ECE/COMPSCI 356 Computer Network Architecture

Lecture 22: Quality of Service

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Overview

- Why QoS?
  - Real-time applications

- Approaches to QoS
  - Fine-grained
    - Integrated services
  - Coarse-grained
    - Differentiated services

Real-time applications

- Applications that are sensitive to the timeliness of data
- Examples
  - Audio and video
  - Industrial control
    - command sent to a robot arm reaches it before the arm crashes into something
  - File transfer
    - database update complete overnight before the business that needs the data resumes on the next day.

An example real-time application

- Data is generated by collecting samples from a microphone and digitizing them using an A →D converter
- The digital samples are placed in packets which are transmitted across the network and received at the other end
- At the receiving host the data must be played back at some appropriate rate

Quality of Service (QoS)

- Real-time applications
  - Need assurance *from the network that data is likely to arrive on time (for some definition* of "on time").
- Non-real-time applications
  - Use an end-to-end retransmission strategy to make sure data arrives *correctly*
  - Cannot provide timeliness.
- Network should treat some packets differently from others
- A network that can provide these different levels of service is said to support quality of service (QoS).

Approaches to QoS

- Fine-grained approaches
  - Provide QoS to individual flows
  - Integrated Services
    - often associated with RSVP (Resource Reservation Protocol).
- Coarse-grained approaches
  - Provide QoS to classes of packets
  - Differentiated Services
    - probably the most widely deployed QoS mechanism

Integrated Services

- Define service classes to meet the needs of different applications.

- Service Classes
  - Controlled Load Service
    - Emulate a lightly loaded network, even though the network may in fact be heavily loaded
  - Guaranteed Service
    - The network should guarantee the maximum delay of any packet is bounded

Overview of Integrated Services

- Flowspec
  - The set of information that a TCP flow provides to the network.
- Admission Control
  - The process of deciding whether the requested service can be satisfied.
- Resource Reservation
  - Network reserves resource based on Flowspec.
- Packet Scheduling
  - Routers and switches schedule packets to satisfy the requested service.

Flowspec

- Two parts:
  - *Rspec:* describes the requested service
    - controlled load service
      - no additional parameters
    - guaranteed service
      - specify a delay bound
  - *Tspec:* describes the flow's bandwidth requirement

Tspec

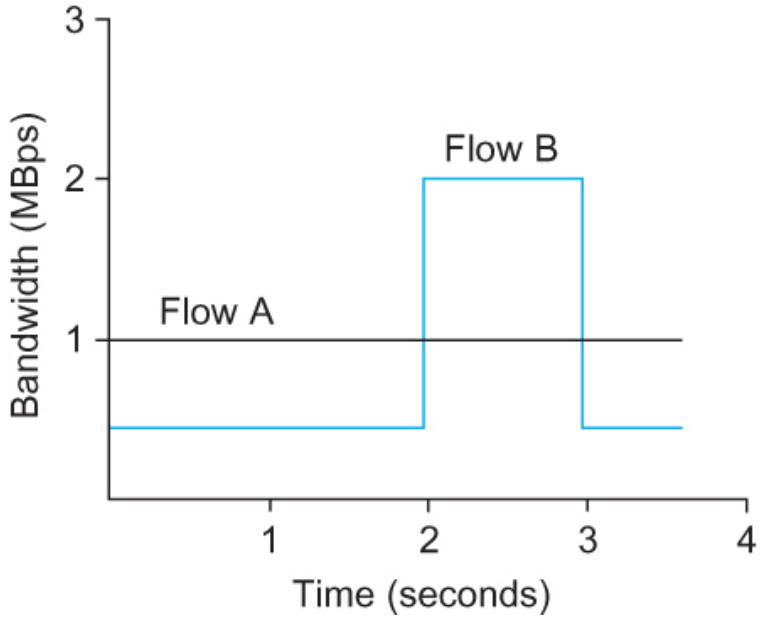
- Challenge
  - Bandwidth of a flow varies constantly
    - E.g., A video application generates more bits per second when the scene is changing rapidly than when it is still
  - How to describe bandwidth requirement of a flow?
- Solution
  - Token Bucket Filter

Token Bucket Filter

- The filter is described by two parameters
  - A token rate r
  - A bucket depth B
- To send a byte, a token is needed
- To send a packet of length n, n tokens are needed
- Initially there are no tokens
- Tokens are accumulated at a rate of r per second
- No more than B tokens can be accumulated
- A source can send a burst of as many as B bytes into the network, but over significant long interval source cannot send more than r bytes per second

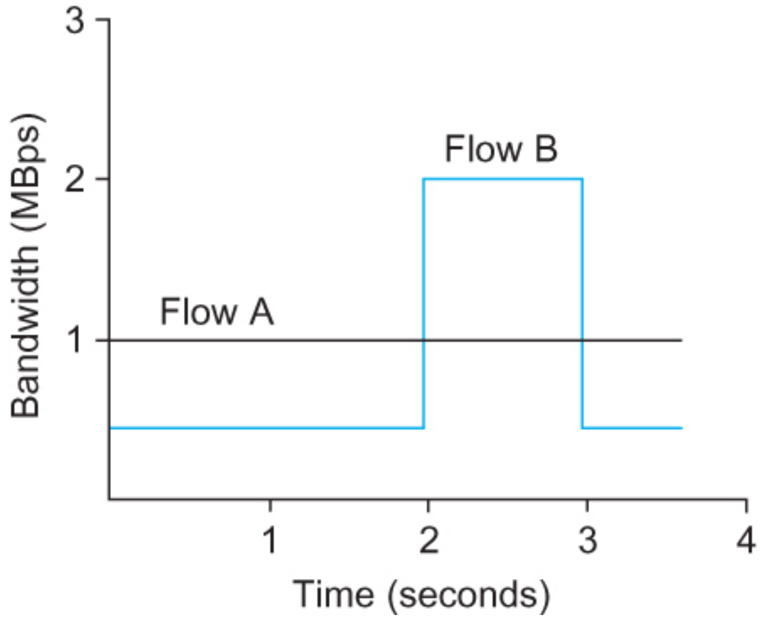
Token Bucket Filter– An Example

- Assume each flow can send data as individual bytes rather than as packets
- Flow A generates data at a steady rate of 1 MBps
  - Can be described by a token bucket filter with a rate r = 1 MBps and a bucket depth of 1 byte
  - It receives tokens at a rate of 1 MBps but it cannot store more than 1 token, it spends them immediately



Token Bucket Filter– An Example

- Flow B sends at a rate that averages out to 1 MBps over the long term, but does so by sending at 0.5 MBps for 2 seconds and then at 2 MBps for 1 second
- *r* is a long term average rate, so flow B can be described by a token bucket with *r* of 1 MBps
- Flow B needs a bucket depth *B* of at least 1 MB, so that it can store up tokens while it sends at less than 1 MBps to be used when it sends at 2 MBps
- For the first 2 seconds, it receives tokens at a rate of 1 MBps but spends them at only 0.5 MBps,
  - So it can save up $2 \times 0.5 = 1$ MB of tokens which it spends at the 3rd second



Admission Control

- Check Rspec and Tspec of the flow
- Admit the service request if resource is enough

Reservation Protocol & Packet Scheduling

- Resource Reservation Protocol (RSVP)
  - Specify Rspec and Tspec
  - Each router on the path reserves resources

- Packet scheduling
  - A router schedules packets so that they receive the requested service

Differentiated Services

- Allocates resources to a small number of classes of traffic.
  - Do not distinguish flows
- Some approaches simply divide traffic into two classes.
  - Best-effort service
  - Premium service
- How to distinguish best-effort and premium?
- Use a bit in packet header
  - The bit is set – premium packet
  - Not set – best-effort packet

Differentiated Services

- Two questions:
  - Who sets the premium bit?
  - What does a router do differently when it sees a packet with the bit set?

Who sets the premium bit?

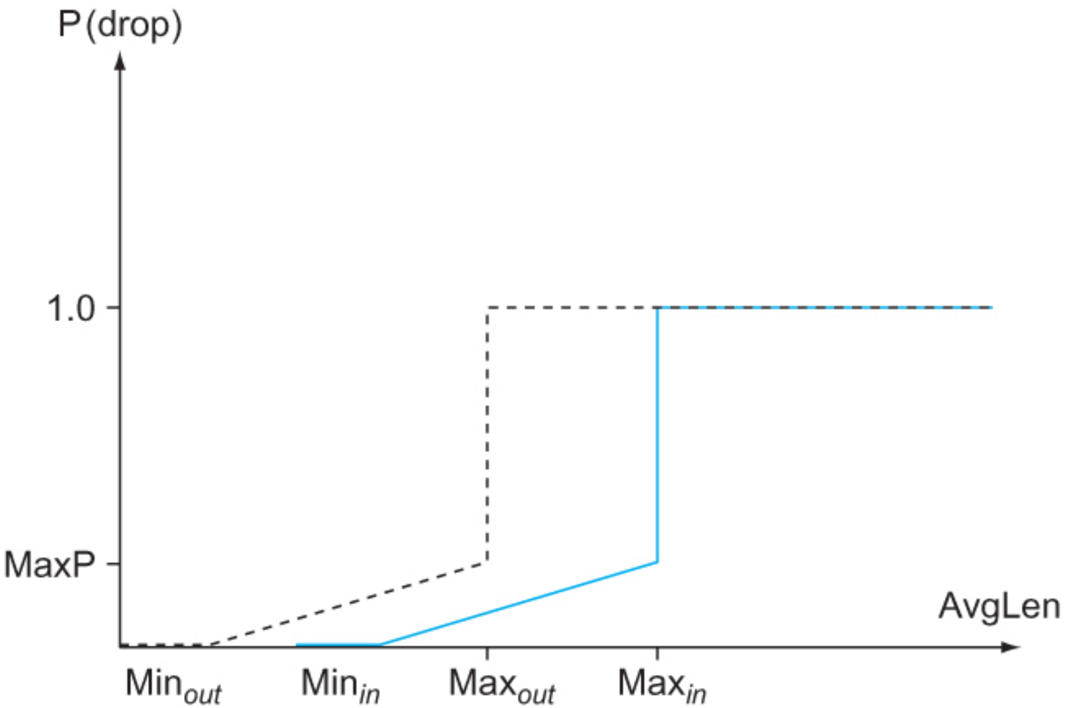
- Not by end hosts
  - End hosts may always set the bit to get better service

- Set the bit at an administrative boundary.
- E.g.,, the router at the edge of an Internet service provider’s network might set the bit for packets arriving on an interface that connects to a particular company’s network.
  - The Internet service provider might do this because that company has paid for a higher level of service than best effort.

What does a router do?

- Expedited forwarding
  - Premium packets are forwarded by a router with minimal delay and loss.
  - Priority scheduling
- Assured forwarding
  - "RED with In and Out" (RIO), enhancement to the basic RED algorithm.
  - Two drop probability curves for two classes of packets
  - Out -- best-effort packets
  - In – premium packets (bit is set)

Assured Forwarding



RED with In and Out drop probabilities

- "out" curve has a lower MinThreshold than "in" curve
- under low levels of congestion, only packets marked "out" will be discarded by RED.
- if congestion becomes more serious, a higher percentage of "out" packets are dropped
- if average queue length exceeds Min$_{in}$, RED starts to drop "in" packets as well.

Remarks on QoS

- “Dead” at the Internet scale
- Areas of success
  - Enterprise networks
  - Residential uplinks
  - Datacenter networks