CSE 123b
Communications Software

Spring 2002

Lecture 10: Quality of Service

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Today's class: Quality of Service

- What's wrong with "Best Effort" service?
- What kinds of service do applications need?
- Integrated services architecture
- Differentiated service architecture

The Problem(s)

- Best effort service model (send and pray)
  - Statistical multiplexing provides efficient use of bandwidth for bursty applications, but…
  - **No isolation** during contention
- Smart hosts-dumb routers architecture
  - Congestion control at end-hosts
  - Resource control feedback occurs slowly (min 1 RTT)
  - Must trust end hosts to behave well

Motivation: Multimedia

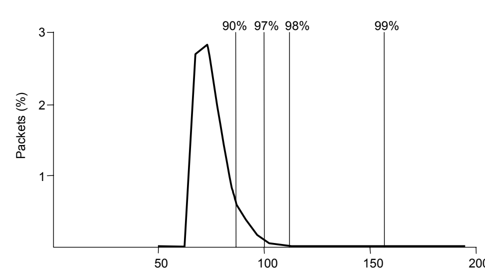
- Playback is a real-time service in the sense that the audio must be received by a deadline to be useful

- Real-time apps need assurances from the network
- Q: What assurances does playback require?

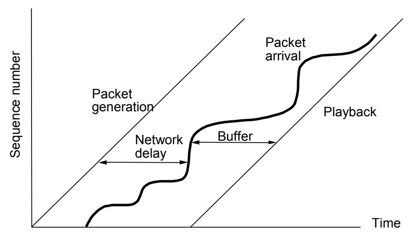
Network Support for Playback

- **Bandwidth**
  - There must be enough on average
  - But we can tolerate to short term fluctuations
- **Delay**
  - Ideally it would be fixed
  - But we can tolerate some variation (jitter)
- **Loss**
  - Ideally there would be none
  - But we can tolerate some losses

Example: Delay and Jitter



Tolerating Jitter with Buffering

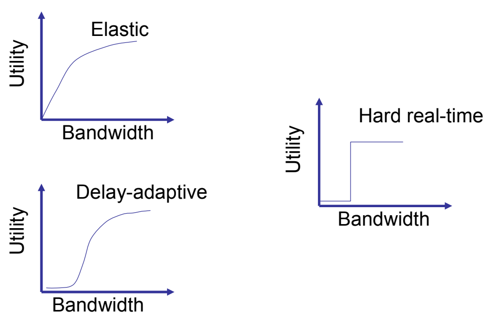


- Buffer before playout so that most late samples will have arrived

Application requirements

- Application variations
  - Rigid – fixed playback point (low jitter)
  - Adaptive – application can vary playback point (jitter ok)
  - Tolerant – can tolerate interrupt/degradation
  - Intolerant – can't
- In reality only two classes
  - Rigid and intolerant applications (e.g. telemedicine)
  - Adaptive and tolerant (e.g. RealPlayer)

Another way to look at it…



The Integrated Services solution

- **Change service model**
  - Multiple service classes; service specification
  - Guaranteed (send and pay), predicted, best-effort
  - Network directly supports **per-application** service requests
- **Change implementation**
  - Hosts explicitly **reserve** network capacity
  - Routers implement **admission control**
  - Routers use explicit **scheduling** mechanisms to provide **isolation** between admitted flows
  - Requires **per-flow state**

Intserv components

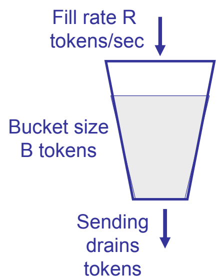
- Service classes
  - What are application demands?
  - What should the network promise?
  - What does the application promise?
- Service interface
  - How are service requirements described?
- Service mechanisms
  - How are service guarantees enforced?

Service interface

- Specify service class
- Specify "flowspec" for application data flow
  - Tspec: describes the flow's traffic characteristics
    - » Average bandwidth + burstiness
  - Rspec: describes the service requested from the network
    - » Delay target
- Send request to network
  - Network can say "no"
  - If network says yes, then try to make sure it happens

Token Buckets

- Common, simple descriptor
- Use tokens to send bits
- Average bandwidth is R bps
- Maximum burst is B bits



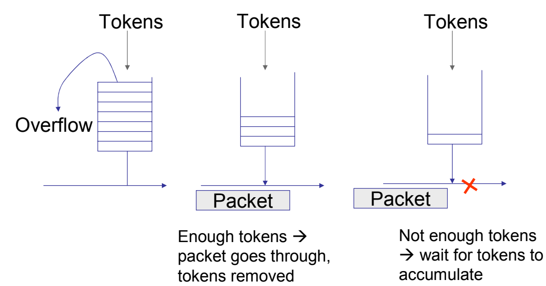
Service mechanisms

- Admission control protocol
  - RSVP
- Shaping/policing
  - Making sure that everyone only sends as much as they requested
- Per-flow scheduling policy in routers
  - Fair Queuing
    - » Each flow gets equal access to bandwidth
  - Weighted Fair Queuing
    - » Each flow gets access to bandwidth proportional to weight

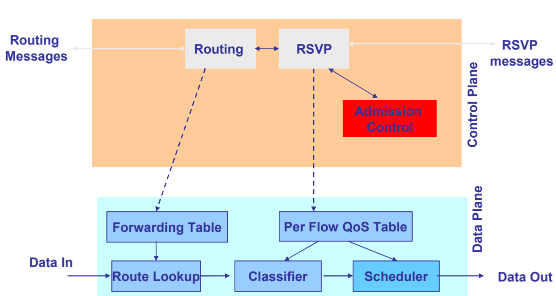
Using Token bucket traffic conditioning

- Operation
  - Token bucket size: *b* (maximum number of tokens)
  - Token bucket rate: *r* (rate at which new tokens are provided)
- Need k tokens to send a packet of k bytes
- Applications
  - **Shaping** (delay packets until k tokens appear)
    - » Long term rate is limited to r, short term bursts to b
    - » Over some interval T, traffic is limited to *b+r**T
  - **Policing** (drop packets if insufficient tokens)
  - **Buffer** management (mark packets and transmit if > k)
    - » Drop marked (i.e. out-of-spec) packets during congestion

Token Bucket Operation

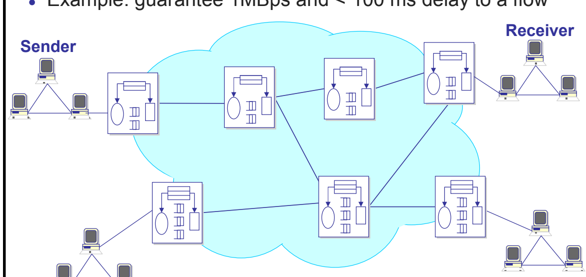


New elements in the router



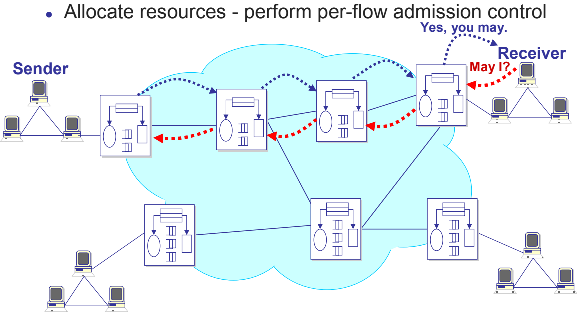
Integrated Services Example

- Example: guarantee 1MBps and < 100 ms delay to a flow



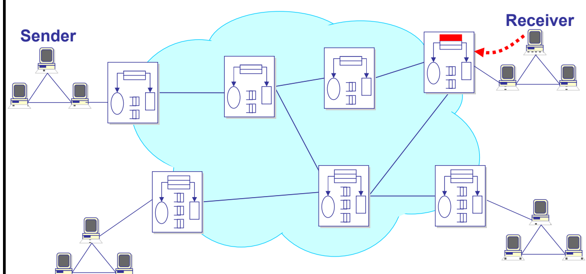
Integrated Services Example

- Allocate resources - perform per-flow admission control



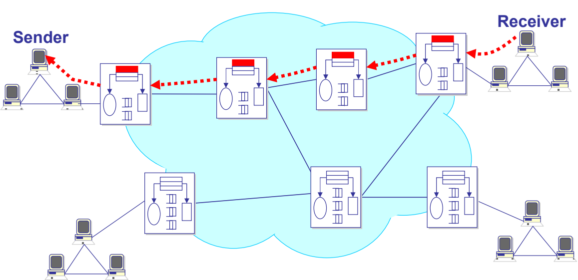
Integrated Services Example

- Install per-flow state



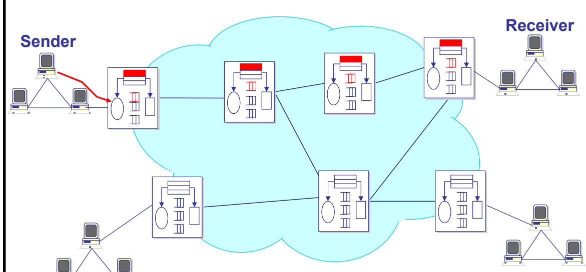
Integrated Services Example

- Install per flow state



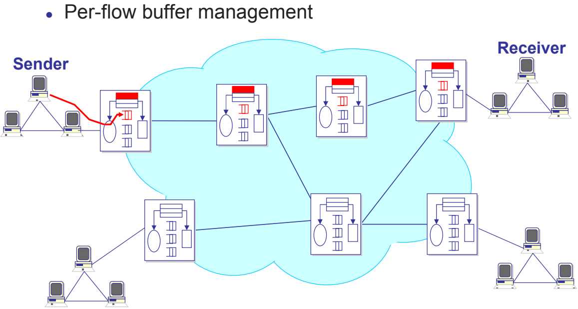
Integrated Services Example: Data Path

- Per-flow classification



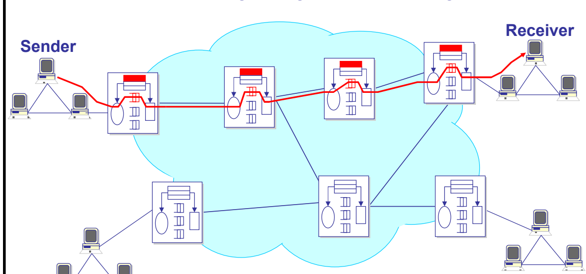
Integrated Services Example: Data Path

- Per-flow buffer management



Integrated Services Example

- Per-flow scheduling (weighted-fair-queuing: WFQ)



Guaranteed service

- Edge routers shape traffic accord to r,b
- Routers implement WFQ
  - Weight set according to share r is of total link capacity
- Parekh & Gallager 91,92 prove bound on delay is b/r!
  - Even if other flows don't behave
- Why not make all service guaranteed service?

Issues?

- End-to-end approach
  - Inter-administrative domain issues
- Scalability (per-flow state)
- Efficiency
- Need to modify applications
- How much bandwidth does my application need?

Differentiated Services

- **Goal**
  - Provided different classes of service for traffic
- **Economic motivation**
  - Extract value through multi-tiered service (like airlines)
    - » Best-effort service is bulk of traffic, but premium service important for capitalization
    - » Aside: impact of flat rate vs usage-based pricing?
  - Bilateral-settlement, not end-to-end
- **Technical motivation**
  - Scalability/simplicity
  - No per-flow state; traffic-aggregates only

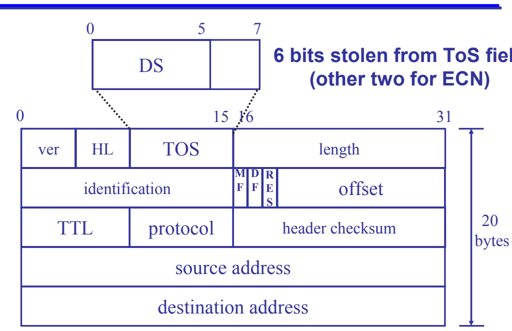
Basic architecture

- **Single network** (for now)
- **Edge routers**
  - Classify traffic as it enters network
  - Possibly shaping/policing to fit a user profile (pre-negotiated)
  - Marks packets to assign them to different traffic classes
- **Core routers**
  - Schedule/drop packets according to markings
  - State proportional to # classes; No per-flow state or signaling
- ***The Network Engineer***
  - Provisions network so there is sufficient bandwidth to accommodate service

Terminology

- **Differentiated Services Code Point** (DSCP)
  - Particular value for 6 bit packet header indicating how packet should be handled; index into table
- **Behavior Aggregate** (BA)
  - Collection of packets on a link with the same DSCP
- **Per-Hop Behavior** (PHB)
  - Forwarding behavior applied by router to packets according to DSCP; not end-to-end
- **DS Domain**
  - Contiguous network using a common set of PHBs and provisioning policy

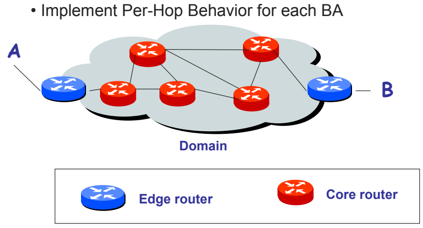
DS header field



6 bits stolen from ToS field (other two for ECN)

DiffServ architecture

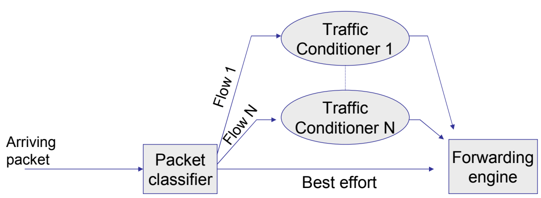
- **Edge router**
  - Shape & police traffic
  - Set particular DiffServ Code Point (DSCP) in DS header field
- **Core router**
  - Implement Per-Hop Behavior for each BA



Standard PHBs

- **Expedited Forwarding** (Jacobson)
  - "Virtual Pipe" between ingress and egress routers
  - Pipe has capacity C (negotiated with ISP)
  - If user sends at rate <= C, network guarantees low delay and loss
  - If user sends > C, excess traffic may be delayed or dropped
- **Assured Forwarding** (Clark)
  - "Better" service to anywhere
  - User profile indicates how much assured traffic is allowed
  - Up to that amount, network provides lower loss vs best-effort
  - Out-of-profile traffic is converted to best-effort

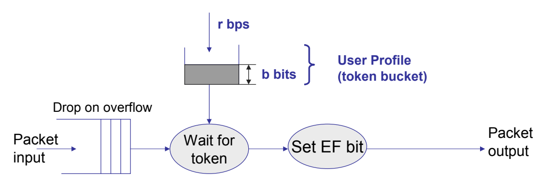
Edge Router Classification



Traffic classified based on packet header (including DSCP)

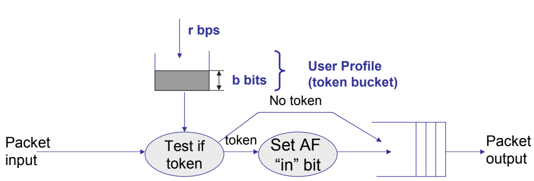
Traffic Conditioning for Expedited Forwarding

- Shape packets according to user profile
- Marked outbound packets with EF to indicate premium service



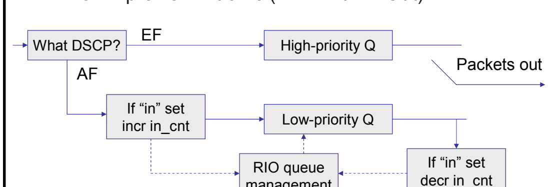
Traffic Conditioning for Assured Forwarding

- Meter packets according to user profile
- Mark in-profile packets with AF
- Out-of-profile packets send with AF cleared



Core Router Scheduling/Buffer Management

- Two strict priority queues (one for EF, one for AF)
  - What if we used WFQ?
- Lower priority queue implements preferential dropping for in-profile AF traffic (RED with In/Out)



Comparison to Best-Effort and Intserv

	Best-Effort	Diffserv	Intserv
Service	Connectivity No isolation No guarantees	Per aggregate isolation Per aggregate guarantee	Per flow isolation Per flow guarantee
Service scope	End-to-end	Domain	End-to-end
Complexity	No setup	Long term setup	Per flow steup
Scalability	Highly scalable (nodes maintain only routing state)	Scalable (edge routers maintains per aggregate state; core routers per class state)	Not scalable (each router maintains per flow state)

Summary

- Some applications need improved service
  - Multimedia, teleoperation, etc.
- Two approaches
  - IntServ: reserve bandwidth end-to-end, and schedule to provide guaranteed service
  - Diffserv: no guarantee, simply differentiate between different classes of service; treat some traffic better than other traffic
- Token bucket abstraction
  - Useful for describing and controlling traffic

For next time…

- Midterm
  - Sanjeev will have additional office hours this week
  - 4pm-5pm Wednesday: AP&M 3337A
- Keep working on projects
  - John-Paul will have additional office hours
  - 1pm-2pm Friday: AP&M 3337D