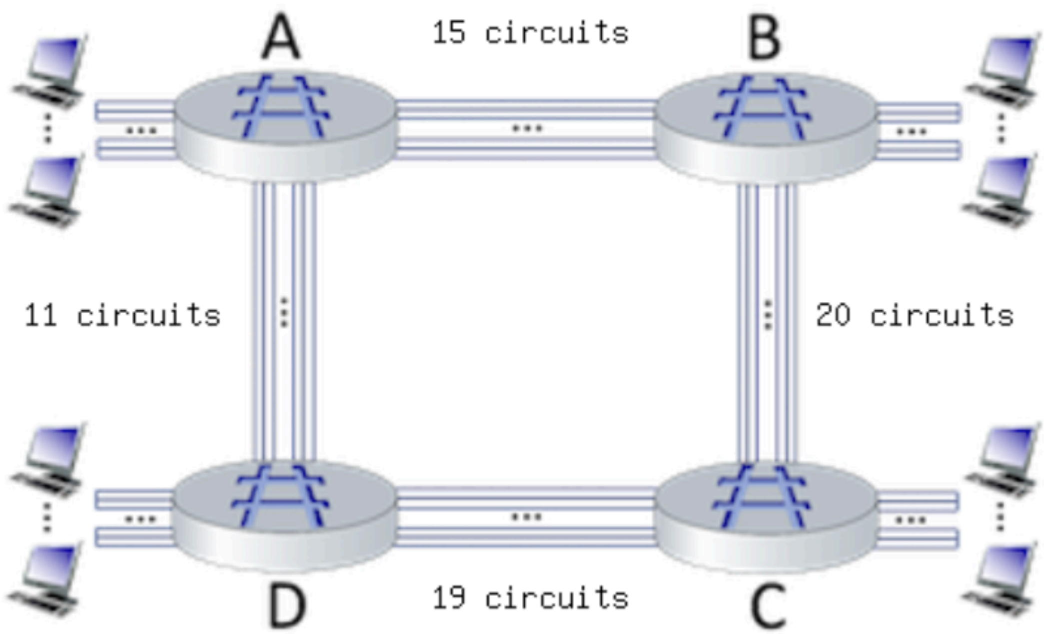
6)Consider the circuit-switched network shown in the figure below, with circuit switches A, B, C, and D. Suppose there are 15 circuits between A and B, 20 circuits between B and C, 19 circuits between C and D, and 11 circuits between D and A.



a)What is the maximum number of connections that can be ongoing in the network at any one time?

b)Suppose that these maximum number of connections are all ongoing. What happens when another call connection request arrives to the network, will it be accepted? Answer Yes or No.

c)Suppose that every connection requires 2 consecutive hops, and calls are connected clockwise. For example, a connection can go from A to C, from B to D, from C to A, and from D to B. With these constraints, what is the maximum number of connections that can be ongoing in the network at any one time?

d)Suppose that 17 connections are needed from A to C, and 12 connections are needed from B to D. Can we route these calls through the four links to accommodate all 29 connections? Answer Yes or No.

Solution hints:

1. The maximum number of connections that can be ongoing at any one time is the sum of all circuits, which happens when 15 connections go from A to B, 20 connections go from B to C, 19 connections go from C to D, and 11 connections go from D to A. This sum is 65.

2. No, it will be blocked because there are no free circuits.

3. There can be a maximum of 30 connections. Consider routes A->C and C->A, sum the bottleneck links, consider any leftover capacity that would allow for B->D and D->B connections, and compare that value to the equivalent of B->D and D->B.

4. Using our answer from question 4, the sum of our needed connections is 29, and we have 30 available connections, so it is possible.

7)A circuit-switching scenario in which Ncs users, each requiring a bandwidth of 20 Mbps, must share a link of capacity 150 Mbps.
A packet-switching scenario with Nps users sharing a 150 Mbps link, where each user again requires 20 Mbps when transmitting, but only needs to transmit 20 percent of the time.

a) When circuit switching is used, what is the maximum number of users that can be supported?

b) Suppose packet switching is used. If there are 13 packet-switching users, can this many users be supported under circuit-switching? Yes or No.

c) Suppose packet switching is used. What is the probability that a given (specific) user is transmitting, and the remaining users are not transmitting?(nps=13)

d) Suppose packet switching is used. What is the probability that one user (any one among the 13 users) is transmitting, and the remaining users are not transmitting?

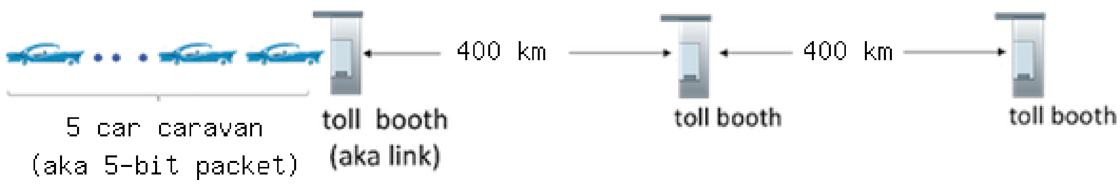
e) When one user is transmitting, what fraction of the link capacity will be used by this user? Write your answer as a decimal.

f) What is the probability that any 6 users (of the total 13 users) are transmitting and the remaining users are not transmitting?

g) What is the probability that more than 7 users are transmitting?

Solution hints:
a)150/20=7
b)No as 12*20=260>150
c)p*(1-p)^(Nps-1)=0.014
d)Nps * p * (1-p)^(Nps-1)=0.18
e)20/150=0.13
f)13c6*p^6*(1-p)^7=0.023
g)Σ i=8,13 choose(13, i) * pi(1-p)13 - i=0.0012

8)Consider the figure below, adapted from Figure 1.17 in the text, 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 tollbooth.



Suppose the caravan has 5 cars, and that the tollbooth services (that is, transmits) a car at a rate of one car per 1 seconds. Once receiving serving a car proceeds to the next tool both, which is 400 kilometers away at a rate of 20 kilometers per second. Also assume that whenever the first car of the caravan arrives at a tollbooth, it must wait at the entrance to the tollbooth 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 tollbooth before the first car in the caravan can pay its toll and begin driving towards the next tollbooth).

a) Once a car enters service at the tollbooth, how long does it take until it leaves service?

b) How long does it take for the entire caravan to receive service at the tollbooth (that is the time from when the first car enters service until the last car leaves the tollbooth)?

c) Once the first car leaves the tollbooth, how long does it take until it arrives at the next tollbooth?

d) Once the last car leaves the tollbooth, how long does it take until it arrives at the next tollbooth?

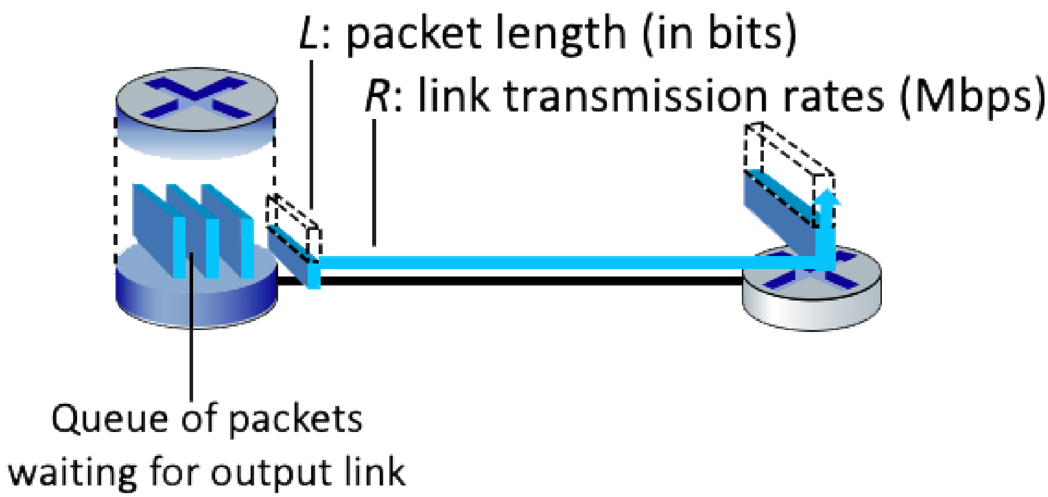
e) Once the first car leaves the tollbooth, how long does it take until it enters service at the next tollbooth?

f) Are there ever two cars in service at the same time, one at the first toll booth and one at the second toll booth? Answer Yes or No

g) Are there ever zero cars in service at the same time, i.e., the caravan of cars has finished at the first toll both but not yet arrived at the second tollbooth? Answer Yes or No

Solution hints:
a) Service time is 1 seconds
b) It takes 5 seconds to service every car, (5 cars * 1 seconds per car)
c) It takes 20 seconds to travel to the next toll booth (400 km / 20 km/s)
d) Just like in the previous question, it takes 20 seconds, regardless of the car
e) It takes 24 seconds until the first car gets serviced at the next toll booth (5-1 cars * 1 seconds per car + 400 km / 20 km/s)
f) No, because cars can't get service at the next tollbooth until all cars have arrived
g) Yes, one notable example is when the last car in the caravan is serviced but is still travelling to the next toll booth; all other cars have to wait until it arrives, thus no cars are being serviced

9)Consider the figure below, in which a single router is transmitting packets, each of length *L* bits, over a single link with transmission rate *R* Mbps to another router at the other end of the link.



Suppose that the packet length is *L*= 8000 bits, and that the link transmission rate along the link to router on the right is *R* = 1 Mbps.

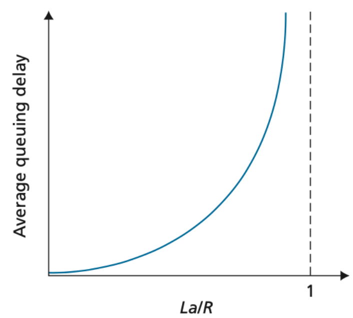
Round your answer to two decimals after leading zeros

a) What is the transmission delay?
b)What is the maximum number of packets per second that can be transmitted by this link?

Solution hints:
a)The transmission delay = L/R = 8000 bits / 1000000 bps = 0.008 seconds

b)The number of packets that can be transmitted in a second into the link = R / L = 1000000 bps / 8000 bits = 125 packets

10)Consider the queuing delay in a router buffer, where the packet experiences a delay as it waits to be transmitted onto the link. The length of the queuing delay of a specific packet will depend on the number of earlier-arriving packets that are queued and waiting for transmission onto the link. If the queue is empty and no other packet is currently being transmitted, then our packet's queuing delay will be zero. On the other hand, if the traffic is heavy and many other packets are also waiting to be transmitted, the queuing delay will be long.



Assume a constant transmission rate of R = 2000000 bps, a constant packet-length L = 1100 bits, and a is the average rate of packets/second. Traffic intensity I = La/R, and the queuing delay is calculated as I(L/R)(1 - I) for I < 1.

a) In practice, does the queuing delay tend to vary a lot? Answer with Yes or No

b) Assuming that a = 25, what is the queuing delay? Give your answer in milliseconds (ms)

c) Assuming that a = 59, what is the queuing delay? Give your answer in milliseconds (ms)

d) Assuming the router's buffer is infinite, the queuing delay is 0.0173 ms, and 1469 packets arrive. How many packets will be in the buffer 1 second later?

e) If the buffer has a maximum size of 877 packets, how many of the 1469 packets would be dropped upon arrival from the previous question?

Solution hints:

a) Yes, in practice, queuing delay can vary significantly. We use the above formulas as a way to give a rough estimate, but in a real-life scenario it is much more complicated.

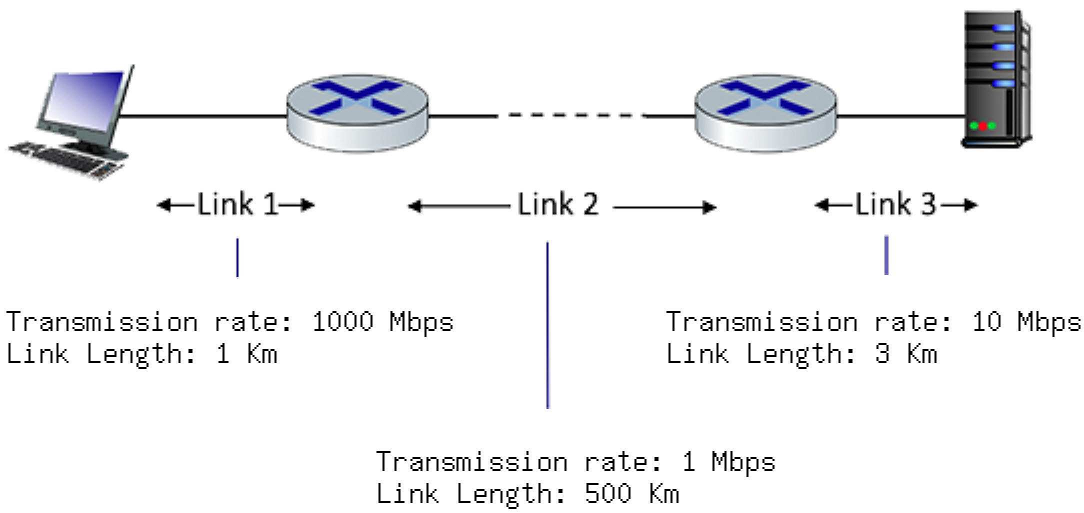
b) Queuing Delay = I(L/R)(1 - I) * 1000 = 0.0138*(1100/2000000)*(1-0.0138) * 1000 = 0.0075 ms.

c) Queuing Delay = I(L/R)(1 - I) * 1000 = 0.0325*(1100/2000000)*(1-0.0325) * 1000 = 0.0173 ms.

d) Packets left in buffer = a - floor(1000/delay) = 1469 - floor(1000/0.0173) = 0 packets.

e) Packets dropped = packets - buffer size = 1469 - 877 = 592 dropped packets.

11)Consider the figure below, with three links, each with the specified transmission rate and link length.



Assume the length of a packet is 12000 bits. The speed of light propagation delay on each link is 3x10^8 m/sec

Round your answer to two decimals after leading zeros

a) What is the transmission delay of link 1?
b) What is the propagation delay of link 1?
c) What is the total delay of link 1?
d) What is the transmission delay of link 2?
e) What is the propagation delay of link 2?
f) What is the total delay of link 2?
g) What is the transmission delay of link 3?
h) What is the propagation delay of link 3?
i) What is the total delay of link 3?
j) What is the total delay?

Solution hints:
Link 1 transmission delay = L/R = 12000 bits / 1000 Mbps = 1.20*10^-5 seconds

Link 1 propagation delay = d/s = (1 Km) * 1000 / 3*10^8 m/sec = 3.33*10^-6 seconds

Link 1 total delay = d_t + d_p = 1.20*10^-5 seconds + 3.33*10^-6 seconds = 1.53*10^-5 seconds

Link 2 transmission delay = L/R = 12000 bits / 1 Mbps = 0.012 seconds

Link 2 propagation delay = d/s = (500 Km) * 1000 / 3*10^8 m/sec = 0.0017 seconds

Link 2 total delay = d_t + d_p = 0.012 seconds + 0.0017 seconds = 0.014 seconds

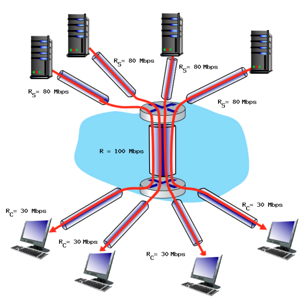
Link 3 transmission delay = L/R = 12000 bits / 10 Mbps = 0.0012 seconds

Link 3 propagation delay = d/s = (3 Km) * 1000 / 3*10^8 m/sec = 1.00*10^-5 seconds

Link 3 total delay = d_t + d_p = 0.0012 seconds + 1.00*10^-5 seconds = 0.0012 seconds

The total delay = d_L1 + d_L2 + d_L3 = 1.53*10^-5 seconds + 0.014 seconds + 0.0012 seconds = 0.015 seconds

12)Consider the scenario shown below, with four different servers connected to four different clients over four three-hop paths. The four pairs share a common middle hop with a transmission capacity of R = 100 Mbps. The four links from the servers to the shared link have a transmission capacity of R_S = 80 Mbps. Each of the four links from the shared middle link to a client has a transmission capacity of R_C = 30 Mbps.



a)What is the maximum achievable end-end throughput (in Mbps) for each of four client-to-server pairs, assuming that the middle link is fairly shared (divides its transmission rate equally)?
b) Which link is the bottleneck link? Format as Rc, Rs, or R
c)Assuming that the servers are sending at the maximum rate possible, what are the link utilizations for the server links (RS)? Answer as a decimal
d) Assuming that the servers are sending at the maximum rate possible, what are the link utilizations for the client links (RC)? Answer as a decimal
e) Assuming that the servers are sending at the maximum rate possible, what is the link utilizations for the shared link (R)? Answer as a decimal

Solution hints:

a) The maximum achievable end-end throughput is the capacity of the link with the minimum capacity, which is 25 Mbps

b) The bottleneck link is the link with the smallest capacity between RS, RC, and R/4. The bottleneck link is R.

c)The server's utilization = Rbottleneck / RS = 25 / 80 = 0.31

d) The client's utilization = Rbottleneck / RC = 25 / 30 = 0.83

e) The shared link's utilization = Rbottleneck / (R / 4) = 25 / (100 / 4) = 1