HW2 - Network Problems

Class	CS 408
Type	Homework

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- **Problem #1**

1) (10 points) In this problem, we consider sending real-time voice from Host A to Host B over a packet-switched network (VoIP). Host A converts analog voice to a digital 64 kbps bit stream on the fly. Host A then groups the bits into 56-byte packets and when a packet is formed, it is send to host B. There is one link between Hosts A and B; its transmission rate is 2 Mbps and its propagation delay is 10 msec. What's the elapsed time since when the first bit is formed (from the original analog signal at Host A) until the bit is received at host B?

$$\frac{Total\ Number\ of\ Packets}{AnalogSignaltoDigital(bit)Conversion}$$

$$(Note : 1\ byte = 8\ bits)$$

$$\frac{56 * 8}{64 * 10^3} = 0.007\ seconds$$

$$Transfer\ Packet\ Time$$
$$= \frac{56 * 8}{2 * 10^6} = 0.000224\ seconds$$

$$Propagation\ Delay$$
$$= 10\ milliseconds = 0.01 seconds$$

$$Elapsed\ Time$$
$$0.007 + 0.000224 + 0.01 = 0.017224\ seconds = 17.224\ msec$$

- **Problem #2**

2) (32 points) Suppose two hosts, A and B, are separated by 20,000 kilometers and are connected by a direct link of $R = 2$ Mbps. Suppose the propagation speed over the link is $2.5 \cdot 10^8\ m/sec$.

a) Calculate the propagation (delay) time t_{prop}

$$Distance\ between\ Host\ A\ and\ B = 2 * 10^7\ km$$
$$Propagation\ speed\ (S) = 2.5 * 10^8\ m/s$$
$$Propagation\ Delay\ (t_{prop}) = distance/speed$$
$$= 2 * 10^7/2.5 * 10^8 = 0.08\ seconds$$

b) Calculate the bandwidth-delay product, i. e. simply do $R \cdot t_{prop}$

$$Transmission\ rate\ (R) = 2Mbps = 2 * 10^6\ bps$$
$$Bandwidth\ Delay\ Product = Transmission\ Rate * t_{prop}$$
$$= 2 * 10^6 * 0.08 = 16 * 10^4\ bits$$
$$= 160000\ bits$$

c) What is the maximum number of bits that will be in the link (propagating from Host A to Host B) at any given time?

$$As\ we\ see\ in\ the\ part\ b,\ bandwidth\ delay\ product\ is\ 16 * 10^4.$$
$$Therefore,\ max\ number\ of\ bits\ that\ will\ be\ propagating\ from$$
$$Host\ A\ to\ Host\ B\ in\ the\ link\ is\ 160000\ bits.$$

d) How long does a single bit propagate in meters for the time needed to transmit a single bit (known as the width - in meters - of a bit in the link)?

$$Transmission\ Rate\ (R) = 2 * 10^6\ bps$$
$$Propagation\ Speed\ (S) = 2.5 * 10^8\ m/s$$

$$Length\ of\ 1\ bit\ on\ the\ transmission\ line = Speed\ /\ Transmission\ Rate$$
$$= \frac{2.5 * 10^8}{2 * 10^6} = 125\ m$$

e) Derive a general expression for the width of a bit in terms of the propagation speed s, the transmission rate R, and the length of the link m. You can use d) for some help and hints.

$$General\ expression\ for\ the\ width\ of\ a\ bit$$
$$= \frac{Transmission\ Rate\ (R) * Speed\ (s)}{Length\ of\ the\ link\ (m)}$$

f) A file of 100 KB (1KB = 1000 B) is send from host A to host B. After Host B receives the whole file, it sends a single acknowledgment (ACK) to Host A. How long does it take for Host A to receive the ACK from Host B after sending the file, assuming that the file is send continuously? ACK size is neglectable.

$$t_{prop} + t_{transmissiom} + t_{prop,\ ACK} = 0.08 + \frac{100 * 10^3 * 8}{2 * 10^6} + 0.08 = 0.56\ second$$

g) Suppose now the file of 100 KB is broken up into 20 packets with each packet containing 40,000 bits. Suppose that each packet is acknowledged by the receiver and the transmission time of an acknowledgment packet is negligible. Finally, assume that the sender cannot send a packet until the preceding one is acknowledged (stop and wait). How long does it take to send the file? You can neglect header sizes.

$$Each\ of\ the\ 20\ packet\ has\ to\ wait\ for\ ACK\ of\ the\ previous\ packet.$$
$$Therefore\ total\ time\ will\ be:$$
$$transmission\ /\ propagation\ of\ the\ 20\ packets$$
$$and\ propagation\ of\ the\ 20\ ACKs.$$

$$20 * t_{transPackets} + 40 * t_{prop}$$
$$= 20 * \frac{40000}{2 * 10^6} + 40 * 0.8 = 3.6\ seconds$$

h) compare the results from f) and g)

$$g\ has\ more\ ACK\ propagations,\ therefore:$$
$$t_g\ >\ t_f$$

- **Problem #3**

3) (8 points) Suppose within your Web browser you click on a link to obtain a Web page. The IP address for the associated URL is not cached in your local host, so a DNS lookup is necessary to obtain the IP address. Suppose that n DNS servers are visited before your host receives the IP address from DNS; the successive visits incur an RTT of $RTT_1, RTT_2, \ldots, RTT_n$. Further suppose that the Web page (consisting of a small amount of HTML text) associated with the link contains exactly eight small objects of neglectable size. Let RTT_0 denote the RTT between the local host and the server containing the Web page and the objects. Assuming zero transmission time per object, how much time elapses from when the client clicks on the link until the client receives the object if we use:

$$Time\ elapsed\ to\ get\ the\ IP\ address\ from\ the\ DNSs:$$
$$RTT_1 + RTT_2 + \ldots + RTT_n$$

a) Non-persistent HTTP with no parallel TCP connections?

$$RTT_1 + RTT_2 + \ldots + RTT_n\ \rightarrow Query\ the\ DNS$$
$$+2\ RTT_0 \rightarrow Setup\ connection$$
$$+8 * 2\ RTT_0 \rightarrow Request\ 8\ files$$
$$= 18\ RTT_0 + RTT_1 + RTT_2 + \ldots + RTT_n$$

b) Non-persistent HTTP with the browser configured for 5 parallel connections?

$$6\ RTT_0 + RTT_1 + RTT_2 + ... + RTT_n$$

c) Persistent HTTP with no parallel connections?

$$10\ RTT_0 + RTT_1 + RTT_2 + ... + RTT_n$$

d) Persistent HTTP with 8 parallel connections?

$$3RTT_0 + RTT_1 + RTT_2 + ... + RTT_n$$

- **Problem #4**

4) **(20 points)** Consider distributing a file of *F*= 15 *Gbits* to *N* peers. The server has an upload rate of u_s =30 Mbps, and each peer has a download rate of d_i = 2 Mbps and an upload rate of u. For N=10, 100, and 1,000 and u = 300 Kbps, 700 Kbps, and 2 Mbps, <u>prepare a chart giving the minimum distribution time for each of the combinations of *N* and u for both client-server distribution and P2P distribution</u>. Show your work!

$$F = 15\ Gbits = 15360\ Mbits$$
$$u_s = 30\ Mbps$$
$$d_i = 2\ Mbps$$

$$D_{cs} = max\{\frac{NF}{u_s}, \frac{F}{d_{min}}\}$$

$$Minimum\ Distribution\ Time\ for\ Client - Server\ Distribution$$

- Case #1

  $N = 10, u = 300Kbps$

  $D = max\{\frac{(10*15360)}{30}, \frac{15360}{2}\} = max\{5120, 7680\} = 7680\ seconds$

- Case #2

  $N = 100, u = 300Kbps$

  $D = max\{\frac{(100*15360)}{30}, \frac{15360}{2}\} = max\{51200, 7680\} = 51200\ seconds$

- *Case #3*

  $N = 1000, u = 300Kbps$

$D = max\{\frac{(1000*15360)}{30}, \frac{15360}{2}\} = max\{512000, 7680\} = 512000 \ seconds$

- Case #4

  $N = 10, u = 700Kbps$

  $D = max\{\frac{(10*15360)}{30}, \frac{15360}{2}\} = max\{5120, 7680\} = 7680 \ seconds$

- Case #5

  $N = 100, u = 700Kbps$

  $D = max\{\frac{(100*15360)}{30}, \frac{15360}{2}\} = max\{51200, 7680\} = 51200 \ seconds$

- *Case #6*

  $N = 1000, u = 700Kbps$

  $D = max\{\frac{(1000*15360)}{30}, \frac{15360}{2}\} = max\{512000, 7680\} = 512000 \ seconds$

- Case #7

  $N = 10, u = 2Mbps$

  $D = max\{\frac{(10*15360)}{30}, \frac{15360}{2}\} = max\{5120, 7680\} = 7680 \ seconds$

- Case #8

  $N = 100, u = 2Mbps$

  $D = max\{\frac{(100*15360)}{30}, \frac{15360}{2}\} = max\{51200, 7680\} = 51200 \ seconds$

- *Case #9*

  $N = 1000, u = 2Mbps$

  $D = max\{\frac{(1000*15360)}{30}, \frac{15360}{2}\} = max\{512000, 7680\} = 512000 \ seconds$

	N = 10	N = 100	N = 1000
u = 300 Kbps	7680	51200	512000
u = 700 Kbps	7680	51200	512000
u = 2 Mbps	7680	51200	512000

$Minimum\ Distribution\ Time\ for\ P2P\ Distribution$

$$F = 15\ Gbits = 15360\ Mbits$$
$$u_s = 30\ Mbps$$
$$d_{min} = 2\ Mbps$$

$$D_{p2p} = max\{\frac{F}{u_s}, \frac{F}{d_{min}}, \frac{NF}{u_s + \sum_{i=1}^{N} u_i}\}$$

- Case #1

  $N = 10$

  $u = 300Kbps = 300/1024Mbps = 0.2929Mbps$

  $\sum_{i=1}^{N=10} u_i = 10 * 0.2929$

  $D = max\{\frac{15360}{30}, \frac{15360}{2}, \frac{10*15360}{30+2.929}\} = max\{512, 7680, 4664.6\} = 7680\ seconds$

- Case #2

  $N = 100$

  $u = 300Kbps = 300/1024Mbps = 0.2929Mbps$

  $\sum_{i=1}^{N=100} u_i = 100 * 0.2929$

  $D = max\{\frac{15360}{30}, \frac{15360}{2}, \frac{100*15360}{30+29.29}\} = max\{512, 7680, 25906\} = 25906\ seconds$

- *Case #3*

  $N = 1000$

  $u = 300Kbps = 300/1024Mbps = 0.2929Mbps$

  $\sum_{i=1}^{N=1000} u_i = 1000 * 0.2929$

  $D = max\{\frac{15360}{30}, \frac{15360}{2}, \frac{1000*15360}{30+292.9}\} = max\{512, 7680, 47568.9\} = 47569\ seconds$

- Case #4

  $N = 10$

  $u = 700Kbps = 700/1024Mbps = 0.6836Mbps$

  $\sum_{i=1}^{N=10} u_i = 10 * 0.6836$

$D = max\{\frac{15360}{30}, \frac{15360}{2}, \frac{10*15360}{30+6.836}\} = max\{512, 7680, 4169.8\} = 7680\ seconds$

- Case #5

  $N = 100$

  $u = 700Kbps = 700/1024Mbps = 0.6836Mbps$

  $\sum_{i=1}^{N=100} u_i = 100 * 0.6836$

  $D = max\{\frac{15360}{30}, \frac{15360}{2}, \frac{100*15360}{30+68.36}\} = max\{512, 7680, 15616.1\} = 15616\ seconds$

- *Case #6*

  $N = 1000$

  $u = 700Kbps = 700/1024Mbps = 0.6836Mbps$

  $\sum_{i=1}^{N=1000} u_i = 1000 * 0.6836$

  $D = max\{\frac{15360}{30}, \frac{15360}{2}, \frac{1000*15360}{30+683.6}\} = max\{512, 7680, 21524.7\} = 21525\ seconds$

- Case #7

  $N = 10$

  $u = 2Mbps$

  $\sum_{i=1}^{N=10} u_i = 10 * 2$

  $D = max\{\frac{15360}{30}, \frac{15360}{2}, \frac{10*15360}{30+20}\} = max\{512, 7680, 3072\} = 7680\ seconds$

- Case #8

  $N = 100$

  $u = 2Mbps$

  $\sum_{i=1}^{N=100} u_i = 100 * 2$

  $D = max\{\frac{15360}{30}, \frac{15360}{2}, \frac{100*15360}{30+200}\} = max\{512, 7680, 6678.3\} = 7680\ seconds$

- *Case #9*

  $N = 1000$

$$u = 2Mbps$$

$$\sum_{i=1}^{N=1000} u_i = 1000 * 2$$

$$D = max\{\frac{15360}{30}, \frac{15360}{2}, \frac{1000*15360}{30+2000}\} = max\{512, 7680, 7566.5\} = 7680\ seconds$$

	N = 10	N = 100	N = 1000
u = 300 Kbps	7680	25906	47569
u = 700 Kbps	7680	15616	21525
u = 2 Mbps	7680	7680	7680

- **Problem #5**

5) **(10 points)** UDP and TCP use 1s complement for their checksums. Suppose you have the following three 8-bit bytes: 01010011, 01100110, 01110100. What is the 1s complement of the sum of these 8-bit bytes? (Note that although UDP and TCP use 16-bit words in computing the checksum, for this problem you are being asked to consider 8-bit sums) Show all work!

$$Given\ 8-bit\ bytes:$$
$$01010011$$
$$01100110$$
$$01110100$$

$$Sum\ of\ the\ given\ 3\ bytes.$$
$$Sum\ \#1\ and\ \#2\ bytes:$$
$$01010011 + 01100110 = 10111001$$

$$Add\ 3rd\ byte\ to\ the\ result.$$
$$01110100 + 10111001 = 100101101$$

$$Deal\ with\ the\ extra\ bit.$$
$$100101101 \rightarrow 00101101 + 1 = 00101110$$

$$Sum\ of\ all\ three\ 8-bit\ bytes:\ 00101110.$$

$$Checksum\ (Invert\ all\ the\ bits):\ 11010001.$$

$$Calculate\ the\ 1\text{'}s\ compliment\ of\ the\ sum:$$
$$Convert\ all\ 0\text{'}s\ \rightarrow\ 1\text{'}s\ and\ all\ 1's\ \rightarrow\ 0's.$$
$$The\ 1\text{'}s\ compliment\ of\ (sum)\ 00101110\ is\ 11010001.$$
$$Note:\ 1\text{'}s\ compliment\ and\ the\ checksum\ are\ same.$$

- **Problem #6**

6) **(10 points)** A TCP machine is sending full windows of 65,535 bytes over a 1-Gbps channel that has a 10-msec one-way delay. What is the maximum throughput achievable? What is the line efficiency?

$$
\begin{gathered}
Maximum\ Achievable\ Throughput \\
= Number\ of\ bits\ sent\ per\ second \\
= 65535\ Bytes/20\ msec \\
= (65535 * 8\ Bits)/(20x10-3sec) \\
= 26.214\ Mbps
\end{gathered}
$$

$$
\begin{gathered}
Line\ Efficiency \\
= Throughput/Bandwidth \\
= 26.214\ Mbps/1\ Gbps \\
= 26.214 * 10-3 \\
= 0.026214 \\
= 2.62\%
\end{gathered}
$$