Midterm Data Communications Review

Chapter 1: Link Layer

Question 1

What's propagation delay? how do you compute it for a given link?

Propagation delay is the time it takes for a signal to travel from one end of a link to the other. It is computed by multiplying the length of the link by the propagation speed of the medium.

Formulate the equation for propagation delay.

$$\text{Propagation delay} = \frac{\text{Length of the link}}{\text{Propagation speed of the medium}}$$

Propagation speed depends on the medium.

- For copper wire, the speed of propagation is 2.3 x 10^8 m/s.
- For optical fiber, the speed of propagation is about 2/3 the speed of light, which is 3 x 10^8 m/s.

Example:

A link has a length of 1000 meters and a propagation speed of 2.3 x 10^8 m/s. What's the propagation delay?

$$\text{Propagation delay} = \frac{1000}{2.3 \times 10^8} = 4.3478 \times 10^{-6} \text{ seconds} = 4.3478 \text{ microseconds}$$

Question 2

If I am seding 1 bit to a host in the moon, which of the following is the dominat factor: transmission delay or propagation delay?

Transmission delay is the time it takes to push all the bits of a message into the link. For 1 bit, this is extremely small, regardless of the transmission speed of the medium.

$$\text{Transmission delay} = \frac{\text{Length of the message (size of data)}}{\text{Transmission speed of the medium (bandwidth)}}$$

For a 1-bit message, with a slow bandwidth of 1 Mbps, the transmission delay is 1 bit / 1 Mbps = 0.000001 seconds or 1 microsecond.

Distance from the moon to the earth is 384,400 km.

$$\text{Propagation delay} = \frac{384,400 \times 10^3}{3 \times 10^8} = 1.2813 \text{ seconds}$$

The propagation delay (1.2813 seconds) is much greater than the transmission delay (1 microsecond).

So, the dominant factor is the propagation delay.

- Distance: enormous distance to the moon.
- Single bit: trasmitting 1 bit is very fast.
- Speed Limit: propagation speed is limited by the speed of light, which is 3 x 10^8 m/s, and constant.

Question 3

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.

transmission delay formula
propagation delay formula

1Mbits = 1,000,000 bits.

Suppose we have a 1Gbps link (1000 Mbps).

$$\text{Transmission delay} = \frac{1 \times 10^6}{1 \times 10^9} = 0.001 \text{ seconds}$$

Assume the distance between two hosts is 10 meter.

$$\text{Propagation delay} = \frac{10}{2 \times 10^8} = 5 \times 10^{-8} \text{ seconds} \approx 0.05 \text{ microseconds}$$

The transmission delay is much greater than the propagation delay.

So, the dominant factor is the transmission delay.

Question 4

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.

1. Halving the cable size by half

Halving the cable size will reduce the propagation delay by **50%**. However in a datacenter the distance between servers is not that large, so the propagation delay reduction is not that significant.

Halving the propagation has not affects on transmission delay.

2. Doubling the bandwidth

Doubling the bandwidth will reduce the transmission delay by **50%**. For large data center, this can be a significant reduction in the time it takes for the data to go from one server to the other.

Example:

- initial bandwidth: 1 Gbps (1 x 10^9 bits/second)
- data size: 1 Petabyte (8 x 10^15 bits)

Initial transmission delay: 1 Gbps

$$\text{Initial transmission delay} = \frac{8 \times 10^{15}}{1 \times 10^{9}} = 8 \times 10^{6} \text{ seconds} \approx 92.6 \text{ days}$$

New transmission delay: 2 Gbps

$$\text{New transmission delay} = \frac{8 \times 10^{15}}{2 \times 10^{9}} = 4 \times 10^{6} \text{ seconds} \approx 46.3 \text{ days}$$

So, doubling the bandwidth will reduce the transmission delay by 50%.

Question 5

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.

Trying to find the balance between the cost and the time it takes for the data to go from one server to the other.

1. Low bandwidth 1Kbps link

- Cost: $1000
- Bandwidth: 1 Kbps (1 x 10^3 bits/second)
- Data size: 1000 bytes = 8 x 10^3 bits
- Transmission Rate: 1 Kbps (1 x 10^3 bits/second)

$$\text{Transmission delay} = \frac{8 \times 10^3}{1 \times 10^3} = 8 \text{ seconds}$$

- Frequency of transmission: sending 1 packet every hour, allow use time to send the packet. 8 seconds is not a big deal.
- Troublesome if data size is larger.

2. High bandwidth 1Gbps link
   - Cost: $1,000,000
   - Bandwidth: 1 Gbps (1 x 10^9 bits/second)
   - Transmission Rate: 1 Gbps (1 x 10^9 bits/second)

$$\text{Transmission delay} = \frac{8 \times 10^3}{1 \times 10^9} = 8 \times 10^{-6} \text{ seconds} = 8 \text{ microseconds}$$

   - more future proof if the data size is larger.

1 Kbps link is cheaper and more cost effective.

Question 6

How many layers does the OSI protocol stack have? List them from top to bottom.

The OSI protocol stack has 7 layers:

1. Application Layer - Provides network services to the end-user.
2. Presentation Layer - translate data between the application layer and the network format
3. Session Layer - manages sessions between applications
4. Transport Layer - responsible for end-to-end error recovery and flow control
5. Network Layer - handles data routing between networks
6. Data Link Layer - provides node-to-node data transfer and error correction
7. Physical Layer - transmits raw bits over a physical medium

Question 7

How many layers does the TCP/IP protocol stack have? List them from top to bottom.

The TCP/IP protocol stack has 4 layers:

1. Application Layer - combines function of Application, Presentation, and Session layers in the OSI model.
2. Transport Layer - resposible for end-to-end error recovery and flow control. (TCP and UDP)
3. Internet Layer - handles routing packets between networks (IP)
4. Link Layer - deals with physical transmission medium and the hardware that connects devices to each other. (Ethernet, WiFi, etc.)

Question 8

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?

Curcuit-switched is the connections that is established between two hosts before the data transmission, the data is then transmitted on a dedicated path. Noone else can use the path for connection.

Unused resources belonging to a call cannot be used by other calls to increase network utilization.

- It has a dedicated allocation once the circuit is established, and the entire bandwidth is dedicated to the two hosts, regardless of whether data is being transmitted or not.
- The capacity of the circuit remains constant.

Question 9

List 1 advantage and 1 disadvantage of making the packet size small in a packet-switched network

Advantage:

- reduced transmission time: smaller packet size means less time to transmit.
- Faster Processing: routers and switches can process smaller packets more quickly.

Disadvantage:

- Increased overhead: each packet needs to carry its own header information, proportion of header data to payload data is higher, reducing the efficiency.

- Less efficient use of bandwidth: smaller packet size means less data is transmitted per packet, which can lead to less efficient use of bandwidth.

Question 10

List 1 advantage and 1 disadvantage of making the packet size big in a packet-switched network.

Advantage:

- more efficient for bulk data transfer: they can send more data per packet, reducing the overhead of sending multiple small packets.

Disadvantage:

- higher latency: larger packets take longer to transmit, which can lead to longer delays.

Question 11

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.

Virtual-circuit is a dedicated path between two hosts. Once the path is established, all packets belonging to the same connection should follow the same path. Physical resources are not exclusively dedicated to the connection.

No, packets belonging to the same connection should follow the same path in a virtual-circuit switched network.

Question 12

True/False. In a datagram-network, each packet carries the destination address in the packet header. Justify your answer.

True. In a datagram-network, each packet carries the destination address in the packet header. This is because the destination address is used to determine the next hop in the network.

Question 13

What's the main motivation for packet switching? Briefly explain.

Packet switching allows multiple connections to share the same resources, and it is more efficient than circuit switching.

Packets can also be routed differently based on network conditions, and if a packet is lost, only the lost packet needs to be retransmitted.

Question 14

True/False. If a node needs to communicate only with nodes on the same link, i.e., with another neighbor, Physical Layer and Link Layer are enough. In other words, no network layer is necessary. Justify your answer.

True, if a node only needs to communicate with nodes on the same link, physical layer and link layer are enough.

The network layer is not necessary. Network layer is only needed if the node needs to communicate with nodes on different networks.

Question 15

How "wide" is a bit on a 1 Gbps link?

A width of a bit means how far the signal can travel before the next bit arrives (the physical distance the bit occupies the medium).

Rate at which bits are transmitted is 1 Gbps, which is 1 x 10^9 bits per second.

Assuming we are using fiber-optic cable, which has a propagation speed of 2/3 the speed of light, i.e., 2 x 10^8 m/s.

$$\text{Distance} = \text{Propagation speed} \times \text{Time}$$

$$\text{Distance} = \frac{2 \times 10^8 \text{ m/s}}{1 \times 10^9 \text{ s}} = 0.2 \text{ meters} = 20 \text{ cm}$$

So, a bit on a 1 Gbps link is 0.2 meters wide or 20 cm wide.

Question 16

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?

Pros:

- Connection-oriented: ensures that data is delivered reliably and in order.
- Efficient Resource Allocation: dedicated resources for each connection, efficient for applications that require consistent data rates.

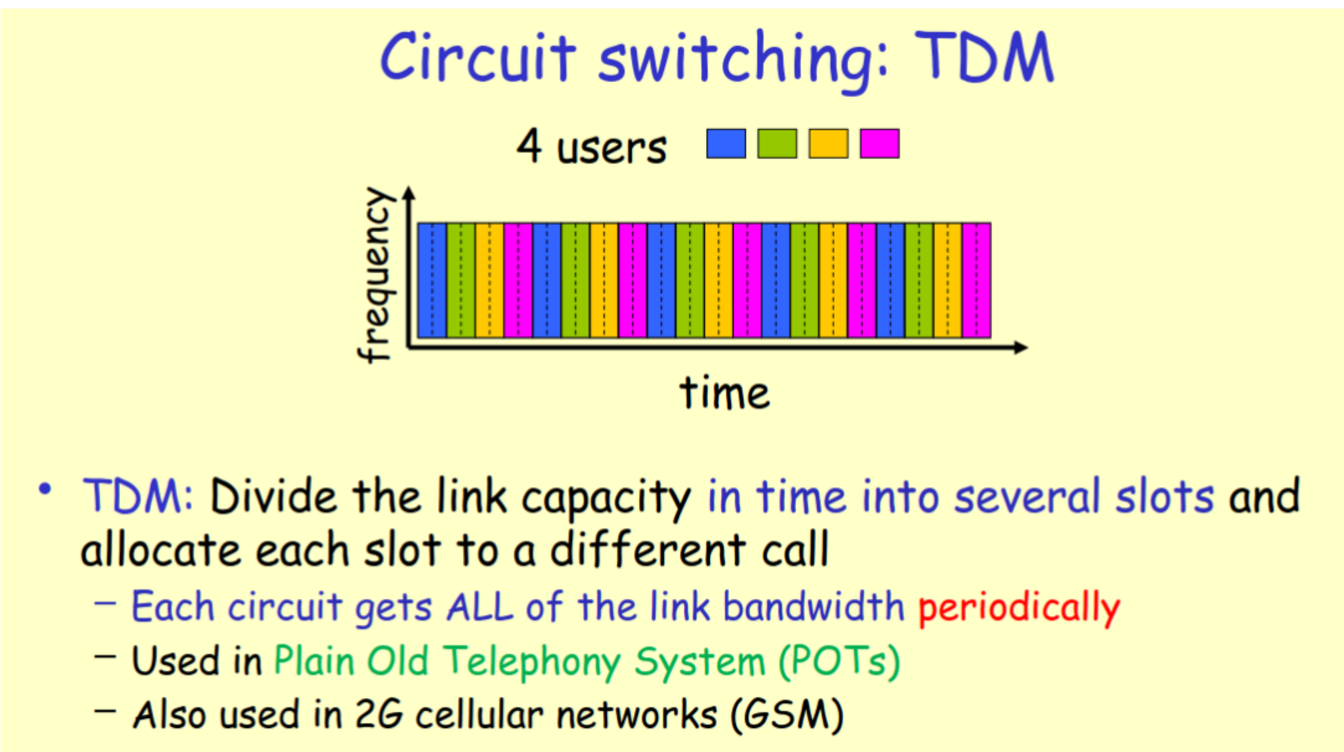
Cons:

- Inefficient Resource Utilization if network is idle or underutilized.
- If the path on the virtual-circuit is broken, the entire connection is broken.

Question 17

Briefly describe how Time Division Multiplexing (TDM) works.

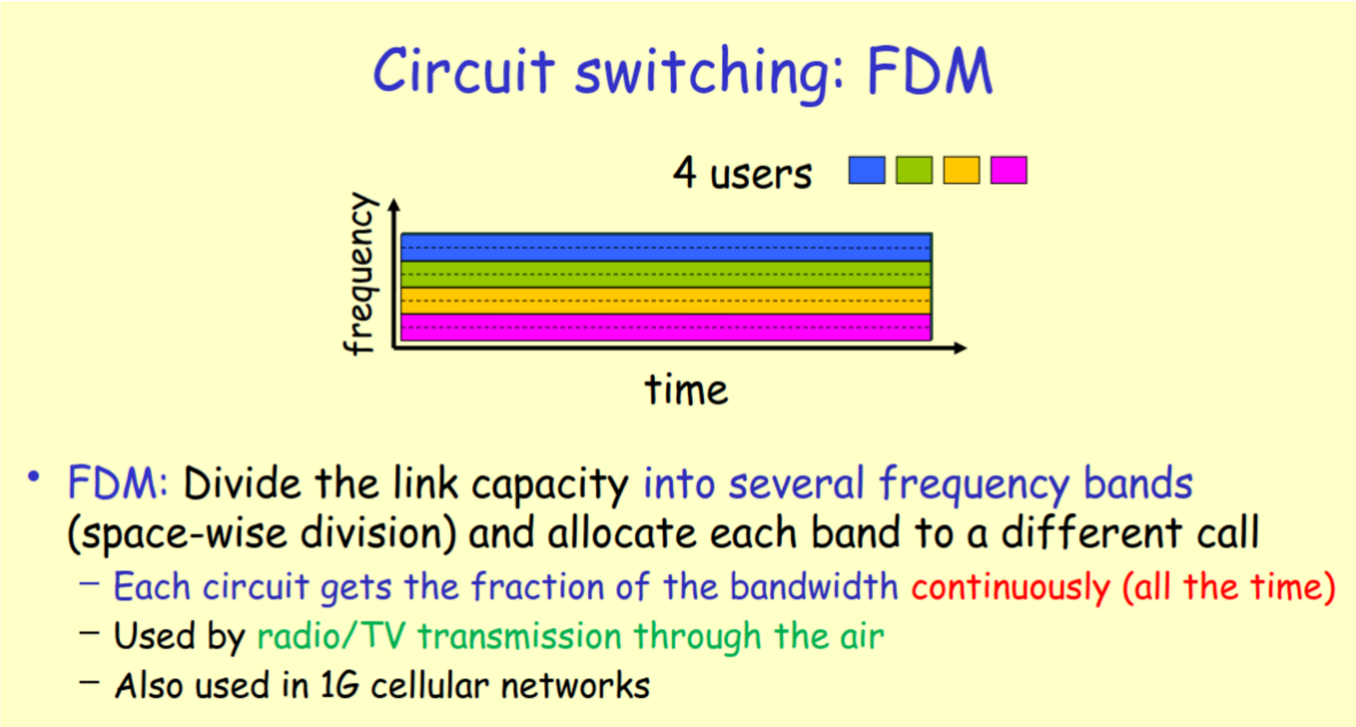
Divides the available bandwidth into time slots, and each connection is assigned a time slot.



Question 18

Briefly describe how Frequency Division Multiplexing (FDM) works.

Divides the available bandwidth into frequency bands, and each connection is assigned a frequency band.



Question 19

Briefly explain what's meant by the "service interface" of a protocol? What's the service interface of the Internet Protocol (IP)?

Service interface is the set of protocols from lower layers that a layer makes available to the layer above it.

In the case of IP, it exports a connectionless, unreliable, "best effort" datagram to the transport layer protocol.

Question 20

Briefly explain what's meant by the "peer interface" of a protocol?

Peer interface is a set of rules that defines how two layers interact with each other.

Peer interface is the communication interface with its counterpart (peer) on another machine.

This interface defines the form and meaning of messages exchanged between protocol peers to implement the service interface.

Question 21

How and why do packets get lost during transmission? Briefly explain.

1. Packet loss during transmission
2. Packet loss due to congestion
3. Packet loss due to errors
4. Packet loss due to network overload
5. Packet lost due to hardware failure
6. Packet lost due to TTL expiration

Question 22

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.

File size: F = M*L bits
Number of links: N
Transmission rate: R bits/sec
Setup time: ts
Header size: h bits

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 ts set-up time and h bits of header appended to the entire file, how long does it take to send the file?

Circuit-switch requires a set up time (Ts) so we add that to the file size + header divided by the transmission rate. This will result in how long it takes to send the file.

$$totalsize = F + h = M * L + h$$

$$transmissiontime = \frac{F}{R} = \frac{M * L + h}{R}$$

$$totaltime = transmissiontime + setuptime = \frac{M * L + h}{R} + ts$$

b. Suppose the network is a packet-switched virtual circuit network such as X.25. Denote the virtual-circuit set-up time by ts. 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?

Virtual circuit networks still need to determine a path so we use Ts as the time it takes to set-up. We then are using packet-switching so the file gets split into several packets M that all get a headers H. We find the time it takes for the packets with headers to send as M x (L + H) / R and put everything together to get the equation above.

$$packetsize = L + h$$

$$totalsize = M * (L + h)$$

$$transmissiontime = \frac{M * (L + h)}{R}$$

$$totaltime = transmissiontime + setuptime = \frac{M * (L + h)}{R} + ts$$

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?

Datagram network doesn't require time to set up a fixed circuit to follow since it constantly changes routes, so Ts is not used here. Since it is packet-switched we have to include the header to all packets so M packets with (L + 2H) size and bitrate of R. The result is the equation above.

$$packetsize = L + 2h$$

$$totalsize = M * (L + 2h)$$

$$transmissiontime = \frac{M * (L + 2h)}{R}$$

$$totaltime = \frac{M * (L + 2h)}{R}$$

Question 23

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.

Given:

- Length of the link: 10000 km
- Bandwidth: 1 Kbps
- Speed of signal: 3 x 10^5 km/s

a. Calculate the minimum RTT for the link.

$$PropagationDelay = \frac{Distance}{Speed} = \frac{10000 \text{ km}}{3 \times 10^5 \text{ km/s}} = 0.0333 \text{ seconds}$$

$$RTT = 2 \times PropagationDelay = 2 \times 0.0333 \text{ seconds} = 0.0666 \text{ seconds}$$

b. How long does it take to transmit 1000 bytes from A to B.

Convert 1000 bytes to bits:

$$1000 \text{ bytes} = 1000 \times 8 = 8000 \text{ bits}$$

$$TransmissionTime = \frac{FileSize}{Bandwidth} = \frac{8000 \text{ bits}}{1000 \text{ bits/sec}} = 8 \text{ seconds}$$

Question 24

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.

Given:

- Distance: 390,000 km
- Speed: 3 x 10^5 km/s
- Bandwidth: 100 Mbps (100,000,000 bits/s)

a. Calculate the minimum RTT for the link.

$$PropagationDelay = \frac{Distance}{Speed} = \frac{390,000 \text{ km}}{3 \times 10^5 \text{ km/s}} = 1.3 \text{ seconds}$$

$$RTT = 2 \times PropagationDelay = 2 \times 1.3 \text{ seconds} = 2.6 \text{ seconds}$$

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?

Convert 25MB to bits:

$$25 \text{ MB} = 25 \times 10^6 \text{ bytes} = 25 \times 10^6 \times 8 = 200 \times 10^6 \text{ bits}$$

$$TransmissionTime = \frac{FileSize}{Bandwidth} = \frac{200 \times 10^6 \text{ bits}}{100 \times 10^6 \text{ bits/s}} = 2 \text{ seconds}$$

$$TotalTime = RTT + TransmissionTime = 2.6 \text{ seconds} + 2 \text{ seconds} = 4.6 \text{ seconds}$$

Question 25

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 tprop in terms of M and s.

M = distance between A and B
s = propagation speed

$$t_{prop} = \frac{M}{s}$$

b. Determine the transmission time of the packet ttrans in terms of L and R.

R = transmission rate in bits per second
L = size of the packet in bits

$$t_{trans} = \frac{L}{R}$$

c. Ignoring processing and queueing delays, how long does it take for the last bit of the packet to arrive at B?

$$t_{total} = t_{prop} + t_{trans} = \frac{M}{s} + \frac{L}{R}$$

d. Suppose host A begins to transmit the packet at time t=0. At time t = ttrans where is the last bit of the packet?

Transmission time is the time it takes for the packet to be placed on the wire. So from 0 to Ttrans its being placed on the wire. By the end of it the entire packet is finally on the wire. Propagation would be the time it takes to go across the wire to B.At time t = ttrans, the last bit of the packet is at the destination.

e. Suppose tprop is greater than ttrans. At time t = ttrans where is the first bit of the packet?

$$Distancetraveledbyfirstbit = s \times t_{trans} = s \times \frac{L}{R}$$

f. Suppose s=2.5*105 km/s, L=100 bits, and R=28 Kbps. Find the distance m so that tprop equals ttrans.

Given:

- s = 2.5 x 10^5 km/s = 2.5 x 10^8 m/s (converting to meters per second)
- L = 100 bits
- R = 28 Kbps = 28,000 bits/s

we want

$$t_{prop} = t_{trans}$$

$$\frac{M}{s} = \frac{L}{R}$$

$$M = \frac{L \times s}{R} = \frac{100 \text{ bits} \times 2.5 \times 10^8 \text{ m/s}}{28,000 \text{ bits/s}} = 892.86 \text{ meters}$$

Question 26

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.

Given:

- Distance A and B: 10,000 km = 10,000,000 meters
- Bandwidth (R): 1 Mbps = 1,000,000 bits/s
- Propagation speed (s): 2.5 x 10^8 m/s

a. Calculate the “bandwidth-delay” product R*tprop.

1. Calculate the propagation delay:

$$t_{prop} = \frac{M}{s} = \frac{10,000,000 \text{ meters}}{2.5 \times 10^8 \text{ m/s}} = 0.04 \text{ seconds}$$

2. Calculate the bandwidth-delay product:

$$R \times t_{prop} = 1,000,000 \text{ bits/s} \times 0.04 \text{ seconds} = 40,000 \text{ bits}$$

b. Provide an interpretation of the bandwidth-delay product.

Bandwidth delay product is the max amount of data that can be in the process of being sent at any given time. 40,000 bits means that at any given time that amount of bits can be in the link.

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.

1. Calculate the transmission time:

$$t_{trans} = \frac{FileSize}{R} = \frac{400,000 \text{ bits}}{1,000,000 \text{ bits/s}} = 0.4 \text{ seconds}$$

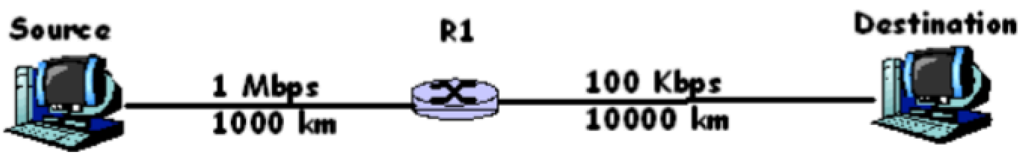
2. Calculate the total time:

$$totaltime = t_{prop} + t_{trans} = 0.04 \text{ seconds} + 0.4 \text{ seconds} = 0.44 \text{ seconds}$$

Question 27

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.

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?

Given:

- Link 1 (Source to R1):
  - Bandwidth: 1 Mbps = 1,000,000 bits/s
  - Length: 1000 km
- Link 2 (R1 to Destination):
  - Bandwidth: 100 Kbps = 100,000 bits/s
  - Length: 10,000 km
- Speed of light: 2 x 10^5 km/s

a. What's the RTT?

1. Calculate the propagation delay for Link 1:

$$t_{prop1} = \frac{1000 \text{ km}}{2 \times 10^5 \text{ km/s}} = 0.005 \text{ seconds}$$

2. Calculate the propagation delay for Link 2:

$$t_{prop2} = \frac{10,000 \text{ km}}{2 \times 10^5 \text{ km/s}} = 0.05 \text{ seconds}$$

3. Total One-Way Propagation Delay:

$$t_{prop} = t_{prop1} + t_{prop2} = 0.005 \text{ seconds} + 0.05 \text{ seconds} = 0.055 \text{ seconds}$$

4. Round Trip Time (RTT):

$$RTT = 2 \times t_{prop} = 2 \times 0.055 \text{ seconds} = 0.11 \text{ seconds}$$

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?

1. Packet size:

$$PacketSize = 1000 \text{ bytes} = 1000 \times 8 = 8000 \text{ bits}$$

2. Transmission time for one packet on Link 1:

$$t_{trans} = \frac{PacketSize}{Bandwidth} = \frac{8000 \text{ bits}}{1,000,000 \text{ bits/s}} = 0.008 \text{ seconds}$$

3. Transmission time for one packet on Link 2:

$$t_{trans} = \frac{PacketSize}{Bandwidth} = \frac{8000 \text{ bits}}{100,000 \text{ bits/s}} = 0.08 \text{ seconds}$$

4. Total transmission time for 1000 packets:

- Since the bottleneck is link 2, we consider its transmission time.

$$TotalTransmissionTime = 1000 \times t_{trans2} = 1000 \times 0.08 \text{ seconds} = 80 \text{ seconds}$$

5. Total Time for Transmission to Complete:

$$TotalTime = TotalTransmissionTime + t_{prop} = 80 \text{ seconds} + 0.055 \text{ seconds} = 80.055 \text{ seconds}$$