Vorlesung Telematik (Computer Networks)

WS2003/04

Quality of Service

Telematics group
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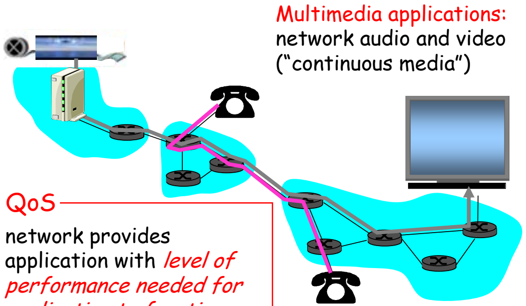
Outline

- **What is Quality of Service (QoS)?**
- Principles and Mechanisms of QoS
- Proposed Techniques for QoS in the Internet
  - ReSource Reservation Protocol (RSVP)
  - Integrated Services
  - Differentiated Services
- Credits:
  - James Kurose, Keith Ross, Computer Networking(2nd Ed.), Addison-Wesley, 2002
  - Nick McKeown, Stanford University

What is Quality of Service?

Multimedia applications: network audio and video ("continuous media")

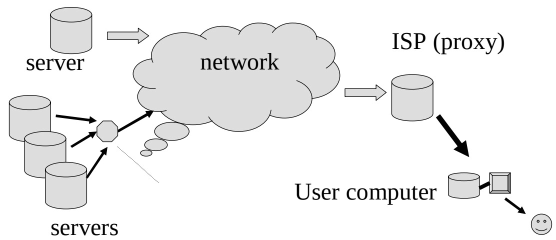


QoS

network provides application with *level of performance needed for application to function.*

Example: Web transfer chain

- User computer



Why QoS?
1.Limited Resource

- QoS is an issue due to *limited resource* problem.
- If resources are unlimited ==> no “quality” problem.
- Got to consider in light of some predictions of bandwidth becomes ”unlimited”.

Why QoS
2. Variety of Services

- Problem of QoS simplifies under single objectives == single service.
  - e.g. -- telephone system -- quality problem was not an issue.
  - e.g. -- butttt. Cellular phone -- quality is an issue.

Why QoS(cont)

- Problem of QoS magnifies in light of multiple objectives == multiple services.
- Two quality dimensions:
  - Time constraints (timely service)
  - Precision
- Two traffic characteristics
  - Quantity (rate)
  - Burstiness

Services

- Voice: Timely - high
  Precision - low
  Volume - medium
  Burstiness - medium
- Email: Timely - low
  precision - high
  volume - variable (low - huge)
  burstiness - might be high
- Web: Timely - medium
  precision - high
  volume - medium
  burstiness - high

Services (cont)

- IRC (Internet Relay Chat):
  Timely - medium-high
  precision - high
  volume - small
  burstiness - small
- Live Video: Timely - high
  precision - low
  volume - high
  burstiness - high

  FTP: Timely - low
  precision - high
  volume - high
  burstiness - depends

Effects of Variety

- Makes mechanisms complex
- Can benefit from sophistication
  ==> can get good utilization!

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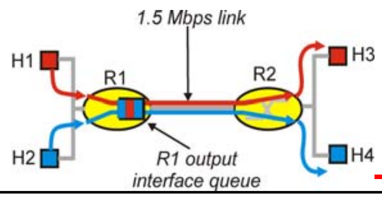
Improving QOS in IP Networks

- Thus far: "making the best of best effort"
- Future: next generation Internet with QoS guarantees
  - RSVP: signaling for resource reservations
  - Differentiated Services: differential guarantees
  - Integrated Services: firm guarantees
- simple model for sharing and congestion studies:



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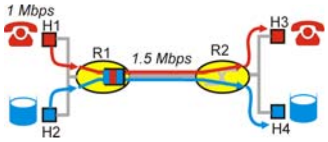
Principles for QOS Guarantees

- Example: 1MbpsI P 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/classifying** needed for router to distinguish between different classes; and new router policy to treat packets accordingly

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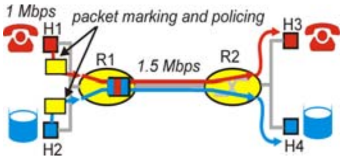
Principles for QOS Guarantees (more)

- 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: **shaping and policing**

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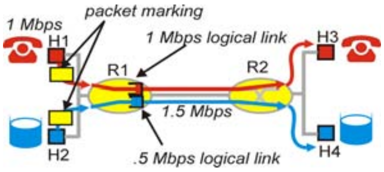
Principles for QOS Guarantees (more)

- 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**

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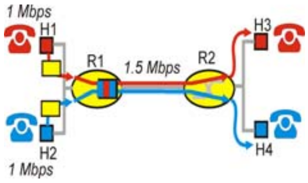
Principles for QOS Guarantees (more)

- *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

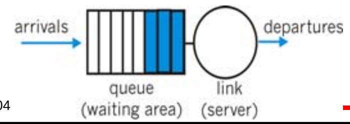
Summary of QoS Principles

- Per-session
  - Call setup, call admission and resource reservation
    - "Can the network accept the call and provide the QoS?"
- Per-packet
  - Packet Classification: "What flow does this packet belong to, and when should I send it?"
  - Shaping: "Am I keeping my side of the contract?"
  - Policing: "Did the user keep his/her side of the contract?"
  - Packet Scheduling: "Sending the packet at the right time."

Let's next look at mechanisms for achieving this ….

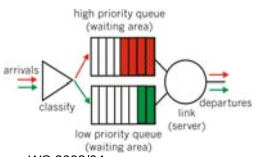
Scheduling And Policing Mechanisms

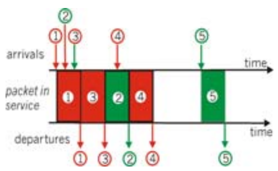
- scheduling: choose next packet to send on link
- FIFO (first in first out) scheduling: send in order of arrival to queue
  - real-world example?
  - discard policy: if packet arrives to full queue: who to discard?
    - Tail drop: drop arriving packet
    - priority: drop/remove on priority basis
    - random: drop/remove randomly



Scheduling Policies: more

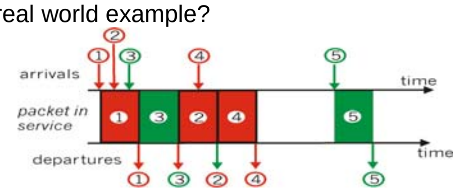
- Priority scheduling: transmit highest priority queued packet
- multiple *classes*, with different priorities
  - class may depend on marking or other header info, e.g. IP source/dest, port numbers, etc..
  - Real world example?





Scheduling Policies: still more

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



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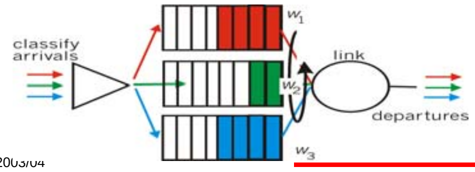
Scheduling Policies: still more

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



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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)

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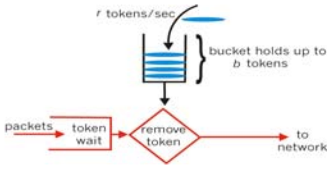
Policing Mechanisms

- 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).*

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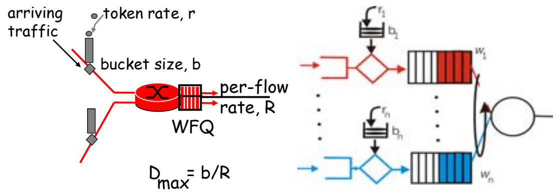
Policing Mechanisms (more)

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



Outline

- What is Quality of Service (QoS)?
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- Proposed Techniques for QoS in the Internet
  - ⇨ **ReSource Reservation Protocol (RSVP)**
  - – Integrated Services
  - – Differentiated Services

Resource Reservation: RSVP

- RSVP is a protocol for establishing a guaranteed QoS path between a sender and receiver(s).
- RSVP establishes end-to-end reservations over a connectionless network.
- RSVP is robust when routers/links fail: traffic is re-routed and new reservations are established.
- RSVP is receiver-initiated and so is designed with multicast in mind.

Resource Reservation: RSVP

The network needs to know the TSpec, the RSpec and the Path followed by packets.

- The TSpec (specification of the transmitted traffic) is only known by the source.
- The Path is only known by the network.
- The Rspec (specification of what the receiver would like to receive).

Resource Reservation: RSVP

So, the sender periodically sends the Tspec to the whole multicast group ("PATH messages").

- The network learns the Path taken by packets in the multicast group.
- The receiver/network learns the TSpec.

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Resource Reservation: RSVP

To initiate a new reservation, a receiver sends messages to reserve resources "up" the multicast tree ("RESV messages").

- The routers forward RESV messages towards the source.
- The routers determine if the reservation can be fulfilled.
- If necessary/possible, the routers merge the requests from different receivers.

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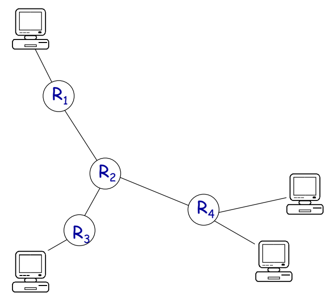
Establishing a reservation

1: The multicast group is established



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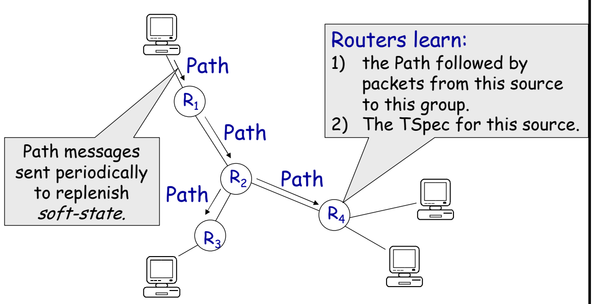
Establishing a reservation

2: RSVP Path messages sent by source(s)



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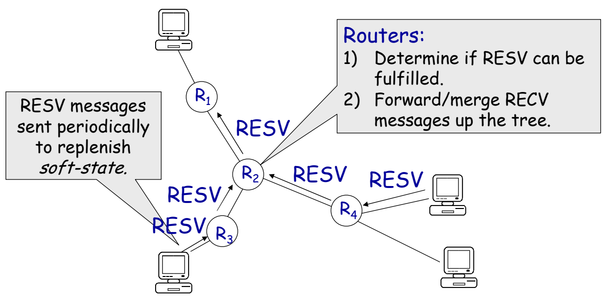
Establishing a reservation

3: RSVP RESV messages sent by receiver(s)



Establishing a reservation
Merging RESV messages

Examples:

1. Router receives RESVs from two receivers, A and B, asking for 100ms delay and 50ms delay respectively. Router passes up request for 50ms.
2. Router receives RESVs for a audio teleconference call with 100 participants requesting 1.5Mb/s each. The tree need support only 1.5Mb/s total data-rate.

RSVP supports many styles of RESV merging.

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  - ⇨ **Integrated Services**
  - Differentiated Services

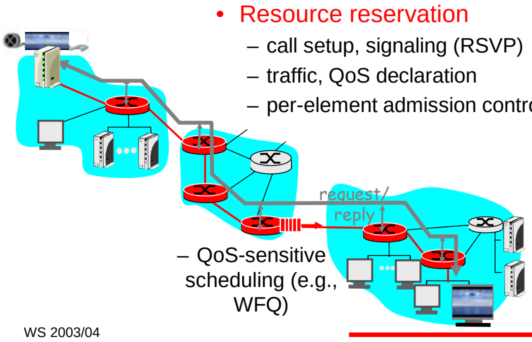
IETF Integrated Services

- 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?

Intserv: QoS guarantee scenario

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



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

Call Admission

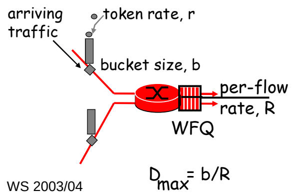
Arriving session must :

- 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."

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IETF Differentiated Services

Concerns with Intserv:

- Scalability: signaling, maintaining per-flow router state difficult with large number of flows
- Flexible Service Models: Intserv has only two classes. Also want "qualitative" service classes
  - "behaves like a wire"
  - relative service distinction: Platinum, Gold, Silver

Diffserv approach:

- simple functions in network core, relatively complex functions at edge routers (or hosts)
- Don't define define service classes, provide functional components to build service classes

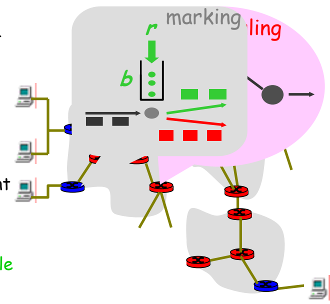
Differentiated Services

- Instead of *per-flow* queues and rates, uses *per-class* queues and rates.
- Much simpler to implement, introduce and manage.
- But… means that many flows share the same queue, state and capacity. So, it is like a simple approximation to Integrated Services.

Diffserv Architecture

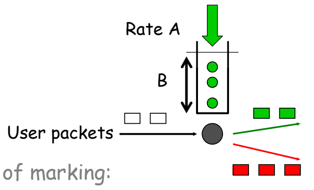
Edge router:
- per-flow traffic management
- marks packets as in-profile and out-profile

Core router:
- per class traffic management
- buffering and scheduling based on marking at edge
- preference given to in-profile packets
- Assured Forwarding



Edge-router Packet Marking

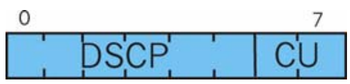
- profile: pre-negotiated rate A, bucket size B
- packet marking at edge based on per-flow profile



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

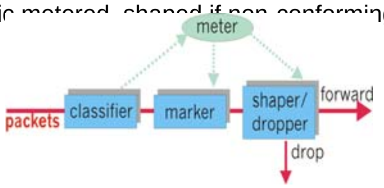
- Packet is marked in the Type of Service (TOS) in IPv4, and Traffic Class in IPv6
- 6 bits used for Differentiated Service Code Point (DSCP) and determine PHB that the packet will receive
- 2 bits are currently unused



Classification and Conditioning

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

- user declares traffic profile (eg, 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

Quality of Service in the Internet

Some Interesting Questions

- What are the key components for Internet QoS?
- How can we implement per-flow buffering and scheduling when the number of flows is large?
- How can we encourage/force users to ask for only the resources they need?
- How can we bill users for the service they receive?

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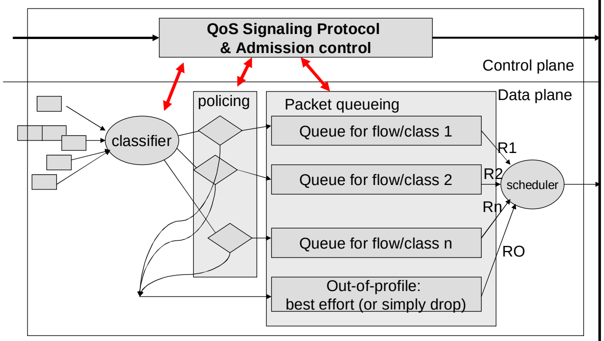
Internet QoS: Summary



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Quality of Service in the Internet

The jury is still out as to what scheme makes most sense, if any.

1. Some people believe that fine-grained guarantees are needed.
2. Others believe that simple, coarse-grained guarantees will be sufficient.
3. Still others believe that a simple strict priority mechanism between “premium” and “best-effort” service will be OK.
4. Many people believe we should just provision a lot more capacity and be done with it!