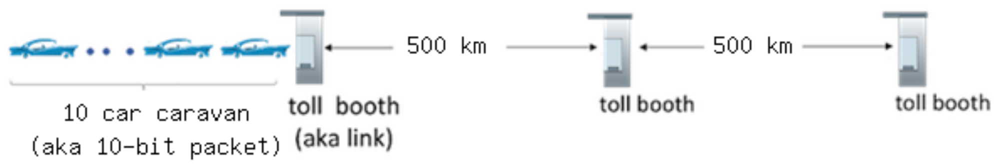
Homework1

CS 664-Computer Networks

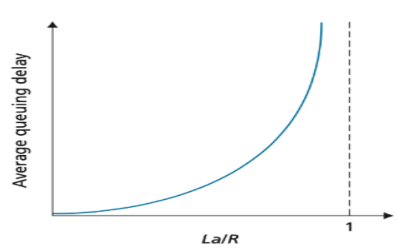
1. Consider the figure below, adapted from Figure 1.17 in the text, which draws the analogy between store-and-forward link transmission and propagation of bits in packet along a link, and cars in a caravan being serviced at a toll booth and then driving along a road to the next tollbooth.



Suppose the caravan has 10 cars, and that the tollbooth services (that is, transmits) a car at a rate of one car per 1 second. Once receiving serving a car proceeds to the next tool both, 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 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). 30 points

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 booth but not yet arrived at the second tollbooth? Answer Yes or No

2. 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 = 1300000 bps, a constant packet-length L = 4800 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. 30 points

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

b. Assuming that a = 29, what is the queuing delay? Give your answer in milliseconds (ms)

c. Assuming that a = 60, what is the queuing delay? Give your answer in milliseconds (ms)

d. Assuming the router's buffer is infinite, the queuing delay is 0.6367 ms, and 924 packets arrive. How many packets will be in the buffer 1 second later?

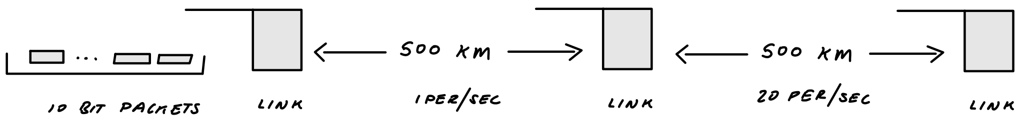
e. If the buffer has a maximum size of 744 packets, how many of the 924 packets would be dropped upon arrival from the previous question?

3. Consider sending a packet from a source host to a destination host over a fixed route. List the delay components in the end-to-end delay. Which of these delays are constant and which are variable?

20 points

4. What are the five layers in the Internet protocol stack? What are the principal responsibilities of each of these layers? 20 points

1. CONSIDER THE FIGURE BELOW WHICH DRAWS AN ANALOGY ON STORE & FORWARD LINK TRANSMISSION & PROPAGATION OF BITS IN A PACKET ALONG A LINK, & CARS IN A CARAVAN BEING SERVICED AT A TOLL BOOTH & THEN DRIVING ALONG A ROAD TO THE NEXT TOLLBOOTH



SUPPOSE THE CARAVAN HAS 10 CARS, & THAT THE TOLLBOOTH TRANSMITS A CAR AT 1 CAR PER SECOND.
ONE RECEIVING SERVING A CAR PROCEEDS TO THE NEXT TOLL BOOTH, WHICH IS 500 KILOMETERS AWAY AT A RATE OF 20 KILOMETERS PER SECOND.
THE ENTIRE CARAVAN MUST BE STORED AT A TOLL BOOTH BEFORE THE FIRST CAR CAN BEGIN TO THE NEXT.

a. ONCE A CAR ENTERS SERVICE AT A TOLL BOOTH, HOW LONG DOES IT TAKE UNTIL IT LEAVES SERVICE?

IT TAKES EXACTLY 1 SECOND FOR A CAR TO BE SERVICED

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.

TOTAL SERVICING TIME 10 CARS * 1 SEC = 10 SECONDS

9 SEC (TIME FOR LAST CAR TO ARRIVE) + 10 SEC (TIME FOR ALL CARS) = 19 SECONDS

TOTAL SERVICING TIME = 19 SECONDS

c. ONCE THE FIRST CAR LEAVES THE TOLL BOOTH, HOW LONG DOES IT TAKE UNTIL IT ARRIVES AT THE NEXT TOLL?

DISTANCE OF TOLLBOOTH : 500 KM

SPEED OF CARS : 20 KM/S

TRAVEL TIME : 500 KM / 20 KM/S = 25 KM/S

D. ONCE THE LAST CAR LEAVES THE TOLLBOOTH, HOW LONG DOES IT TAKE UNTIL IT ENTERS SERVICE AT THE NEXT TOLL?

TRAVEL TIME : 500 KM / 20 KM/S = 25 KM/S

E. ONCE THE FIRST CAR LEAVES THE TOLL BOOTH, HOW LONG DOES IT TAKE UNTIL IT ARRIVES AT THE NEXT TOLL?

TRAVEL TIME : 500 KM / 20 KM/S = 25 KM/S

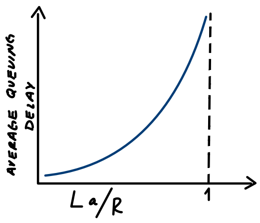
F. ARE THERE EVER TWO CARS SERVICED AT THE SAME TIME, ONE AT THE FIRST TOLL BOOTH, & ONE AT THE SECOND TOLL BOOTH? YES OR NO

NO, THERE ARE NO SITUATIONS WHERE TWO CARS ARE IN SERVICE AT DIFFERENT TOLL BOOTHS SIMULTANEOUSLY

G. ARE THERE EVER ZERO CARS IN SERVICE AT THE SAME TIME, ONE AT THE FIRST TOLL BOOTH, AND ONE AT THE SECOND TOLL BOOTH? ANSWER YES OR NO.

YES

2. 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 EARLY ARRIVING PACKETS THAT ARE QUEUED & WAITING FOR TRANSMISSION ONTO THE LINK. IF THE QUEUE IS EMPTY & NO OTHER PACKET IS CURRENTLY BEING TRANSMITTED, THEN OUR PACKETS QUEUING DELAY WILL BE ZERO. ON THE OTHER HAND, IF THE TRAFFIC IS HEAVY & MANY OTHER PACKETS ARE ALSO WAITING TO BE TRANSMITTED, THE QUEUING DELAY WILL BE LONG.



CONSTANT TRANSMISSION RATE $R = 1300000$ bps

CONSTANT PACKET LENGTH $L = 4800$ bits

AVERAGE RATE PACKETS/SECOND a PACKETS/SECOND

TRAFFIC INTENSITY $I = La/R$

QUEUING DELAY $Q = I(L/R)(1-I)$ FOR $I < 1$

A. IN PRACTICE, DOES THE QUEUING DELAY TEND TO VARY A LOT? ANSWER YES OR NO

B. ASSUMING THAT $a = 29$, WHAT IS THE QUEUING DELAY? GIVE YOUR ANSWER IN MILLISECONDS.

FIRST WE MUST COMPUTE TRAFFIC INTENSITY $I = La/R$

$I = 4800(29)/1300000$

$I = 139,200/1,300,000$

$I = 1,392/13,000$

$I = 0.1070769...$

$I < 1$; $0.107 < 1$

NOW WE CAN COMPUTE THE QUEUING DELAY $Q = I(L/R)(1-I)$

$Q = 0.107(L/R)(1-0.107)$

$Q = 0.107(4800/1,300,000)(1-0.107)$

$Q = 0.107(6/1625)(0.893)$

$Q = 0.107(0.003692)(0.893)$

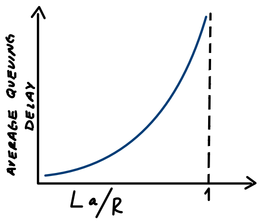
$Q = 0.0003542$

CONVERT SECONDS TO MILLISECONDS

0.0003542 SECONDS · 1000 MILLISECONDS = 0.3542

$\boxed{Q = 0.3542 \text{ MILLISECONDS}}$

2. 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 EARLY ARRIVING PACKETS THAT ARE QUEUED & WAITING FOR TRANSMISSION ONTO THE LINK. IF THE QUEUE IS EMPTY & NO OTHER PACKET IS CURRENTLY BEING TRANSMITTED, THEN OUR PACKETS QUEUING DELAY WILL BE ZERO. ON THE OTHER HAND, IF THE TRAFFIC IS HEAVY & MANY OTHER PACKETS ARE ALSO WAITING TO BE TRANSMITTED, THE QUEUING DELAY WILL BE LONG.



CONSTANT TRANSMISSION RATE	$R = 1300000$ bps
CONSTANT PACKET LENGTH	$L = 4800$ bits
AVERAGE RATE PACKETS/SECOND	a packets/second
TRAFFIC INTENSITY	$I = La/R$
QUEUING DELAY	$Q = I(L/R)(1-I)$ FOR $I < 1$

C. ASSUMING THAT $a=60$, WHAT IS THE QUEUING DELAY? GIVE YOUR ANSWER IN MILLISECONDS.

FIRST WE MUST COMPUTE TRAFFIC INTENSITY $I = La/R$

$I = 4800(60s)/1300000$

$I = 288,000/1,300,000$

$I = 0.2215$

$I < 1$; $I < 0.2215$

NOW WE CAN COMPUTE THE QUEUING DELAY $Q = I(L/R)(1-I)$

$Q = 0.2215(L/R)(1 - 0.2215)$

$Q = 0.2215(4800/1,300,000)(1 - 0.2215)$

$Q = 0.2215(0.003692)(0.7785)$

$Q = 0.0006376$

CONVERT SECONDS TO MILLISECONDS

0.0006376 SECONDS $\cdot$ 1000 MILLISECONDS $= 0.6376$

$\boxed{Q = 0.6376 \text{ MILLISECONDS}}$

D. ASSUMING THE ROUTER BUFFER IS INFINITE, THE QUEUING DELAY IS 0.6367 MS, & 924 PACKETS ARRIVE HOW MANY PACKETS WILL BE IN THE BUFFER 1 SECOND LATER?

GIVEN VARIABLES

$Q = 0.6376$ ms

$a = 60$ PACKETS PER 1 SECOND

$R = 1300000$

$L = 4800$

PACKETS PER SECOND $= R/L = 1300000/4800 \approx 270.83$ PACKETS/SECOND

924 PACKETS IN A BUFFER

AFTER 1 SECOND 60 PACKETS ARRIVE

270.83 PACKETS ARE BEING TRANSMITTED

$924 + 60 - 270.83 \approx$ $\boxed{731.1 \text{ PACKETS IN BUFFER AFTER 1 SECOND}}$

E. IF THE BUFFER HAS A MAXIMUM SIZE OF 744 PACKETS, HOW MANY OF THE 924 PACKETS WOULD BE DROPPED UPON ARRIVAL FROM THE PREVIOUS QUESTION?

BUFFER CAPACITY = 744 PACKETS

PACKETS ARRIVING = 924 PACKETS

$\boxed{\text{PACKETS DROPPED} = 924 - 744 = 180 \text{ PACKETS}}$

CS 664 COMPUTER NETWORKS

HOMEWORK 01

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3. CONSIDER SENDING A PACKET FROM A SOURCE HOST TO A DESTINATION HOST OVER A FIXED ROUTE. LIST THE DELAY COMPONENTS IN THE END TO END DELAY.
WHICH OF THE DELAYS ARE CONSTANT & WHICH ARE VARIABLE?

1. PROCESSING DELAYS – d_{PROC} DEPENDS ON MAXIMUM RATE A ROUTER CAN FORWARD PACKETS
2. TRANSMISSION DELAYS – $d_{TRANS} = L/R$, L = PACKET LENGTH (BITS), R = LINK TRANSMISSION RATE (BPS)
3. PROPAGATION DELAYS – $d_{PROP} = d/s$, d = LENGTH OF PHYSICAL LINK, S = PROPAGATION SPEED ($\sim 2 \times 10^8$ m/sec)
4. QUEUING DELAYS – DEPENDS ON CONGESTION LEVEL

$\boxed{\text{1. PROCESSING DELAYS – FIXED; 2. TRANSMISSION DELAYS – FIXED; 3. PROPAGATION DELAYS – FIXED; 4. QUEUING DELAYS – VARIABLE}}$

4. WHAT ARE THE FIVE LAYERS IN THE INTERNET PROTOCOL STACK?
WHAT ARE THE PRINCIPLE RESPONSIBILITIES OF EACH OF THESE LAYERS?

1. APPLICATION LAYER SUPPORTS NETWORK APPLICATIONS SUCH AS HTTP, IMAP, SMTP, DNS. THIS LAYER EXCHANGES MESSAGES TO IMPLEMENT SOME APPLICATION SERVICE USING SERVICES OF THE TRANSPORT LAYER.

2. TRANSPORT LAYER PROCESSES THE DATA TRANSFER USING TCP, UDP. IT'S A PROTOCOL THAT TRANSFERS M FROM PROCESS TO ANOTHER RELIABLY, USING THE SERVICES OF THE NETWORK LAYER.
THE TRANSPORT LAYER PROTOCOL ENCAPSULATES APPLICATION LAYE

3. NETWORK LAYER IS IN CHARGE OF ROUTING DIAGRAMS FROM SOURCE TO DESTINATION USING IP & ROUTING PROTOCOLS.
NETWORK LAYER PROTOCOL TRANSFERS TRANSPORT – LAYEY SEGMENTS $[H_t \mid M]$ FROM ONE HOST TO ANOTHER, USING LINK LAYER SERVICES. THE NETWORK-LAYER PROTOCOL ENCAPSULATES TRANSPORT – LAYER SEGMENT $[H_t \mid M]$ WITH NETWORK LAYER HEADER H_N TO CREATE A NETWORK LAYER DATAGRAM. H_N USED BY NETWORK LAYER PROTOCOL TO IMPLEMENT ITS SERVICE.

4. LINK LAYER USES DATA TRANSFER BETWEEN NEIGHBORING NETWORK ELEMENTS. ETHERNET, 802.11 (WIFI), PPP. THE LINK LAYER PROTOCOL TRANSFERS DATAGRAM $[H_N \mid [H_t \mid M]$ FROM HOST TO NEIGHBORING HOST, USING NETWORK – LAYER SERVICES
THE LINK LAYER PROTOCOL ENCAPSULATES NETWORK DATAGRAM $[H_N \mid [H_t \mid M]$, WITH LINK – LAYER HEADER H_l TO CREATE A LINK – LAYER FRAME.

5. PHYSICAL LAYER TRANSFERS BITS "ON THE WIRE"