CMPT 434 Assignment 1
Winter 2019
Due Date: Saturday January 25th
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Part B

(1) (4 marks) Consider two nodes connected by a single dedicated link within an OCN (on- chip network), SAN (system/storage area network), LAN (local area network), or WAN (wide-area network), and suppose that we wish to transmit a single 100 byte (including header) packet from one node to the other. Calculate the total delay and the percentage of the total delay that is propagation delay for each network, assuming that:

- the link data rate is 4 Gbps (i.e., $4x109$ bps);
- there is no queuing delay;
- the total node processing delay (not overlapped with any other component of delay) is x + (0.5 nanoseconds/byte), where x (the portion of this delay that is independent of packet size) is 0 microseconds for the OCN, 0.3 microseconds for the SAN, 3 microseconds for the LAN, and 30 microseconds for the WAN; and
- the link distances are 0.5 cm, 5m, 5000m, and 5000 km, for the OCN, SAN, LAN, and WAN, respectively, with the speed of signal propagation in each case equal to 200,000 km/s (approximately 2/3 of the speed of light in a vacuum).

(Assuming the given measurements are infinitely precise.)

(a) What is the node processing delay?
   (i) On the OCN?
   $NPD_{OCN} = 100b * (0.5ns/b) = 50ns = 5.0\text{e}{-8}s$
   (ii) On the SAN?
   $NPD_{SAN} = 0.3ns + (100b * 0.5ns/b) = 50.3ns = 5.3\text{e}{-8}s$
   (iii) On the LAN?
   $NPD_{LAN} = 3\mu s + (100b * 0.5ns/b) = 3\mu s + 50ns = 3.05\text{e}{-6}s$
   (iv) On the WAN?
   $NPD_{WAN} = 30\mu s + (100b * 0.5ns/b) = 30\mu s + 50ns = 3.005\text{e}{-6}s$

(b) What is the propagation delay?
   (i) On the OCN?
   $PD_{OCN} = 0.005m/200,000,000\text{m}\,\text{s}^{-1} = 2.5\text{e}{-11}s$
   (ii) On the SAN?
   $PD_{SAN} = 5m/200,000,000\text{m}\,\text{s}^{-1} = 2.5\text{e}{-8}s$
   (iii) On the LAN?
   $PD_{LAN} = 5,000m/200,000,000\text{m}\,\text{s}^{-1} = 2.5\text{e}{-5}s$
   (iv) On the WAN?
   $PD_{WAN} = 5,000,000m/200,000,000\text{m}\,\text{s}^{-1} = 2.5\text{e}{-2}s$

(c) What is the percentage of the total delay which is propagation delay?
   (i) On the OCN?
   $OCN = PD_{OCN}/(PD_{OCN} + NPD_{OCN}) = 2.5\text{e}{-11}s/(2.5\text{e}{-11}s + 5.0\text{e}{-8}s) \approx 0.05\%$
   (ii) On the SAN?
   $SAN = PD_{SAN}/(PD_{SAN} + NPD_{SAN}) = 2.5\text{e}{-8}s/(2.5\text{e}{-8}s + 5.3\text{e}{-8}s) \approx 32\%$
   (iii) On the LAN?
   $LAN = PD_{LAN}/(PD_{LAN} + NPD_{LAN}) = 2.5\text{e}{-5}s/(2.5\text{e}{-5}s + 3.05\text{e}{-6}s) \approx 89\%$
   (iv) On the WAN?
   $WAN = PD_{WAN}/(PD_{WAN} + NPD_{WAN}) = 2.5\text{e}{-2}s/(2.5\text{e}{-2}s + 3.005\text{e}{-6}s) \approx 100\%$

(2) (4 marks) Consider a message consisting of n packets, each of 1000 bytes (including header), that traverses 4 links in a store-and-forward packet-switched network (i.e., there are 3 intermediate nodes between the source and destination that the message passes through). The propagation delay on each link is 1 ms. The transmission rate on each link is 100 Mbps (i.e., 100 x 106 bps). Neglecting processing and queueing delays, and assuming that the packets are sent back-to-back without intervening delays, give the total delay from when the first bit is sent at the source until all packets have been completely received at the destination for the following values of n:

(a) $n = 1$
The propagation delay between the sender and receiver on this network is $4 * 1ms = 4ms = 0.004s$.
Total message size is $1000 bytes * 8 bits/byte = 8000 bits$.
The transmission rate is $100Mbps = 100000000bps$
Then it takes $8000b/100000000bps = 8\text{e}{-5}s$ to get the last bit on the wire.
Consider the last bit sent from the receiver. It get on the wire after $8\text{e}{-5}s$. It takes $1ms$ to get to the next node.
This is repeated 4 times before the last bit is received at its destination. Then, the total delay is $4 * (8\text{e}{-5}s + 1\text{e}{-3}s) = 4.32\text{e}{-3}s$

(b) $n = 12$
If the total amount of data is increased 12 fold, then we should expect the only thing to change is the total message size.
Now, the total message size is $1000 bytes/message * 8 bits/byte * 12 messages = 96000 bits$.
Then, it takes $96000b/100000000bps = 9.6\text{e}{-4}s$ for the last bit to get on the wire, and the total delay will then be $4 * (9.6\text{e}{-4}s + 1\text{e}{-3}s) = 7.84\text{e}{-3}s$

(3) (4 marks) Give the maximum data rate, as measured in Kbps, for transmissions on a channel with bandwidth H = 400 KHz and a signal to noise ratio of 63, for each of the following two cases. (Hint: for each case, use whichever of Nyquist's theorem and Shannon's theorem imposes the tightest constraint.)

(a) Each transmitted symbol has 2 possible values (i.e., transmits just a single bit)
According to Nyquist's Theorem, the maximum symbol rate is $baud = 2H = 800Kbps$ symbols per second. Then, the baud is also the maximum data rate because there is only 1 bit per symbol.
According to Shannon's Theorem, the maximum bps is $400,000Hz * \log 21 + 63$ which gives $bps_{max} = 400,000 * 6 = 2,400Kbps$
In this case, Nyquist's Theorem places the greatest constraint on the maximum data rate.

(b) Each transmitted symbol has 32 possible values.
With Nyquist's Theorem, the maximum symbol rate is $baud = 2H = 800K$ symbols per second. Then, the $bps_{max} = 800K * 32 = 25,600Kbps$
With to Shannon's Theorem, we find the same result, and the $bps_{max} = 2,400Kbps$
In this case, Shannon's Theorem places the greatest constraint on the maximum data rate.