**Question 1**

1. **List 4 different types of end-systems (hosts). Is a Web server an end-system?**

Answer: An end system is a device that is connected directly to the Internet, creating an interface that individual users can access. For example, PC, laptop/tablet, ATM, Smart phones, and if the Web Server is referred to the hardware server (computer), I think it is an end-system.

1. **What is a client program? What is a server program? Which program typically requests and receives service from the other?**

Answer: The client program is the software in client machine which is used to request data from server and set communication with the server.

The server program is the software running in server machine which is used to response to every client’s request and set communication between client and server, sometimes server to server, based on some protocol.

The client requests and receives service from the server.

**Question 2**

**Suppose two hosts, *A* and *B*, are separated by 10,000 kilometers and are connected by a direct link of bandwidth *R* = 1 Mbps. Suppose the propagation speed over the link is 2.5\*108 meters/sec.**

1. **Calculate the “bandwidth-delay product” of the link, *R*\**t*prop.**

Answer: 

1. **Consider sending a file of 4\*105 bits from host A to host B. Suppose the file is sent continuously as one big message. What is the maximum number of bits that will be in the link at any given time?**

Answer: By the time the first bit arrive, there are 40Kbits already sent. In that case, during the delay time, the link holds 40Kbits data, so the maximum number of bits in the link is 40Kbits.

1. **Provide an interpretation of the bandwidth-delay product**

Answer: The maximum traffic (data) in a given network at any time.

**Question 3**

**Suppose there is exactly one switch between a sending host and a receiving host. The transmission rates between the sending host and the switch and between the switch and the receiving hosts are *R*1 and *R*2, respectively, and the propagation delays on each link are τ1 and τ2, respectively. Ignoring queueing and processing delays, what is the total end-to-end delay to send a packet of length *L* from the sending host to the receiving host?**

Answer: 

**Question 4**

**A communication link is divided into two channels, thus implementing a FDM scheme. According to this scheme, each channel serves a separate traffic stream where all packets have equal transmission time *T* and equal inter-arrival time *R*>*T*.**

**Consider, alternatively, statistical multiplexing of the two streams by combining the two channels into a single channel with transmission time *T*/2 for each packet. Show that**

1. **The average system time of a packet will be decreased from *T* to some value between *T*/2 and 3*T*/4.**

Answer:



Assume that packet arrives in uniform distribution. When, . When  grows larger, is smaller than  (more unlikely to wait)

So the average system time is between  and .

1. **The standard deviation of waiting time in the queue will be increased from 0 to as much as *T*/4.**

Answer: in the worst case, R=T



So 

So the standard deviation is between 0 and T/4;

1. **Based on the results of (a) and (b), discuss the pros and cons of statistical multiplexing versus FDM.**

Answer: In FDM network, a single packet can have fewer delay when sending, but sending relatively slower than statistical multiplexing.

In statistical Multiplexing network, a single packet could have more delay when waiting for sending, but the transmission delay is relatively smaller because it has larger bandwidth.

**Question 5**

**In IEEE 802.11 wireless networks, when the channel becomes idle, stations must wait a certain number of time units before transmitting. The purpose of this strategy is to avoid collisions, i.e., avoid that all the stations start transmitting at the same time.**

**Assume that an 802.11 network consists of four stations, and each station waits for an integer number of time units that is uniformly distributed between 1 and 32. What is the probability that exactly two stations choose to wait for the same amount of time (and therefore collide)?**

Answer:



**Question 6**

**One link in a network is failure-prone, but all the other links are stable. The network topology is sampled every second and, if the topology has changed, the routes are recalculated. Each second, the failure-prone link changes from up to down with probability *p* and from down to up with probability *q*. What is the rate at which the routes in the network are recalculated?**

Answer:

It is a two-state Markov chain. First we need to know the steady state of each state.



So the probability that the link stay up is , the link stay down is 

So  (turn/sec)

**Question 7**

**A circuit-multiplexed point-to-point link can accommodate one call at any time. The arrival times of calls *X* and *Y* are uniformly distributed in the time interval [0,5]. The holding time of call *X* is one unit, and that of *Y* is two units. An arriving call that finds a busy link is lost. Find the blocking probability of calls *X* and *Y*.**

Answer: Set call X arrive time as Tx, Y as Ty.

The area is shown in the shadow of the picture.

So the probability of blocking is:



  

