01-Introduction

1. **Short Answer Questions**

   a. What's **propagation delay**? How do you compute it for a given link?
   b. If I am sending 1 bit to a host in the moon, which of the following is the dominant factor: **Transmission delay** or **propagation delay**? Justify your answer.
   c. If I am sending 1Mbits to a host in the same room, which of the following is the dominant factor: **Transmission delay** or **propagation delay**? Justify your answer.
   d. I have a datacenter where two servers exchange huge amounts of data (in the order of petabytes). I need to reduce the time it takes for the data to go from one server to the other. A friend of mine suggests that I reduce the cable size connecting the two servers by half, and another friend suggests that I increase the bandwidth of the cable two folds. Which suggestion should I follow? Justify your answer.
   e. NASA establishes a lunar base and needs to establish a data link between the control station in Houston and the lunar base. They only need to send a packet of 1000 bytes every hour that contains some information about the things to be done. They can set up a low bandwidth 1Kbps link for $1000 or a high bandwidth 1Gbps link for $1,000,000. Which one should they choose and why? Justify your answer.
   f. How many layers does the **OSI protocol stack** have? List them from top to bottom.
   g. How many layers does the **TCP/IP protocol stack** have? List them from top to bottom.
   h. In a **circuit-switched network** can unused resources belonging to a call be used by other calls to increase network utilization? Why or why not?
   i. List 1 advantage and 1 disadvantage of making the **packet size small** in a packet-switched network.
   j. List 1 advantage and 1 disadvantage of making the **packet size big** in a packet-switched network.
   k. In a **virtual-circuit switched network**, can packets belonging to the same connection, i.e., communicating pairs, follow different paths in the network and arrive out-of-order at the destination? Justify your answer.
   l. True/False. In a **datagram network**, each packet carries the destination address in the packet header. Justify your answer.
   m. What's the main motivation for **packet switching**? Briefly explain.
   n. True/False. If a node needs to communicate only with **nodes on the same link**, i.e., with another neighbor, **Physical Layer** and **Link Layers** are enough. In other words, no network layer is necessary. Justify your answer.
   o. How "**wide**" is a bit on a 1 Gbps link?
   p. Suppose you are developing a standard for a new type of network. You need to decide whether your network will use virtual-circuits or datagram forwarding. What are the pros and cons of using **virtual-circuits**?
   q. Briefly describe how Time Division Multiplexing (TDM) works.
   r. Briefly describe how Frequency Division Multiplexing (FDM) works.
   s. Briefly explain what's meant by the "**service interface**" of a protocol? What's the service interface of the Internet Protocol (IP)?
   t. Briefly explain what's meant by the "**peer interface**" of a protocol?
   u. How and why do packets get lost during transmission? Briefly explain.

2. Consider sending a file **F=M*L** bits over a path of **N** links. Each link transmits at R bits/sec. The network is lightly loaded so that there are **no queuing delays**. When **packet switching** is used, the M*L bits are broken up into **M packets**, each packet **L bits**. Also assume that the **propagation delay is negligible**.

    a. Suppose that the network is **circuit-switched**. Further suppose that the transmission rate of the circuit between the source and the destination is **R bps**. Assuming $\mathbf{t_s}$ set-up time and **h** bits of header appended to the entire file, how long does it take to send the file?
    b. Suppose the network is a **packet-switched virtual circuit network** such as X.25. Denote the virtual-circuit set-up time by $\mathbf{t_s}$. Suppose the sending layers add a total of **h** bits of header to each packet. How long does it take to send the file from the source to the destination?
    c. Suppose the network is a **packet-switched datagram network** such as the Internet. Now suppose that each packet has **2*h** bits of header. How long does it take to send the file?

3. Suppose two nodes A and B are connected via a point-to-point link. The length of the link is 10000km and its bandwidth is 1Kbps. Assume the speed of signal on the wire is $3x10^5$ km/sec.

    a. Calculate the **minimum RTT** for the link.
    b. **How long** does it take to transmit 1000 bytes from A to B.

4. Suppose a **100 Mbps** 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 390,000 km, and data travels over the link at the speed of light, i.e., $3x10^5$ km/sec.

    a. Calculate the **minimum RTT** for the link.
    b. 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 25MB. What is the **minimum amount of time** that will elapse between when the request for the data goes out and the transfer is finished?

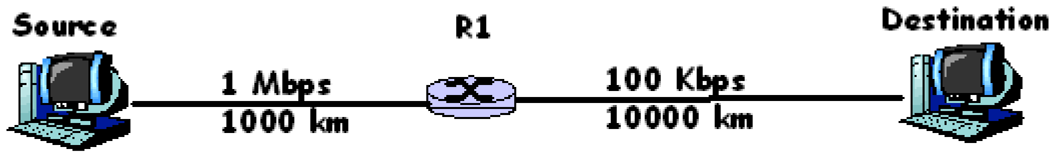
5. Consider two hosts A and B connected by a single link of rate **R bps**. Suppose that the two hosts are separated by **M** meters and suppose the propagation speed along the link is **s** m/sec. Host A is to send a packet of size **L bits** to host B.

    a. Express propagation delay $\mathbf{t_{prop}}$ in terms of **M** and **s**.
    b. Determine the transmission time of the packet $\mathbf{t_{trans}}$ in terms of **L** and **R**.
    c. Ignoring processing and queueing delays, how long does it take for the last bit of the packet to arrive at B?
    d. Suppose host A begins to transmit the packet at time t=0. At time t = $\mathbf{t_{trans}}$ where is the last bit of the packet?
    e. Suppose $\mathbf{t_{prop}}$ is greater than $\mathbf{t_{trans}}$. At time t = $\mathbf{t_{trans}}$ where is the first bit of the packet?
    f. Suppose $s=2.5*10^5$ km/s, L=100 bits, and R=28 Kbps. Find the distance **m** so that $\mathbf{t_{prop}}$ equals $\mathbf{t_{trans}}$

6. Suppose two hosts A and B are separated by 10,000 kilometers and are connected by a direct link of **R=1 Mbps**. Suppose the propagation speed over the link is $2.5*10^8$ m/sec.

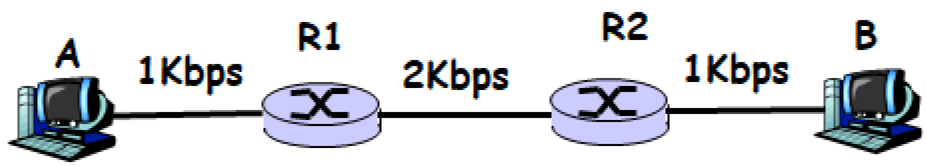
    a. Calculate the “**bandwidth-delay**” product $\mathbf{R*t_{prop}}$.
    b. Provide an interpretation of the bandwidth-delay product.
    c. Consider sending a file of 400,000 bits from host A to host B. Suppose the file is sent continuously as one big message. How long does it take for the last bit of the message to arrive at B.

7. Consider the packet switched network shown below. The bandwidth of the link between the source and router R1 is 1 Mbps and the length of the link is 1000 kms. The bandwidth of the link between router R1 and the destination is 100Kbps and the length of the link is 10000 kms. Assume that the speed of light is $2*10^5$ km/sec.



   a. What's the **RTT**?
   b. Assume that the source sends 1000 packets each of length 1000 bytes to the destination. How long does it take for the transmission to complete?

8. Consider the following network. Bandwidth of the link between A and R1 is **1 Kbps**. Bandwidth of the link between R1 and R2 is **2 Kbps**. Bandwidth of the link between R2 and B is **1 Kbps**. Assume that an application at A sends 10 packets each of size 1000 bytes. Assuming that the transmission starts at time 0, compute how long it takes for the last packet to arrive at B. Ignore the propagation, processing and queuing delays.



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