Lecture 18:
Buffering & Scheduling

CSE 123: Computer Networks
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HW 3 due NOW
Lecture 18 Overview

- Buffer Management
  - FIFO
  - RED

- Traffic Policing/Scheduling
Typical high-performance router

- IQ + VoQ + OQ
  - Speedup of 2
  - Central scheduler
  - Fixed-sized internal cells

- Pro
  - Can achieve utilization of 1
  - Can scale to > Tb/s

- Con
  - Multiple congestion points
  - Complexity
Key Router Challenges

- **Buffer management**: which packet to drop when?
  - We only have finite-length queues
- **Scheduling**: which packet to transmit next?
Basic Buffer Management

- FIFO + drop-tail
  - Simplest choice
  - Used widely in the Internet
- FIFO (first-in-first-out)
  - Implies single class of traffic
- Drop-tail
  - Arriving packets get dropped when queue is full regardless of flow or importance
- Important distinction:
  - FIFO: scheduling discipline
  - Drop-tail: drop policy
FIFO/Drop-Tail Problems

- Leaves responsibility of congestion control completely to the edges (e.g., TCP)
- Does not separate between different flows
- No policing: send more packets $\Rightarrow$ get more service
- Synchronization: end hosts react to same events
Active Queue Management

- Design active router queue management to aid congestion control

- Why?
  - Router has unified view of queuing behavior
  - Routers see actual queue occupancy (distinguish queue delay and propagation delay)
  - Routers can decide on transient congestion, based on workload
Design Objectives

- Keep throughput high and delay low
  - High power (throughput/delay)

- Accommodate bursts

- Queue size should reflect ability to accept bursts rather than steady-state queuing

- Improve TCP performance with minimal hardware changes in router
Random Early Detection

- Detect incipient congestion
- Assume hosts respond to lost packets
- Avoid window synchronization
  - Randomly mark packets
- Avoid bias against bursty traffic
RED Algorithm

- Maintain running average of queue length in router

- If $\text{avg} < \text{min}_{th}$ do nothing
  - Low queuing, send packets through

- If $\text{avg} > \text{max}_{th}$, drop packet
  - Protection from misbehaving sources

- Else drop/mark packet in a manner proportional to queue length
  - Notify sources of incipient congestion
  - Dropping vs Marking tradeoff (Explicit Congestion Notification)
RED Operation

Max thresh

Min thresh

Average Queue Length

P(drop)

1.0

max_p

min_th

max_th

Avg queue length

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Non-responsive Senders

1 UDP (10 Mbps) and 31 TCPs sharing a 10 Mbps line
Token Bucket Basics

- Parameters
  - $r$ – average rate, i.e., rate at which tokens fill the bucket
  - $b$ – bucket depth (limits size of burst)
  - $R$ – maximum link capacity or peak rate (optional parameter)
- A bit can be transmitted only when a token is available

\[
\frac{b \cdot R}{R - r}
\]

Maximum # of bits sent

- Graph showing
  - $r$ bps
  - $b$ bps
  - $\leq R$ bps
  - $b/(R-r)$
  - $b \cdot R/(R-r)$
  - slope $r$
  - slope $R$

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For next time…

- Read Ch. 6.3-4 in P&D