Lecture 23 Overview

- Buffer Management
  - FIFO
  - RED

- Traffic Policing/Scheduling
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 $\text{avg} < \text{min}_{\text{th}}$ do nothing
  - Low queuing, send packets through

- If $\text{avg} > \text{max}_{\text{th}}$, 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

$P_{\text{drop}}$

1.0

$max_p$

$min_{\text{th}}$

$max_{\text{th}}$

Avg queue length

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Non-responsive Senders

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

UDP (#1) - 10 Mbps
TCP (#2)
TCP (#32)
Bottleneck link (10 Mbps)

UDP (#1)
TCP (#2)
TCP (#32)
UDP vs. TCP
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

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Traffic Policing

- Drop packets that don’t meet user profile
- Output limited to average of $r$ bps and bursts of $b$

![Diagram of Traffic Policing]

- Packet input
- Test if token
- User Profile (token bucket)
- No token, drop
- Packet output

Packet output

$r$ bps

b bits

User Profile
(token bucket)
Traffic Shaping

- Shape packets according to user profile
- Output limited to average of $r$ bps and bursts of $b$

Packet input → Wait for token → Packet output

Queue, Drop on overflow

User Profile (token bucket)

$r$ bps → $b$ bits

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Shaping Example

- \( r = 100 \text{ Kbps}; \ b = 3 \text{ Kb}; \ R = 500 \text{ Kbps} \)

(a) \( 3\text{ Kb} \)

\( T = 0 \): 1Kb packet arrives

(b) \( 2.2\text{ Kb} \)

\( T = 2\text{ms} \): packet transmitted

\( b = 3\text{ Kb} - 1\text{ Kb} + 2\text{ms} \times 100\text{Kbps} = 2.2\text{Kb} \)

(c) \( 2.4\text{ Kb} \)

\( T = 4\text{ms} \): 3Kb packet arrives

(d) \( 3\text{ Kb} \)

\( T = 10\text{ms} \): packet needs to wait until enough tokens are in the bucket

(e) \( 0.6\text{ Kb} \)

\( T = 16\text{ms} \): packet transmitted
Using Token buckets for Buffer Management

- Mark packets that exceed user profile
- During congestion, drop marked packets first

Using Token buckets for Buffer Management

Packet input → Test if token

- If token:
  - Mark packet
  - User Profile (token bucket)→ Packet output
- No token:
  - Packet output

Packet throughput r bps

User Profile (token bucket)

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For next time…

- HW 4 is due in a Week
- Read Ch. 6.5 in P&D