Problem Set #1

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1. Circuit switching has a dedicated connection to the between nodes, which means that the two nodes can utilize the full bandwidth of that link, compared to packet-switching, in which the two nodes might have to share the bandwidth with other nodes.

2. With TDM, you can use the whole bandwidth for a certain quanta but with FDM you won't be able to use all of the bandwidth.

3. (a) $d_{\text{prop}} = m/s$

   (b) $d_{\text{trans}} = L/R$

   (c) $d_{\text{end-to-end}} = d_{\text{prop}} + d_{\text{trans}}$

   (d) d_{trans} is the time it takes to put all the bits into the link. This means that the first bit will be put into the link at $t = 0$ and the last bit at $t = d_{\text{trans}}$. So, the last bit will be 0 m from host A.

   (e) The first bit was sent out at $t = 0$, so it has been travelling for d_{trans} seconds. Multiply that by the speed of the medium to get $s \cdot d_{\text{trans}}$.

   (f) If d_{prop} is less than d_{trans}, that means it takes less time for the physical bit to travel from host A to host B than it takes to put all the bits into the link. Since this is the case, the first bit of the packet should have already arrived.

   (g)

$$\begin{aligned} d_{\text{prop}} &= d_{\text{trans}} \\ \frac{m}{s} &= \frac{L}{R} \\ m &= \frac{Ls}{R} \approx \boxed{535.7 \text{ km}} \end{aligned}$$

4. The total time elapsed is equal to creation time + end-to-end delay = creation time + d_{prop} + d_{trans}.

$$\frac{56 \text{ bytes} \cdot 8 \text{ bits/byte}}{65000 \text{ bits/s}} + \frac{56 \text{ bytes} \cdot 8 \text{ bits/byte}}{10^6 \text{ bits/s}} + 20 \text{ ms} \approx \boxed{27.3 \text{ ms}}$$

5. (a) There can be 15 Mbps/150 Kbps = $\boxed{100}$ users supported when circuit switching is used.

   (b) Since each users is only transmitting 10% of the time, the probability that a given user is transmitting is $\boxed{.1}$.

(c) The probability that exactly half of the 20 users are transmitting simultaneously, where $X \sim \text{Binomial}(20, 0.1)$, is $P(X = 10) = \binom{20}{10}(0.1)^{10}(1-0.1)^{20-10} = \boxed{0.00000644}$.

6. (a) The minimum RTT is $385000 \text{ km} \cdot 3 \times 10^8 \text{ m/s} \cdot 2 \approx \boxed{2.6 \text{ s}}$.

   (b) $2.6 \text{ s} \cdot 1 \text{ gigabit/s} = 2.6 \text{ gigabits} = \boxed{325 \text{ MB}}$.

   (c) The bandwidth delay product would be the number of bits you can send before you can receive a response.

7. (a)

$$\begin{aligned}
\text{Throughput} &= \text{TransferSize}/\text{TransferTime} \\
\text{TransferSize} &= 2 \text{ MB} \\
\text{TransferTime} &= \text{RTT} + \frac{\text{TransferSize}}{\text{Bandwidth}} = 0.316 \text{ s} \\
\text{Throughput} &= \boxed{50.63 \text{ Mbps}}
\end{aligned}$$

   (b) Assuming one-way delay = RTT/2,

$$\begin{aligned}
\text{Throughput} &= \text{TransferSize}/\text{TransferTime} \\
\text{TransferSize} &= 2 \text{ MB} \\
\text{TransferTime} &= \text{one-way delay} + \frac{\text{TransferSize}}{\text{Bandwidth}} = 0.166 \text{ s} \\
\text{Throughput} &= \boxed{96.4 \text{ Mbps}}
\end{aligned}$$

8. $1/(10 * 10^9 \text{ bits/s}) \cdot 2.5 \times 10^8 \text{ m/s} = \boxed{.023 \text{ m/bit}}$

9. (a) $1 \text{ Gbps} \cdot 20000 \text{ km}/2.5 \times 10^8 \text{ m/s} = 80 \text{ Mb} = \boxed{10 \text{ MB}}$

   (b) When sending the one file, the maximum number of bits in the link will be the whole file size (800000 bits). The last bit will be transmitted at 80 μs, so the first bit will be 200 km through the link, and so the whole file will be in the link.

   (c) Each packet will be recieved after

$$\frac{40000 \text{ bits}}{10^9 \text{ bits/s}} + \frac{20000 \text{ km}}{2.5 \times 10^8 \text{ m/s}} = 80.04 \text{ ms}$$

   Then, host B will need to send an acknowledgement, which will take another

$$\frac{20000 \text{ km}}{2.5 \times 10^8 \text{ m/s}} = 80 \text{ ms}$$

   Finally, for all the packets, it will take

$$20 * (80.04 \text{ ms} + 80 \text{ ms}) = \boxed{3.2 \text{ s}}$$

10. (a) $36000 \text{ km}/2.4 \times 10^8 \text{ m/s} = \boxed{0.15 \text{ s}}$

    (b) $10 \text{ Mbps} \cdot 0.15 \text{ s} = 1.5 \text{ Mb} = \boxed{187.5 \text{ KB}}$

    (c) Since it sends a photo every minute, the transmission time of each photo should be 60 s for it to be continuously transmitting.

$$\begin{aligned} \text{TransmissionTime} &= \frac{x}{\text{Bandwidth}} \\ x &= \text{TransmissionTime} \cdot \text{Bandwidth} \approx \boxed{75 \text{ MB}} \end{aligned}$$

    (d) The maximum number of bits that can be in the link at any given time is simply the bandwidth delay product, which is