COMP 4320 Introduction to Computer Networks
Homework Assignment 1 Liam Maher
Due on Sunday, June 30 on Canvas (upload your answer sheet)

Instruction: Every student should finish the following questions independently. Give justification for the results (e.g., show the time-domain diagram and/or calculation process) to receive credits. Scan your answer sheet and upload it to Canvas.

In the following, for simplicity of your calculation, let K denote 1000, and M denote 1 million.

1. Calculate the total time (defined as the interval from the moment that the handshaking starts to the moment that the last bit of the file is received by the destination) required to transfer a 1000-KB file in the following cases, assuming an RTT of 50 ms, a packet size of 1 KB data, and an initial 2×RTT of "handshaking" before data is sent:

(a) The bandwidth is 1.5 Mbps, and data packets can be sent continuously.

Soln:

RTT = 50 ms

Make Bandwidth KBps -> 1.5 Mbps = 1.5 * 1000 / 8 KBps = 1500 / 8 = 187.5 KBps

Calc T_t = File size / bandwidth = 1KB/187.5KBps = 5.3333 ms

T_p = RTT/2 = 50/2 = 25 ms

# of packets = 1 * 1000 = 1000

D = 2*RTT + 1000 * T_t + T_p

= 2*50ms + 1000 * 5.3333 + 25

= 100 + 5333.3 + 25

= 5458.3 ms

= 5.4583 s

(b) The bandwidth is 1.5 Mbps, but after we finish sending each data packet we must wait one RTT before sending the next.

Soln:

RTT = 50 ms

Make Bandwidth KBps -> 1.5 Mbps = 1.5 * 1000 / 8 KBps = 1500 / 8 = 187.5 KBps

Calc T_t = File size / bandwidth = 1KB/187.5KBps = 5.3333 ms

T_p = RTT/2 = 50/2 = 25ms

# of packets = 1 * 1000 = 1000

D = 2*RTT + 999(T_t + RTT) + T_t + T_p

= 2*50 + 999(5.3333 + 50) + 5.3333 + 25

= 100 + 999(55.3333) + 5.3333 + 25

= 100 + 55278 + 5.3333 + 25

= 55408.3333 ms

= 55.40833 s

(c) The bandwidth is "infinite," meaning that we take transmit time to be zero, and up to 20 packets can be sent per RTT.

Soln:
RTT = 50 ms
$T_t = 0$ ms
T_p = RTT/2 = 50 / 2 = 25
# of packets = 1000*1 = 1000
So 50 batches
D = 2*RTT + 50*RTT + T_p
= 2*50 + 50*50 + 25
= 100 + 2500 + 25
= 2625 ms
= 2.625 s

(d) The bandwidth is infinite, and during the first RTT we can send one packet (2^{1-1}), during the second RTT we can send two packets (2^{2-1}), during the third we can send four (2^{3-1}), and so on. (hint: the sum of the geometric series is given by: $1+2+\ldots 2^{n-1} = 2^n - 1$)

Soln:

RTT = 50ms

$T_t = 0$ ms
T_p = RTT/2 = 50 / 2 = 25
# of packets = 1000*1 = 1000
Need smallest n such that $2^n - 1 >= 1000$

2^10 – 1 = 1023 so we need 10 batches

D = 2*RTT + (10-1)*RTT + T_p

= 2*50 + 9*50 + 25

= 100 + 450 + 25

= 575 ms

= .575 s

2. Consider a point-to-point link 50 km in length. At what bandwidth would propagation delay (at a speed of 2×10^8m/s) equal transmit delay for 100-byte packets? What about 512-byte packets?

Soln for 100 byte packet:
Distance = 50 km * 1000 = 50,000 m
Speed of medium: $2\text{x}10^8$m/s
T_p = Distance / speed of medium = 50,000 m / $2\text{x}10^8$ = 0.00025 s = .25 ms
Packet size
We need where $T_t = T_p$

T_t = file size / bandwidth

So we need to find bandwidth
100byte*8 = 800 bits
800/ bandwidth = 0.25 ms
0.00025s = 800/bandwidth
Bandwidth(bps) = 800 bits / .00025 s
Bandwidth = 3200000 bps
= 3.2 Mbps

Soln for 512 byte packet:
Distance = 50 km * 1000 = 50,000 m
Speed of medium: $2x10^8$m/s
T_p = Distance / speed of medium = 50,000 m / $2x10^8$ = 0.00025 s = .25 ms
Packet size
We need where $T_t = T_p$

T_t = file size / bandwidth
So we need to find bandwidth
512byte*8 = 4096 bits
4096bits/bandwidth = 0.25 ms
.00025s = 4096/bandwidth
Bandwidth(bps) = 4096 bits / .00025s
Bandwidth = 1638400 bps
= 16.384 Mbps

3. Suppose a 1-Gbps point-to-point link is being set up between the Earth and a new lunar colony. The distance from the moon to the Earth is approximately 385,000 km, and data travels over the link at the speed of light—3×10^8 m/s.

(a) Calculate the minimum RTT for the link.

Soln:
RTT = 2 * Propogation delay
T_p = Distance / speed of medium
= 385,000 * 1000 (to convert to meters) / $3x10^8$
= 385,000,000 / $3x10^8$
= 1.283333 s
RTT = 2 * T_p
= 2 * 1.283333
= 2.5667 seconds

(b) Using the RTT as the delay, calculate the delay × bandwidth product for the link.
Soln:
Bandwidth = 1 Gbps = 1,000,000,000 bps
Delay = RTT = 2.5667 seconds
Delay * Bandwidth = 2.5667 seconds * 1,000,000,000 bps
(seconds cancel) = 2566700000 bits

= 2566.7 Mb

= 2.5667 Gbits

(c) What is the significance of the delay × bandwidth product computed in (b)?

Soln: When multiplying the delay x bandwidth, the seconds cancel out living us with, in this case, 2.5667 Gbits. This number is significant as it is the maximum amount of data that can be in transit on the network at a given time. For example, in the treadmill/conveyor belt example used in the class lectures, the maximum amount of data that could be on that conveyor belt at a given time is 2.5667 Gbits of data between the eath and new lunar colony.

(d) A camera on the lunar base takes pictures of the Earth and saves them in digital format to disk. Suppose Mission Control on Earth wishes to download the most current image, which is 25 MB. What is the minimum amount of time that will elapse between when the request for the data goes out and the transfer is finished?

Soln:

T_p =1.2833333s

Image size =25 MB (Mega bytes not megabits)

25MB * 8 = 200 Mbits

Now we must find Transmission time

T_t = file size / bandwidth

= 200 Mbits / 1000000000 bits/s

= 200000000 bits / 1000000000 bits/s

= 0.2 seconds

Now we must find total time

Total time elapsed = RTT + T_t

= 2.5667s + 0.2s

= 2.7667 seconds

4. For the following, assume that no data compression is done. Calculate the bandwidth necessary for transmitting in real time:

(a) High-definition video at a resolution of 1920×1080, 24 bits/pixel, 30 frames/second.

Soln:

Total pixels/frame = 1920*1080=2,073,600 pixels

Total bits/frame = 2,073,600 * 24 = 49,766,400 bits

Total bits/sec = 49,766,400 * 30 = 1,492,992,000 bits/sec

Therefore, total Bandwidth required ~ 1,492.992 Mbps or 1.492992 Gbps

(b) POTS (plain old telephone service) voice audio of 8-bit samples at 8 KHz.

Bits/sample = 8

Sample rate = 8 KHz

Bits/sec = 8 bits/sample * 8000 samples/second = 64,000 bits/second

Bandwidth required = 64000 bits/second = 64 Kbps

(c) GSM mobile voice audio of 260-bit samples at 50 Hz.

Bits/sample = 260

Sample rate = 50 hz

Bits/second = 260 bits/sample * 50 samples/second = 13000 bps

Bandwidth required = 13000 bits/s = 13 Kbps

(d) HDCD high-definition audio of 24-bit samples at 88.2 kHz.

Soln:

Bits/sample = 24

Sample rate = 88.2 KHz

88.2 Khz = 88200 samples/second

Bits/second = 24 bits/sample * 88200 samples/second = 2116800 bits/second

Bandwidth required = 2116800 bits/second = 2.1168 Mbps