CS408 – Computer Networks – Fall 2024 - HW 1 – Due October 21, 2024, 14:30

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- **Please submit manually (hardcopy printed on paper) by the end of the class.**
- **You have to type your answers over computer and then take a printout. No handwritten submissions please. And please do not ask if you can submit handwritten homework since if I could say "yes" to that question, I would not write all of these stuff.**
- **No late submissions**
- **Everyone must submit his/her own work! Plagiarized homework will be graded as minus 100 and will be reported to the Dean's office for disciplinary actions according to university regulations.**
- **If you find solution manual or key or an online tool for any of these questions from somewhere, you are not allowed to use them. Using such material will be considered as plagiarism.**
- **BE AWARE OF ALL TYPE OF UNIT CONVERSIONS. BE CAREFUL ABOUT THE ARITHMETIC. NO PARTIAL GRADES!!!!!!**

1) (40 points) Consider a packet switched network for the communication of two end points *A* and *B*. There are two switching nodes, *X* and *Y*, between *A* and *B*. The capacity of the link between *A* and *X* is 10 Mbps (10,000,000 bps). The capacity of the link between *X* and *Y* is 5 Mbps (5,000,000 bps). The capacity of the link between *Y* and *B* is 2 Mbps (2,000,000 bps).

A wants to send a file of 50 Kbytes (50,000 bytes) to *B* using this packet switching network. One packet has 5000 bytes of data and 100 bytes of header. After receiving the entire file, *B* sends an acknowledgment back to *A* through the same network. The recipient *B* imposes 0.001 sec processing delay before sending the acknowledgment after receiving the last packet (no other processing delays in the network). Assume there is no transmission time for the acknowledgment.

The network is not used for another communication until acknowledgment is received.

The distance between *A* and *X* is 60 km: The distance between *X* and *Y* is 60 km. Finally, the distance between *Y* and *B* is 30 km. The speed of signal is 300,000 km/s.

a) What is the round-trip time for sending the file and receiving its acknowledgment in the abovementioned scenario? Show your work.

Hint: draw the packets as we did in class to understand the scenario.

Solution 1-a)

Link A to X: 10 Mbps = 10,000,000 bps (bits per second)

Link X to Y: 5 Mbps = 5,000,000 bps

Link Y to B: 2 Mbps = 2,000,000 bps

File size: 50,000 bytes = 50,000 × 8 = 400,000 bits

Packet size: 5000 bytes (data) + 100 bytes (header) = 5100 bytes = 5100 × 8 = 40,800 bits per packet

Transmission Delays:

- Note from the lecture slides: Transmission delay is the amount of time needed to put **all the bits of packet** into the communication.

Transmission time A to X:

Transmission time = Packet size / Link capacity = 40,800 bits / 10,000,000 bps = 0.00408 seconds

Transmission time X to Y:

Transmission time = Packet size / Link capacity = 40,800 bits / 5,000,000 bps = 0.00816 seconds

Transmission time Y to B:

Transmission time = Packet size / Link capacity = 40,800 bits / 2,000,000 bps = 0.0204 seconds

Propagation Delays:

- Note from the lecture slides: Propagation delay is the time it takes **a bit** to propagate from one router to the next.

Signal speed = 300,000 km/s.

Propagation delay A to X:

Propagation delay = Distance / Speed of light = 60 km / 300,000 km/s = 0.0002 seconds

Propagation delay X to Y:

Propagation delay = Distance / Speed of light = 60 km / 300,000 km/s = 0.0002 seconds

Propagation delay Y to B:

Propagation delay = Distance / Speed of light = 30 km / 300,000 km/s = 0.0001 seconds

Total Transmission and Propagation Times:

There are 10 packets to send (50,000 bytes / 5100 bytes per packet = 9.8 packets).

- Note: Since the number of packets comes out to 9.8, this means that 9 full packets can each carry 5100 bytes. However, the remaining portion (the last 0.8) still needs to be sent, which would require a 10th packet.

Transmission time per packet: 0.00408 + 0.00816 + 0.0204=0.03264 seconds.

Total transmission time: 0.03264 × 10 = 0.3264 seconds.

Total propagation delay: 0.0002 + 0.0002 + 0.0001 = 0.0005 seconds. (We do not have to multiply by 10.)

Round-Trip Time (RTT):

Forward time: 0.3264 + 0.0005 = 0.3269 seconds.

Return time: The same path is used for the acknowledgment.

Processing delay at B: 0.001 seconds.

Total RTT is: 0.3269 + 0.001(Processing delay) + 0.0005(Propagation delay to go back to A) = 0,3284 seconds.

b) What is the throughput of this system? Show your work.

Notice: be aware of bit and byte conversion.

Solution 1- b)

- Note: Throughput is the total data sent divided by the total time.

File size: 50,000 bytes = 400,000 bits.

Total round-trip time (RTT): 0,3284 seconds.

Throughput = 400,000 bits / 0,3284 seconds = 1 218,02679659 bps.

2) (30 points) In a production line, three robots work with the following job descriptions and performance figures. *RobotA* carries the items to *RobotB* for inspection. After *RobotB* finishes the inspection, it puts the item on a conveyor band. At the end of the band, *RobotC* gets the item and pack it. The rate of *RobotA* to carry the items is 3 items/min. *RobotB* spends 15 seconds for the inspection of an item and another 10 seconds to put the item on the band. The travel time for an item on the conveyor band is 150 seconds. Finally, *RobotC* packs one item in 15 seconds. Assume there is enough storage area for all of the robots if the items need to wait.

What is the total production time for 10 items? Explain your answer.

Solution 2)

Robot A: Carries items at 3 items/min = 1 item every **20 seconds**.

Robot B: Inspects each item for 15 seconds. Places the inspected item on the conveyor for **10 seconds**. Total time per item for Robot B = 15 + 10 = 25 seconds.

Conveyor: Takes 150 seconds for each item to reach Robot C.

Robot C: Packs each item in 15 seconds.

From these numbers, we can see that RobotB is the slowest, taking 25 seconds to process each item. Even though RobotA can deliver items every 20 seconds, it will have to wait for RobotB to finish inspecting and placing the item on the conveyor. Similarly, RobotC can pack items faster, but it will also have to wait for RobotB to place the next item on the conveyor.

So, RobotB is the **bottleneck** of the system, which means it controls the overall speed of the production line.

Since RobotB is the bottleneck, we know it controls the rate of production. For every item, RobotB will take 25 seconds to inspect and place it on the conveyor. So, the rate of the production line is one item every 25 seconds.

RobotA starts the process by delivering the first item to RobotB after 20 seconds.

RobotB inspects the first item and places it on the conveyor band in 25 seconds, so the first item reaches the conveyor after 20 + 25 = 45 seconds.

The second item will be delivered by RobotA in another 20 seconds, but RobotB can only start working on it once it finishes the first item. So RobotB will complete the second item 25 seconds after the first, and so on for the rest of the items.

RobotB will take: 10 × 25 = 250 seconds.

After each item is inspected, it takes an additional 150 seconds for it to travel to **RobotC** on the conveyor. Therefore, even though **RobotB** finishes all 10 items in 250 seconds, the last item will still be traveling on the conveyor.

The first item will reach **RobotC** after 45 (Robot A (20 second) and Robot B's first completion) + 150 (conveyor time) = 195 seconds.

After RobotB finishes processing the first item, it begins working on the second item. Since RobotB takes 25 seconds to process each item, the second item will be finished and placed on the conveyor 25 seconds after the first item was placed on the conveyor. So, the second item is placed on the conveyor at:

45 seconds + 25 seconds = 70 seconds.

The second item will also spend 150 seconds on the conveyor, so it will reach RobotC at:

70 seconds+150 seconds=220 seconds.
Each additional item will be placed on the conveyor 25 seconds after the previous one because RobotB processes each item in 25 seconds. So the time each item reaches RobotC is:

First item reaches RobotC at 195 seconds.

Second item reaches RobotC at 220 seconds.

Third item reaches RobotC at 245 seconds.

Fourth item reaches RobotC at 270 seconds, and so on…….

RobotB will process the 10th item in exactly 25 seconds after the 9th item. Since the 9th item is placed on the conveyor at 225 seconds + 25 = 250 seconds, the 10th item will be placed on the conveyor at 250 seconds.

The 10th item will also spend 150 seconds on the conveyor, so it will reach RobotC at: 250 + 150 seconds = 400 seconds.

Thus, RobotC will begin packing the 10th item at 400 seconds. Since RobotC takes 15 seconds to pack each item, the final packing will finish at:

400 seconds + 15 seconds = 415 seconds.

This is the total time required to complete the entire process for all 10 items.

3) (30 points) Consider a direct link with capacity 25 Kbps (25000 bits per second) between two end points *A* and *B*. The link layer protocol between *A* and *B* is that *A* sends two packets consecutively. Then *A* waits for an acknowledgment from *B* in order to send the next two packets. There is no processing delay at *B* to send an acknowledgement after receiving the second packet. The length of one packet is 4750 bits of data and 250 bits of header. The length of the acknowledgment packet is 50 bits with no extra header. The length of this link is 10 km, and the speed of signal is 200,000 km/s.

What is the utilization of this link at the steady state?

Show your work.

Solution 3)

Link capacity: 25 Kbps = 25,000 bps

Packet size: 4750 bits (data) + 250 bits (header) = 5000 bits per packet

Number of packets sent before waiting for acknowledgment: 2

Acknowledgment packet size: 50 bits

Link distance: 10 km

Signal propagation speed: 200,000 km/s

Transmission Time for 1 packet = Packet size / Link capacity: 5000 bits / 25,000 bps = 0.2 seconds.

Transmission Time for 2 packets= 2 × 0.2 seconds=0.4 seconds.

Propagation delay = Distance / Propagation Speed = 10 km / 200,000 km/s = 0.00005 seconds.

Round-trip Propagation Delay = 2 × 0.00005 seconds = 0.0001 seconds.

The time to transmit the acknowledgment = 50 bits / 25,000 bps = 0.002 seconds.

The total cycle time:

Sending two packets (total transmission time: 0.4 seconds).

The round-trip propagation delay (0.0001 seconds).

The transmission time for the acknowledgment (0.002 seconds).

The total: 0.4 + 0.0001 + 0.002 = 0,4021 seconds.

Utilization is the fraction of time spent transmitting data relative to the total time of the cycle. In this case, the time spent transmitting actual data is the transmission time for the two packets (0.4 seconds). The total time for the cycle is 0.4021 seconds.

Utilization = 0.4 / 0.4021 = 0,99477741855.

The utilization of the link at the steady state is approximately 99.5%.

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