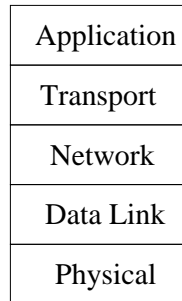


Layered Architecture



1

TCP: Transmission Control Protocol

- Application Multiplexing/Demultiplexing
- Error Detection
- Reliable Data Transfer
- Congestion Control

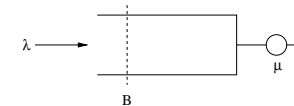
2

Congestion Control

- Why is congestion “bad”?
 - How does congestion affect performance of applications?
 - How to avoid (react to) congestion?
- > One of the most important problems in networking

3

Congestion: Example 1



$$p_n = \frac{1 - \rho}{1 - \rho^{B+1}} \rho^n, \quad n = 0, \dots, B$$

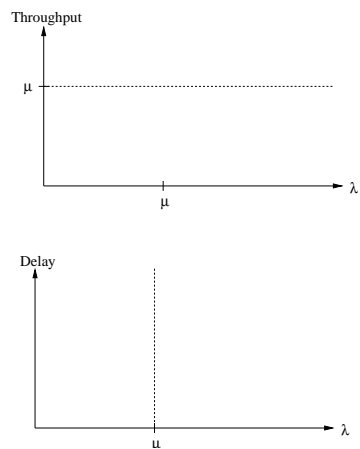
Throughput is equal to $(1 - p_0)\mu = \mu\rho\frac{(1-\rho^B)}{(1-\rho^{B+1})}$

Average delay is equal to $\frac{1}{\mu} + \sum_{n=1}^{B-1} n\frac{1}{\mu}p'_n$

4

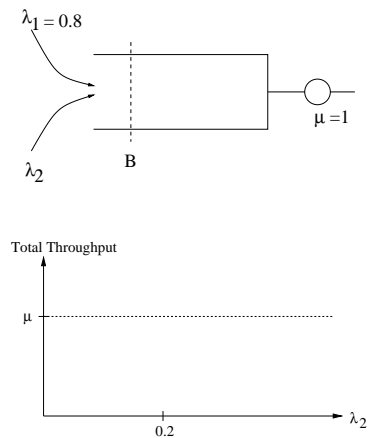
Congestion: Example 1

For large B :



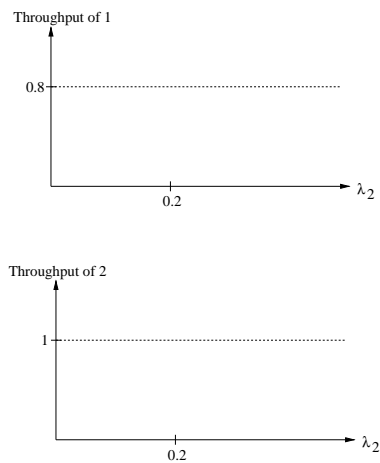
5

Congestion: Example 2



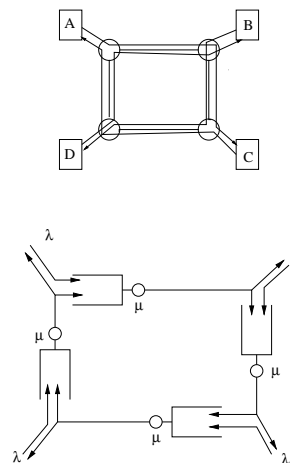
6

Congestion: Example 2



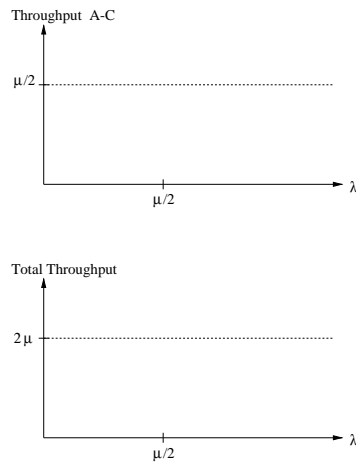
7

Congestion: Example 3



8

Congestion: Example 2



9

How to Deal with Congestion

- Packet discarding
- Packet blocking
- Call (Session) blocking

10

Congestion Control: Classification

Open-Loop Control: During connection setup, the transmission rate of a connection is determined.

- Call Admission Control
- Policing: Leaky Bucket

Closed-Loop Control / Feed Back Control: Connections are informed dynamically about the congestion state of the network, and asked to adapt their rate accordingly.

- TCP Congestion Control

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Transmission Rate Policing: Leaky Bucket

Issue:

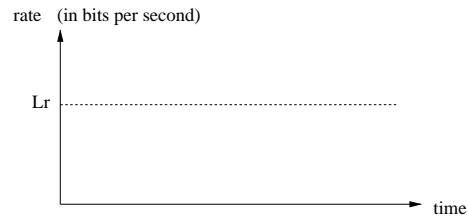
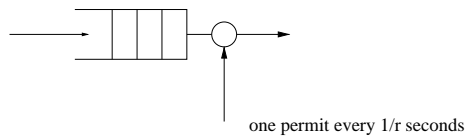
- During call admission control, a connection was assigned a rate of r packets per second.
- How do we make sure that the connection does not transmit packets at a higher rate?

– > Leaky Bucket

12

Leaky Bucket

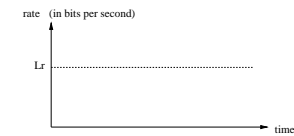
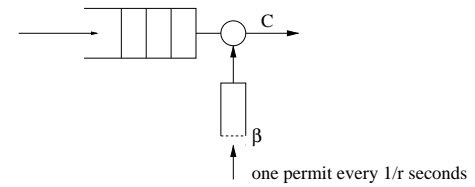
First Approach



L : length of one packet

13

Leaky Bucket



Average rate: Lr bits per second

Peak rate: C bits per second for at most $\frac{\beta L}{C}$ seconds

14

TCP Congestion Control

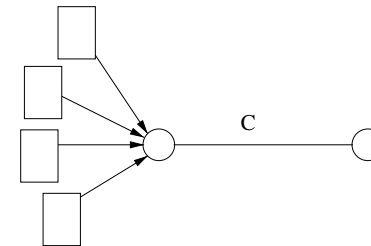
- Closed-Loop Control
- Dynamically changes sender window size (TCP window size)

Issue

- Fairness

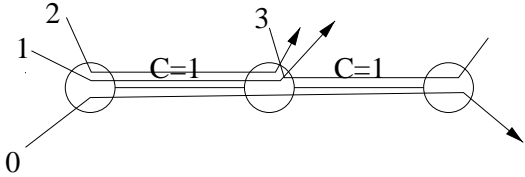
15

Fairness



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Max-Min Fairness



(for exact definition see additional handout)