Computer Networks
Solved Problems on Delay
(Transmission, Propagation, Queuing and Processing delay)

1. Suppose that the packet length is 4000 bits, and that the link transmission rate along the link from the first router to the second is 10 MBps. What is the transmission delay?

   L = 4000 bits
   R = 10 MBps = 10 x 8 x 10^6 bps
   Transmission Delay = L/R = 4000 / (10 x 8 x 10^6)
   = 0.00005s = 50 microseconds

2. The one hop transmission delay for a packet through a twisted pair cable between points A and B is 0.2s. What happens to the transmission delay(increases, decreases, no change) if:
   - B is moved to a point C, 500 m further away from A.
     No change

   - The cable is changed to a coaxial cable
     Decreases.
     (In general, coaxial cables have 80x more transmission capacity than twisted-pair cables)
     ($d \propto 1/R$)

   - The bandwidth of the network is increased 5 fold.
     Decreases.
     ($d \propto 1/R$)

   - The data being transferred is clumped into larger packets.
     Increases.
     ($d \propto L$)

3. A cable is able to transfer 5 packets each of 500 bits length in 0.4 seconds into the link connecting one router to another. What is the transmission delay?

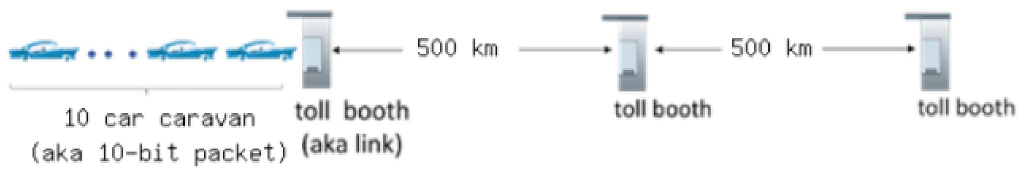
   Transmission Delay = L/R
   L = 5000 bits
   R = Bits transmitted per second
   = Total bits transmitted/ Total time taken
   = (5* 5000) / 0.4
   Transmission Delay = 500/ ((5*5000)/0.4) = 0.4/5 = 0.08s
   OR
   Transmission delay = time taken to put only one packet into the link

= 0.4 / 5 = 0.08s

4. There are two ways you can send a 10TB of data from Bengaluru to Chennai. You have a dedicated link for this very purpose transmitting at 100Mbps and a special courier option with delivery in one day. Which would you prefer to use?

   10 TB = $10 * 10^{12} * 8$ bits.
   Using the dedicated link, it will take $10 * 10^{12} * 8 / (100 * 10^{6})$ = 80000 seconds ~ 9 days. But with the special courier option, it would arrive in a single day. Hence the courier option would be preferred for speedy delivery.

5. Consider the figure below, which draws the analogy between store-and-forward link transmission and propagation of bits in packet along a link, and cars in a caravan being serviced at a toll booth and then driving along a road to the next toll booth.



   Suppose the caravan has 10 cars, and that the toll booth services a car (that is, transmits) at a rate of one car per 5 seconds. Once receiving service, a car proceeds to the next toll booth, which is 500 kilometers away at a rate of 20 kilometers per second. Also assume that whenever the first car of the caravan arrives at a toll booth, it must wait at the entrance to the toll booth until all of the other cars in its caravan have arrived, and lined up behind it before being serviced at the toll booth. (That is, the entire caravan must be stored at the toll booth before the first car in the caravan can pay its toll and begin driving towards the next toll booth).

   a. Once the first car leaves the toll booth, how long does it take until it arrives at the next toll booth?

      It takes 25 seconds to travel to the next toll booth (500 km / 20 km/s)

   b. Once the last car leaves the toll booth, how long does it take until it arrives at the next toll booth?

      Just like in the previous question, it takes 25 seconds, regardless of the car

   c. Once the first car leaves the toll booth, how long does it take until it enters service at the next toll booth?

It takes 70 seconds until the first car gets serviced at the next toll booth (10-1 cars * 5 seconds per car + 500 km / 20 km/s)

d. Are there ever two cars in service at the same time, one at the first toll booth and one at the second toll booth?

No, because cars can't get service at the next tollbooth until all cars have arrived

e. Are there ever zero cars in service at the same time, i.e., the caravan of cars has finished at the first toll booth but not yet arrived at the second toll booth?

Yes, one notable example is when the last car in the caravan is serviced but is still traveling to the next toll booth; all other cars have to wait until it arrives, thus no cars are being serviced.

6. An optical fiber cable is able to transfer packets across the network at a speed of 70% of the speed of light in 10 microseconds. What is the distance the packet traverses?

Speed of propagation = 70% of 3×10^8 m/s
= $0.7 \times 3 \times 10^8$
= 2.1×10^8 m/s
Propagation delay = d/s
Distance traversed = Propagation delay x speed of propagation
= $2.1 \times 10^8 \times 10 \times 10^{-6} = 2100$ m

7. The time taken by a packet to travel across a link is 1000 times the time taken for the packet to be inserted in the link. Assuming no queuing and processing delay, what is the transmission delay of the link if it connects an end to end distance of 2km in the network in a total of 3 microseconds ?

Speed of transmission s = 1000 x Transmission delay
Distance d = 2000 m

Assuming no queuing and processing delay,
End to end delay = Transmission delay + Propagation delay
$3 = d_{trans} + 2000 / (1000 \times d_{trans})$
$d_{trans}^2 - d_{trans} \times 3 + 2 = 0$

Solving the equation,
d_{trans} can be either 2 microseconds or 1 microsecond.

8. The propagation delay faced by Bob when he sends a packet to Alice is 0.05s. He thinks if he increases the bandwidth of his network, he'll be able to send the packet to her faster. Is he right?

   No. Propagation delay is independent of bandwidth. It only depends on distance d of the communicating peers and the speed of transmission s in the employed medium.

9. Queuing Delay is the only delay that does not vary. True or False?

   False. Queuing delay is the only delay that varies. The processing delay, transmission delay, and propagation delay are constant, if the route is fixed.

10. Bob can't reduce the distance between Alice and himself to help transmit packets faster. So he is looking into different cables to help him. His research helped him discover that twisted pair cables, coaxial cables and optical fiber cables allow packet propagation at speeds of 50%, 65% and 70% of the speed of light respectively. Which medium should he use to make Alice get his packets faster?

    Optical fiber cables, because ($d \propto 1$ / speed of transmission)

11. Charlie tries to load both Alice's and Bob's websites on his system. Alice's server is 14m away and Bob's server is 8m away from Charlie's PC. If Charlie is connected to Alice's server through unguided media and Bob's through twisted pair cable (assume speed of transmission at 50% of the speed of light), whose website will load first on Charlie's system?

    Comparing the propagation delays for both cases, d/s,
    Propagation delay for Alice's site = $14 / (3 \times 10^8)$
    Propagation delay for Bob's site = $8 / (0.5 \times 3 \times 10^8) = 16 / (3 \times 10^8)$

    Alice's site will load first as the propagation delay is lesser.

12. Suppose two hosts, A and B, are separated by 5000 kilometers and are connected by a direct link of R = 4 Mbps. Suppose the propagation speed over the link is $2 * 10^8$ m/s. What is the maximum number of bits that the link can contain at any point of time during propagation?

    d = 5000 x 1000 m
    $d_{prop} = d/s$
    Maximum number of bits during propagation = $R * d_{prop}$ = 4 Mbps * $(5000*1000 / (2*10^8))$
    = 0.1 Mb

    There can be a maximum of 10^5 bits at any point of time during propagation in the link.

13. A new transmission is going to happen between Alice and Bob for a message of 4 bytes. The link through which they are connected passes through a router and also can only allow a maximum of 100 bits to be transferred at a time. In that case, what is the queuing delay Bob would face due to the router when Alice sends him a message?

    The entire message can fit in 1 packet and since no other packet has to be transmitted, there is no need for a queue. Therefore, the queuing delay would be 0.

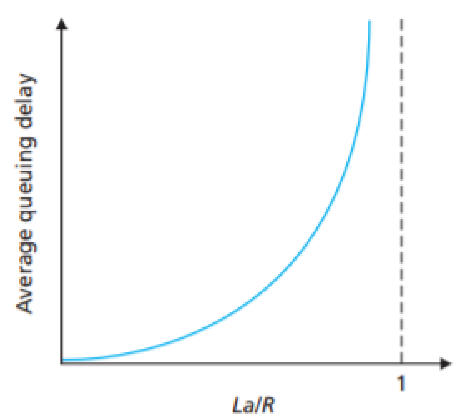
14. Regarding queuing delay,
    a. If one packet arrives every L/R seconds, then what is the queuing delay?

       0. There is no queue.

    b. If N packets arrive every N(L/R) seconds, then what is the average queuing delay of the packets?

       Then the first packet transmitted has no queuing delay; the second packet transmitted has a queuing delay of L/R seconds; and more generally, the Nth packet transmitted has a queuing delay of (N - 1)L/R seconds.
       So, the average is $= (0+L/R +2L/R+....+(N-1)L/R) / N$
       $= (N-1)L / 2R$

15. Consider the queuing delay in a router buffer, where the packet experiences a delay as it waits to be transmitted onto the link.
    Traffic intensity I = La/R, and the queuing delay is calculated as I(L/R)(1 - I) for I < 1 as shown in the below diagram.



    a. Assume a constant transmission rate of R = 1700000 bps, a constant packet-length L = 1000 bits, and a is the average rate of packets/second which is 31. What is the queuing delay? Give your answer in milliseconds (ms)

Traffic Intensity, I = La/R = 1000 x 31 / 1700000 = 0.0182 packets
Queuing delay = I(L/R)(1 - I) * 1000
= 0.0182*(1000/1700000)*(1-0.0182) * 1000
= 0.0105 ms.

b. Assuming the router's buffer is infinite, the queuing delay is 0.0204 ms, and 522 packets arrive. How many packets will be in the buffer 1 second later?

Packets leaving the buffer after 1 second = (1s /0.0204 x 10^{-3}s)
Packets left in buffer = arrived packets - packets gone
= 522 - floor(1/0.0204 x 10^{-3}) = 0 packets. (cannot be negative)

c. If the buffer has a maximum size of 500 packets, how many of the 522 packets would be dropped upon arrival from the previous question?

Packets dropped = packets - buffer size = 522 - 500 = 22 packets.

16. Data traveling in Alice's network of 2 computers, takes a one hop transmission delay of 0.003ms to go from one computer to the other. If the queuing delay is 1 microsecond and the distance between the two systems is 3km, find the time taken by Alice's router for bit level error checking and processing if the total nodal delay is 0.04ms.

$d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}$
$0.04 \times 10^{-3} = d_{proc} + 0.001 \times 10^{-3} + 0.003 \times 10^{-3} + 3000/(3 \times 10^8)$
Processing delay, $d_{proc} = (0.04 - 0.01 - 0.001 - 0.003) \times 10^{-3} = 0.026$ ms