CSE/EE 461 Lecture 22
Quality of Service

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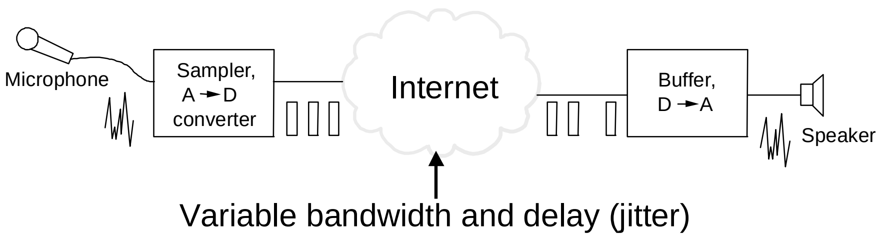
Peterson, Chapter 6.5

Quality of Service

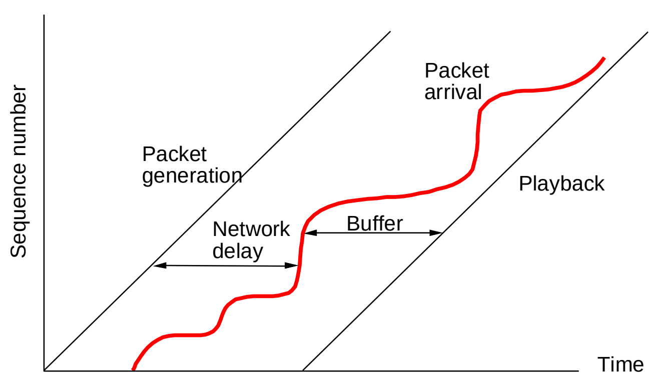
- What kinds of service do different applications need?
  - Web is built on top of "best-effort" service
  - Other applications may need more
    - Internet telephone service (voice over IP)
    - streaming audio/video
    - real-time games
    - remote controlled robotic surgery
- What mechanisms do we need to support these more demanding applications?
  - as with multicast, will need network to do more

An Audio Example

- Playback is a real-time service
  - audio must be received by a deadline to be useful
  - buffering can allow small variations in bw, delay

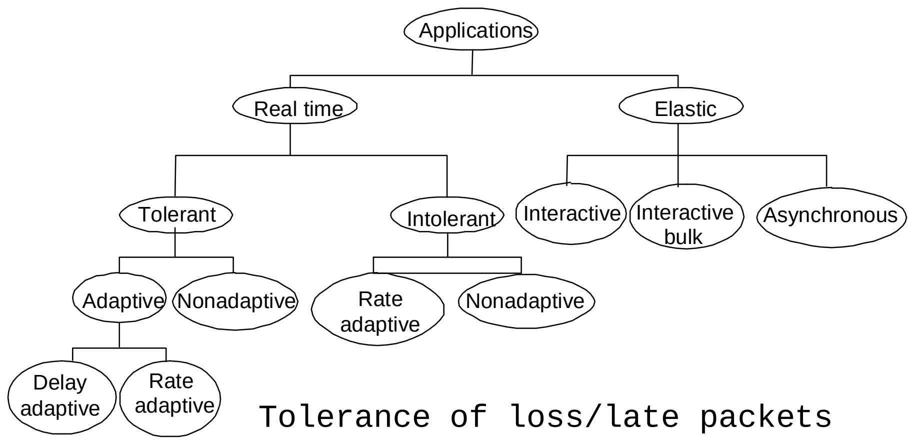


Tolerating Jitter with Buffering



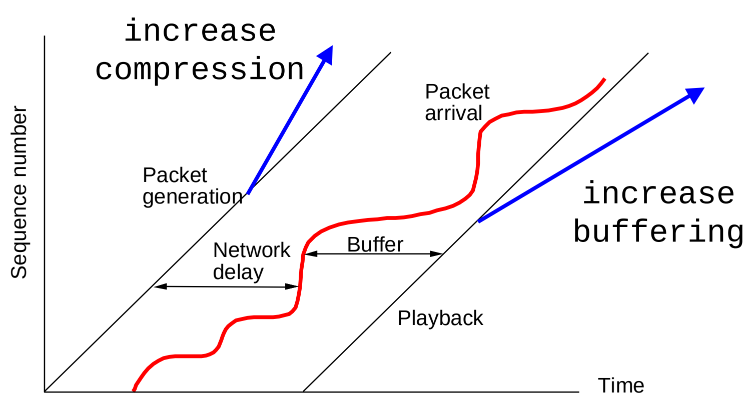
- Insert variable delay before playout to give time for late samples to arrive

Taxonomy of Applications



Tolerance of loss/late packets
Adaptivity to rate/delay change

Adapting to Network Change



- Adapt to changes in network behavior by exploiting application-specific techniques

Roadmap – Various Mechanisms

Simple to build,
Weak assurances

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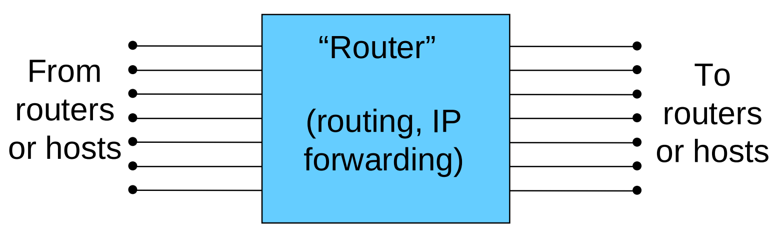
Complex to build,
Strong assurances

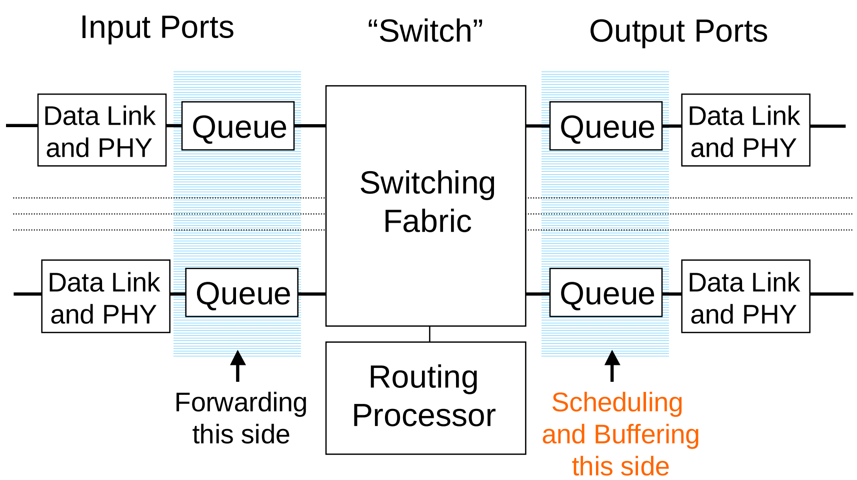
FIFO with Drop Tail	Classic Best Effort
FIFO with RED	Congestion Avoidance
Weighted Fair Queuing	Per Flow Fairness
Differentiated Services	Aggregate Guarantees
Integrated Services	Per Flow Guarantees

What's in a Router?



- By convention, draw input ports on left, output on right. (But in reality a single physical port handles both directions.)

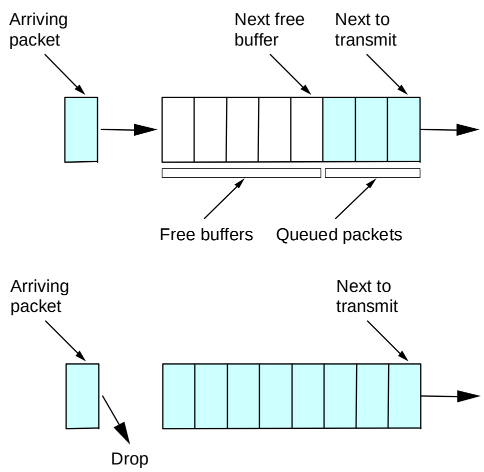
Model of a Router



Scheduling and Buffer Management

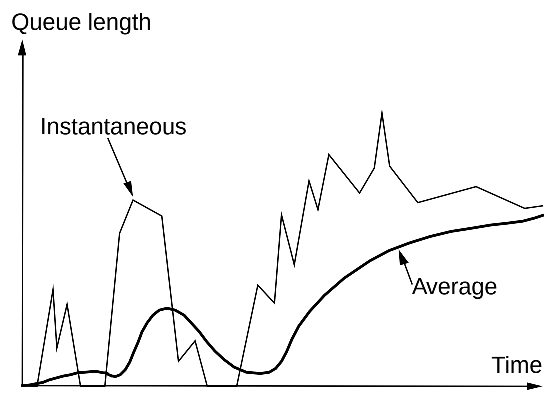
- Two different functions implemented at the queue
- A scheduling discipline
  - This is the order in which we send queued packets
  - Examples: FIFO or priority-based
- A buffer management policy
  - This decides which packets get dropped or queued
  - Examples: Drop tail, random drop, or per flow

FIFO with Tail Drop



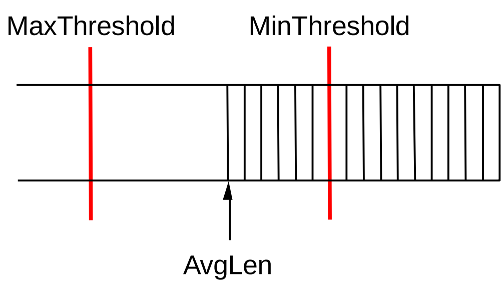
Incipient Congestion at a Router

- Sustained overload causes queue to build and overflow



Random Early Detection (RED)

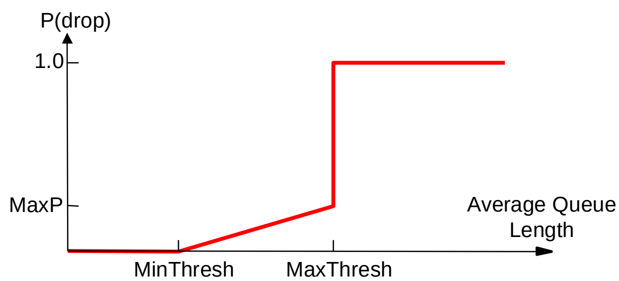
- Routers monitor average queue and send "early" signal to source by dropping a packet



- Paradox: early loss can improve performance!

Red Drop Curve

- Start dropping a fraction of the traffic as queue builds
  - Expected drops proportional to bandwidth usage
  - When queue is too high, revert to drop tail
  - Nice theory, difficult to set parameters in practice



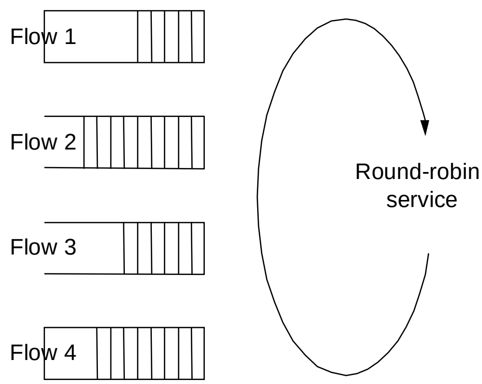
RED Penalty Box

- FIFO is not guaranteed (or likely) to be fair
  - If some hosts don't play by the rules, they can grab more bandwidth
- Neither is RED
  - senders can still ignore packet loss signals
- One solution: penalty box
  - keep track of flows sending faster than average
  - preferentially drop packets for those flows
  - after drop, verify that flow reduced its rate
    - if not, drop more of its packets

Fair Queuing (FQ)

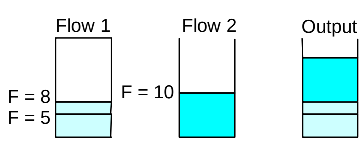
- Fair Queuing is an alternative approach
  - Maintain one queue per traffic source (flow) and send packets from each queue in turn
    - Simulate round robin since packets are different sizes
  - Provides each flow with its "fair share" of the bandwidth, no matter what any flow does
  - However, bandwidth per flow can change if number of flows increases/decreases
- Weighted Fair Queueing (WFQ)
  - proportionately increase rate given to certain flows

Fair Queuing



Fair Queueing and WFQ

- Want to proportionally share bandwidth
  - At the “bit” level, but must send whole packets
- Approximate with <u>finish</u> times for each packet
  - finish (F) = arrive + length*rate; rate depends on # of flows, weight
  - Send in order of finish times, except don’t preempt transmission if a new packet arrives that should go first

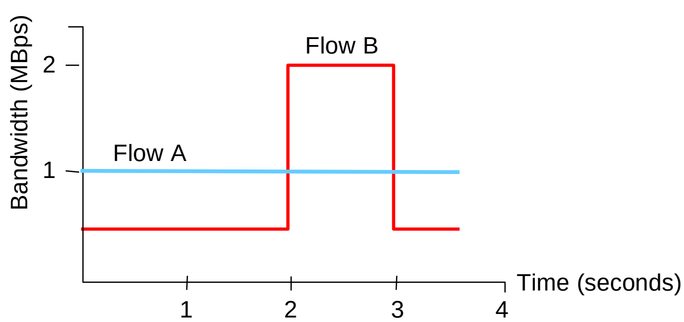


Supporting QOS Guarantees

- Flowspecs. Formulate application needs
  - Need descriptor (token bucket) for guarantee
- Admission Control. Decide whether to support a new guarantee
  - Network must be able to control load to provide guarantees
- Signaling. Reserve network resources at routers
  - Analogous to connection setup/teardown, for router reservations
- Packet Scheduling. Implement guarantees
  - Various mechanisms can be used, e.g., explicit schedule, priorities, WFQ, …

Specifying Bandwidth Needs

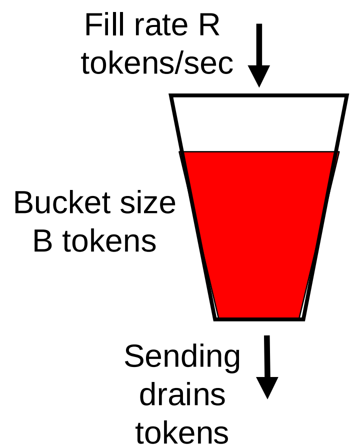
- Problem: Many applications have variable demands



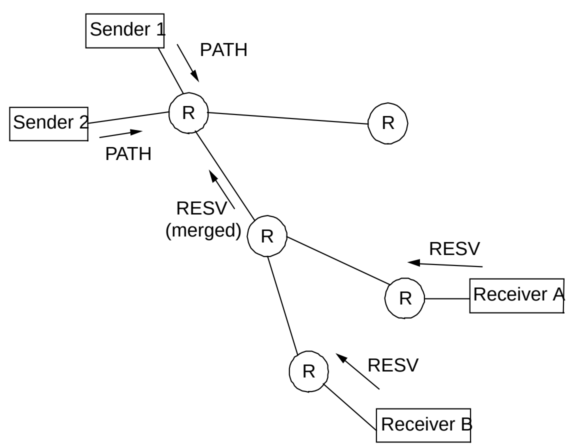
- Same average bandwidth, but very different needs over time
  - example: MPEG compression rate depends on how much changes from frame to frame

Token Buckets

- Simple model
  - reflects both average, variability over time
- Use tokens to send bits
- Avg bandwidth is R bps
- Maximum burst is B bits



Resource Reservation Protocol (RSVP)



RSVP Issues

- RSVP is receiver-driven to be able to support multicast applications
- Only reserve resources at a router if there are sufficient resources along the entire path
  - both for average bandwidth and maximum bursts
- What if there are link failures and the route changes?
  - receivers periodically refresh by sending new requests toward sender
- What if there are sender/receiver failures?
  - reservations are periodically timed out

IETF Integrated Services

- Fine-grained (per flow) guarantees
  - Guaranteed service (bandwidth and bounded delay)
  - Controlled load (bandwidth but variable delay)
- RSVP used to reserve resources at routers
  - Receiver-based signaling that handles failures
  - Router can police that flow obeys reservation
- Priorities, WFQ used to implement guarantees
  - Router classifies packets into a flow as they arrive
  - Packets are scheduled using the flow's resources
  - Flows with guaranteed service scheduled before controlled load, scheduled before best effort

IETF Differentiated Services

- A coarse-grained approach to QOS
  - Packets are marked as belonging to a small set of services, e.g, premium or best-effort, using the TOS bits in the IP header
- Marking policed at administrative boundaries
  - ISP marks 10Mbps (say) of your traffic as premium depending on your service level agreement (SLAs)
- Routers understand only the different service classes, not individual reservations
  - Use priority queues or WFQ for each class, not for each flow

Two-Tiered Architecture