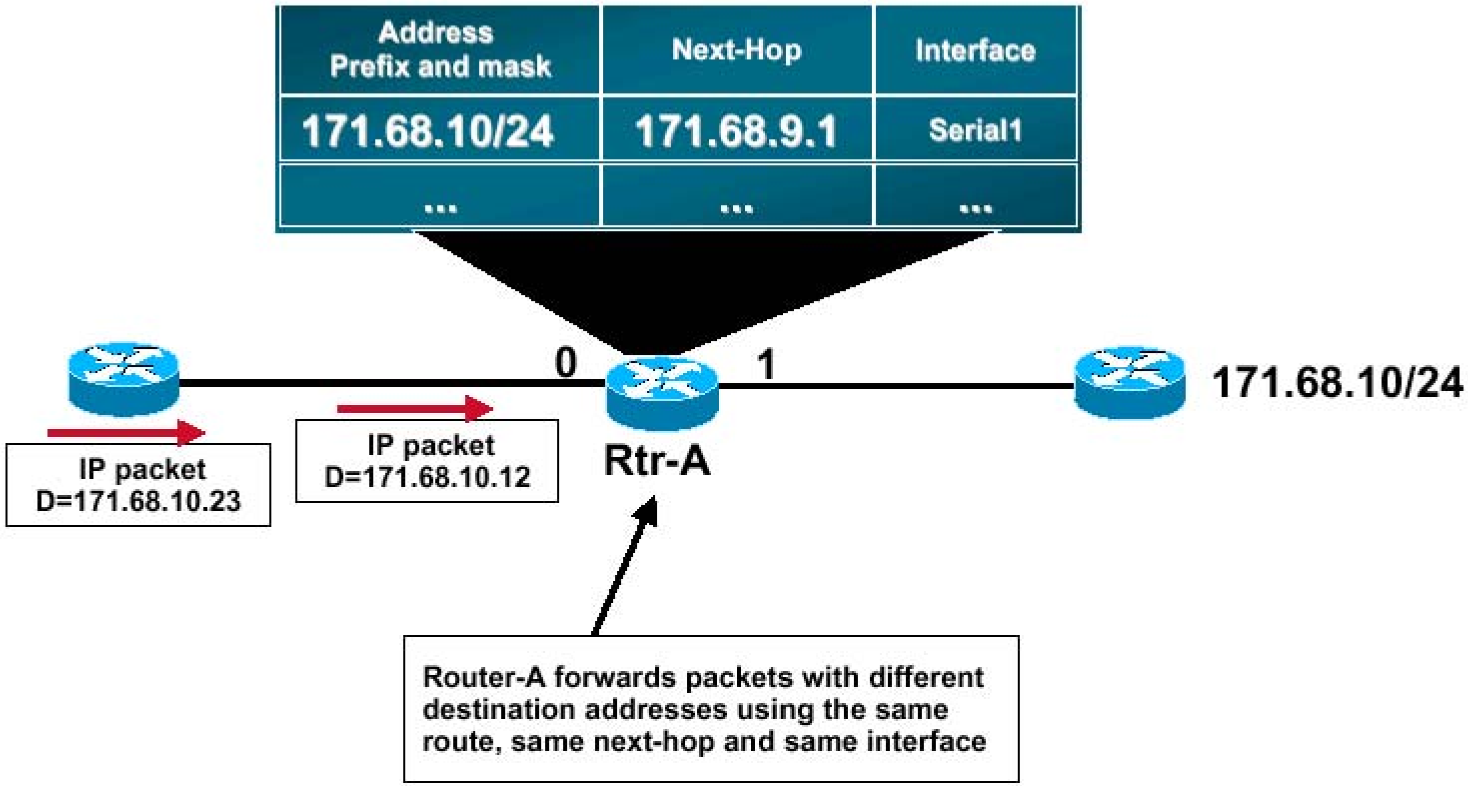
IP Forwarding

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

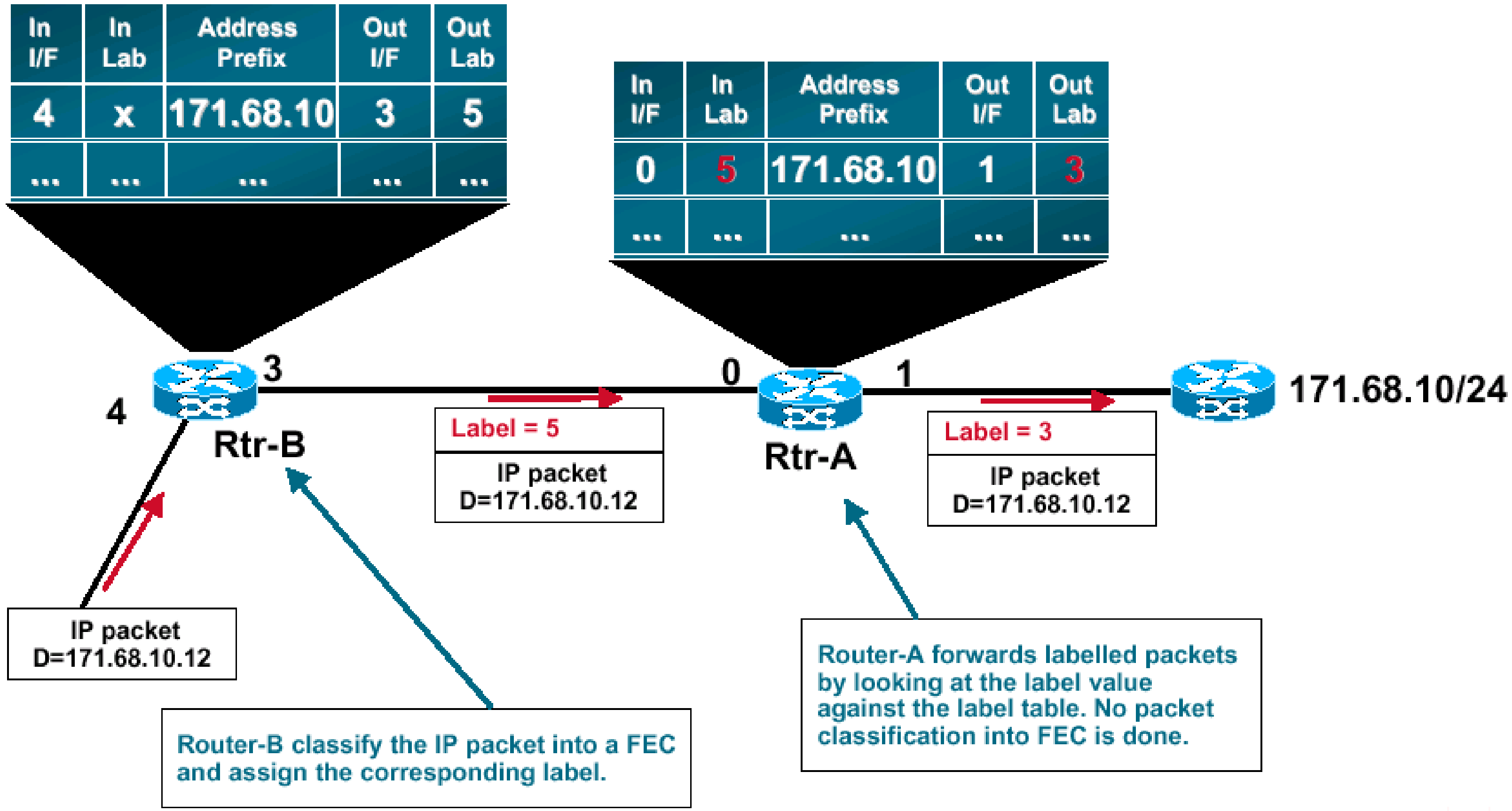


NIF node forwarding Engine

IP Forwarding (cont'd)

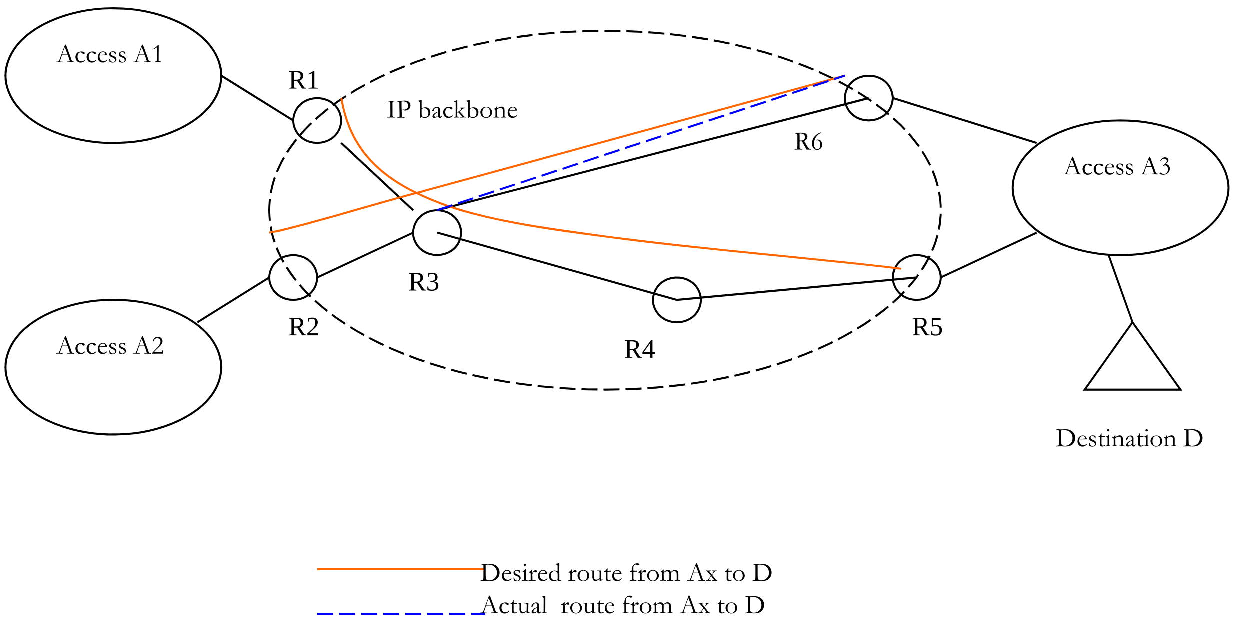


MPLS forwarding



FEC:
Forwarding
Equivalence
Class

MPLS Network



Traffic Engineering to override shortest path route

MPLS Advantages

- Router can use any information in determining label assignment, not limited to packet header.
- How to distribute labels may become more and more complicated, without any impact on the routers that merely forward labeled packets.
- 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.
- 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

- Principles
  - classify multimedia applications
  - identify network services applications need
  - making the best of best effort service
- Protocols and Architectures
  - specific protocols for best-effort
  - mechanisms for providing QoS
  - architectures for QoS
    - multiple classes of service
    - QoS guarantees, admission control

Thank you

Any questions?