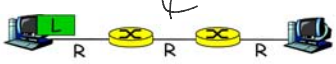
Chapter 1: End-to-End Delay Calculations

Class Exercise 1: Delay Calculation



- Example of a lightly loaded network with three hops
  - Circuit set-up time = *x* sec.
  - Propagation delay = *d* sec. per hop
  - Packet size = *p* bits
  - Data rate at each link (hop) = *R* bps (bits/sec.)
  - Ignore queueing delay and processing delay
- Find the total delay *T* in sending an L-bits message over this 3-hop path in (i) a circuit-switched network and (ii) a packet-switched network

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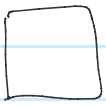
L bits long



p bits

$\frac{L}{p} = n$ # of plcts

$d_{trans} = \frac{p}{R}$

(i) circuit switching : $T = x + \frac{p}{R} \times n + d + d + d$

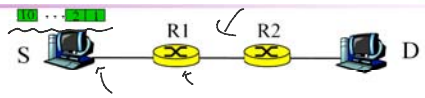
$= x + \frac{p}{R} \cdot \frac{L}{p} + 3d = x + \frac{L}{R} + 3d$

(2) plct-switching : $T = \frac{p}{R} \times n + d + \frac{p}{R} + d + \frac{p}{R} + d =$

last bit of last plct just arrived to the first router

$= \frac{p}{R} \cdot \frac{L}{p} + 3d + 2 \cdot \left(\frac{p}{R}\right)$ ///

Class Exercise 2: multiple vs. single packet



- Example of a lightly loaded network with three hops
  - Propagation delay = 50 ms sec. per hop
  - Transmission delay of a packet = 10ms
  - # of packets to transmit : n = 10
  - Ignore queueing delay and processing delay
- **(Q1)** When does the packet #1 (first packet) arrive to D?
- **(Q2)** Find the total delay *T* in sending 10 packets back to back from S to D.
- **(Q3)** What is the total delay *T* if all 10 packets are combined into a single (giant) packet at S?

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$d_{trans} = 10$ ms

$n = 10$

(Q1) $T = 10 + 50 + 10 + 50 + 10 + 50$

plct 1 just arrived to R1

$= 180$ ms

(Q2) $T = \underbrace{10 \cdot 10}_{100\text{ms}} + 50 + 10 + 50 + 10 + 50 = 270$ ms

(Q2) $T = \underbrace{10 \cdot 10}_{100ms} + 50 + 10 + 50 + 10 + 50 = 270\ ms$

(Q3) d_{trans} (bigger pkts) $= 10 \cdot 10 = 100\ ms$

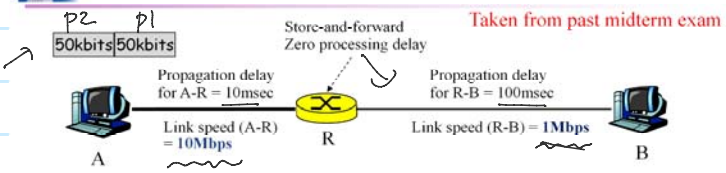
$T = 100 + 50 + 100 + 50 + 100 + 50 = 450\ ms$

Warning !! (Q2) 180 ms for 1 pkts → 10 pkts

→ $180 \times 10 = 1800\ ms$. XXX

Class Exercise 3: Asymmetric setting

Taken from past midterm exam



- End-to-end delay for A to deliver two packets (sent back-to-back) in a packet-switched network to B
  - Each packet is 50 kbits long
  - Queue at R is initially empty

ⓐ $\frac{50k}{10M} = 5\ ms$, P1 is on A-R

ⓐ $\frac{50k}{10M} + \frac{50k}{1M} + 10\ ms = 20\ ms$

P2 is at R1

P1 arrives to R ⓐ 15 ms

For P1, $d_{trans\ (R-B)} = \frac{50k\ bits}{1Mbps} = 50\ ms$

P1 will leave R ⓐ $15\ ms + 50\ ms = 65\ ms$

$d_{queueing}$ (for P2 at R) $= 65 - 20 = 45\ ms$

$T = 65\ ms + 50\ ms + 100\ ms = 215\ ms$ ← 50 ms

P1 arrives to (B) ⓐ $5 + 10 + 50 + 100 = 165\ ms$