Course: Communication Networks

Date: 9/5

Topics Covered: HW #1

- MATTHEW KRUEGER -

1. You are moving into a new apartment building. Your 20 unit building offers, for the same cost, two choices for Internet service: 20 Mbps DSL or 80 Mbps cable.

   (a) If speed is your main concern, is 80 Mbps always the better deal? Why?
   (b) Could your answer to (a) depend on the number of units in your building? Why?
   (c) Which option would be best if you have privacy concerns? Why?

DSL: Digital Subscriber Line - more downstream than upstream. Dedicated connection

Cable: frequency division multiplexing - 40 Mbps - 1.2 Gbps downstream. 30 - 100 Mbps upstream. Shared connection

a) Not necessarily. Because cable is a shared connection, if the bandwith / # of connections is high, or there is heavy usage, DSL would be a better deal, with a guaranteed 20Mbps

b) Yes. if all or most users (20) use internet at the same time, cable will likely provide slower speeds. The more users on cable the greater potential drop in speed, which DSL may avoid.

c) DSL is better for privacy as it is not a shared connection; DSL is direct from building to ISP, while cable is shared with other users in area - which is a greater security threat.

2. Suppose users share a 50 Mbps link. Also suppose that each user **requires** 15 Mbps when transmitting, but each user only transmits 2% of the time *(hint: see the discussion of statistical multiplexing in the text in Sec. 1.3.2; this might also help)*.

   (a) If the link is **circuit-switched**, how many users can share it without exceeding capacity?

Now suppose that the link is **packet switched** and shared by 25 users.

   (b) What is the probability that exactly n of the 25 users are transmitting simultaneously? *(Hint: Your answer will be a formula in terms of n; not a precise number).*
   (c) Find the probability that 25 users can share the link without exceeding the link capacity.

a) number of users $= \left\lfloor \frac{\text{capacity}}{\text{bandwidth per user}} \right\rfloor = \left\lfloor \frac{50 \text{ Mbps}}{15 \text{ Mbps}} \right\rfloor = \lfloor 3.33 \rfloor = 3$ users

b) $\text{Bin}(n=25, p=0.02) = \binom{25}{k}(0.02)^k(0.98)^{25-k}$

c) $P(>3 \text{ active}) = 1 - P(\leq 3) = 1 - \sum_{k=0}^{3} \binom{25}{k}(0.02)^k(0.98)^{25-k} = 0.9986$

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3. Two hosts, **A** and **B**, are separated by length $L = 2112$ km and connected by a rate $R = 250$ Mbps link with a propagation speed of $s_{prop} = 2.5 \times 10^8$ m/s.

   (a) Find both an **expression** and a **value** for (1) the length l_b of each bit (meters/bit; *based on the values you have, you can try to see what expression might result in these units*); (2) the propagation delay d_{prop} of each bit (in seconds); and (3) the link's bandwidth-delay product, $R \times d_{prop}$.

   (b) Find an **expression** and a **value** for the number of bits required to fill the length of the link. What interpretation of the bandwidth-delay product ($R \times d_{prop}$) does this suggest?

   (c) Find an expression for the time t required to send a portable hard disk's F bits over this link *(Hint: be sure to consider all the forms of delay that you have information for)*. After what value of F would it be faster to ship the hard disk via a 24hr delivery service?

$d = 2112$ km

$R = 250$ Mbps

$s_{prop} = 2.5 \cdot 10^8$ m/s

a) ① $l_b = \dfrac{s_{prop}}{R} = \dfrac{2.5 \cdot 10^8}{1} \dfrac{[m]}{[\cancel{s}]} \cdot \dfrac{1}{250} \dfrac{[\cancel{s}]}{[\cancel{Mbps}]} \cdot \dfrac{1}{10^6} \dfrac{[\cancel{Mbps}]}{[b]} = 1 \dfrac{\text{meter}}{\text{bit}}$

② $d_{prop} = \dfrac{d}{s_{prop}} = \dfrac{2112}{2.5 \cdot 10^8} \dfrac{[\cancel{km}][s]}{[\cancel{m}]} \cdot \dfrac{10^3}{1} \dfrac{[\cancel{m}]}{[\cancel{km}]} = 0.008448$ seconds

③ $R \cdot d_{prop} = 250$ mbps $\cdot$ 0.008448 s $= 2.112$ mbps $=$ 2112000 bits

b) Expression: $l_b \cdot R \cdot d_{prop}$

Value: $\dfrac{1}{1} \dfrac{[m]}{[\cancel{b}]} \cdot \dfrac{2112000}{1} [\cancel{b}] = \dfrac{2112000}{1} [\cancel{m}] \cdot \dfrac{1}{10^3} \dfrac{[km]}{[\cancel{m}]} = 2112$ km

c) delay $= \underbrace{\cancel{d_{proc}}}_{=0} + \underbrace{\cancel{d_{queue}}}_{=0} + \underbrace{d_{trans}}_{= \frac{F}{R}} + \underbrace{d_{prop}}_{= \frac{L}{s_{prop}}}$

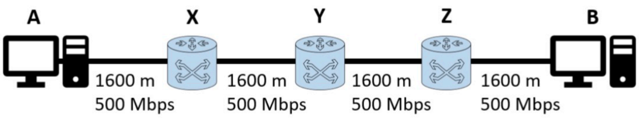
"d" in this problem...

$$\text{delay} = \frac{F}{R} + \frac{L}{S}$$

** variables in Question are different than lecture slides **

$86400 = \dfrac{F}{250 \text{ Mbps}}s + 0.008448 = 21.6$ terabytes

4. Suppose that in the store-and-forward network shown below the link propagation speeds are all 2×10^8 m/s, all packets are 2000 bytes long, and all processing delays are 0.



   (a) If Node A generates and transmits one packet (and there are no other packets in the system), how long will it take for that packet to travel to Node B?

   (b) If Node A instantaneously generates 50 packets (and there are no other packets in the system), how long will it take the 1st packet to travel to B? How about the nth packet?

   (c) If Node A instantaneously generates 100 packets every 4 ms (and initially there were no other packets in the system), what throughput is achieved assuming zero packet loss (i.e., this sending rate does not exceed the system's bottleneck rate)?

   (d) Suppose that the Y-Z link's transmission rate drops to 250 Mbps. What is the max. theoretical throughput to B that A can hope to achieve? What will happen if A attempts to send packets at a higher rate for a sustained period? Please try to be specific.

$L = 2000$ b

$d_{prop} = 2 \cdot 10^8$ m/s

$d_{proc} = 0$

a) delay$_{A \to X}$ $= \underbrace{\cancel{d_{proc}}}_{=0} + \underbrace{\cancel{d_{queue}}}_{=0} + \underbrace{d_{trans}}_{= \frac{L}{R}} + \underbrace{d_{prop}}_{= \frac{d}{s_{prop}}}$

$d_{trans} = \dfrac{2000 \cdot 8 b}{500 \text{ mbps}} = 32$ ms

$d_{prop} = \dfrac{1600}{2 \cdot 10^8 \text{ m/s}} = 8$ µs

delay $= 0.8$ µs $+ 0.32$ ms

$A \to X = 4$(delay)

1st $A \to B = 160$ ms

b) 1st packet: 160 ms

nth packet: $(n-1) d_{trans} + d_{tot}$

nth packet $= [n-1][32 \text{ ms}] + [160 \text{ ms}]$

c) $\dfrac{100(2000 \cdot 8)[b]}{4 \text{ ms}} = 4 \cdot 10^8$ bps

d) pt1: 250 Mbps due to bottle neck

pt2: the finite capacity of buffer @ node Y's queue may be filled and packets dropped. (Lost packets) Lost packets may be retransmitted by previous node, source, or system.

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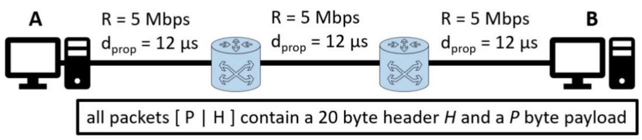
5. A $P = 80$ byte message is to be sent from host A to host B over the three-link path depicted below. Each link has a 5 Mbps capacity and 12 μs propagation delay. Suppose that all path processing and queuing delays are negligible. Also assume that, regardless of message size, every packet traversing the path also includes an additional 20 byte header, H.



(a) How long does it take to move the message from host A to host B if the message is not segmented (i.e., if $P = 80$ bytes)?

(b) How long does it take to move the message from host A to host B if the message is segmented into two 40 byte message payloads (hint: you may now have to consider queueing delay)?

(c) In general, as the number of segmentations is increased, the total store-and-forward delay first decreases then it increases. Why?

(Hint: Referencing the pipelining / timing diagrams we saw in lecture may be useful.)

delay = dproc + dqueue + dtrans + dprop

$= 0$ $\quad = 0 \quad = \frac{L}{R} \quad = 12\mu s$

$= \frac{100 \text{ MBps}}{5 \text{ mBps}}$

$= 160\ \mu s$

a) $3(160\ \mu s) + 3(12\mu s)$

time to move A→B : $516\ \mu s$

b) $d_{trans} = \left[\frac{(40+20)\cdot 8}{5\cdot 10^6}\right] = 96\ \mu s$

$d_{tot} = 3(d_{trans} + d_{prop}) + d_{queue}$

$= 3(96\mu s + 12\mu s) + 96\mu s$

$= 420$ ms

c) # of segments ↑ segment size ↓ header size =

→ initially decreases because smaller segments can be transmitted quicker with same size header.

→ then increases because of the overhead to transmit too many small segments with constant header size for each.

ex 3 bit message would require 20 Bytes alone;

Diminishing returns!

6. Short-answer questions:

(a) List two arguments for, and two arguments against, adopting layered network protocols.

(b) How do message, segment, datagram, and frame packets differ from one another?

(c) It is observed that in steady-state (i.e., queues are neither growing or shrinking), packets spend on average 80 μs in a fixed packet-size network before departing at a rate of 75,000 packets per second. On average, how many packets should we expect to find traversing the network? *(hint: see our discussion of Little's Law)*.

(d) How do content provider networks and the tier-1 ISP networks differ?

(e) How do network viruses, worms, and Trojan horses differ from each other?

a) for:

1. modularity: smaller & more manageable layers
2. Interoperability: Standardized interfaces allow for easier implementation

against:

1. overhead: many processing requirements can reduce efficiency
2. complexity: many interactions between different layers can make total system complex.

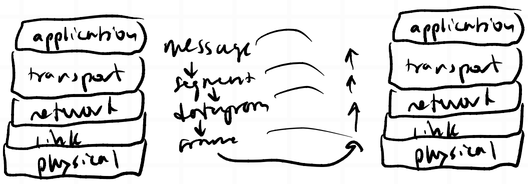
b)

messages: user application message @ application layer

segments: data @ the transport layer

datagram: data @ network layer

frame packets: data @ link layer



c) $L = \lambda w$

$w = 80\mu s$

$\lambda = 75{,}000$ pps

$L = \frac{80\ [\mu s]}{1} \cdot \frac{1\ [s]}{10^6\ [\mu s]} \cdot 75{,}000$

= 6 packets expected @ any given time

d) Content providers: host & deliver content

ex: netflix, google

Tier 1 ISP: provide core connectivity

ex: AT&T, Sprint

e)

virus: self-replicating malicious software in legitimate program/file. requires user action

worm: self-replicate without user intervention. standalone malware

Trojan horse: user initiated. hidden inside legitimate program allows attackers to gain unauthorized access.