COMP3234B Computer and Communication Networks

Assignment 2 (8%)

Due by: 23:59 Wednesday March 20, 2024

Total mark is 100.

1. (20 marks) [Store-and-Forward in Packet-Switched Networks (Learning Outcome 3)]
Host A wants to send a file of 15 Mbytes to Host B as shown in the figure below, where the routers use store-and-forward packet switching. The transmission rates of the three links on the path from Host A to Host B are R1=600 Kbps, R2=1.5Mbps, and R3=1.2 Mbps, respectively. The propagation delays along the three links are 2ms, 4ms, 3ms, respectively. Ignore queuing delay and nodal processing delay. There is no packet loss nor error. Use 1K=1000 convention in the calculation.

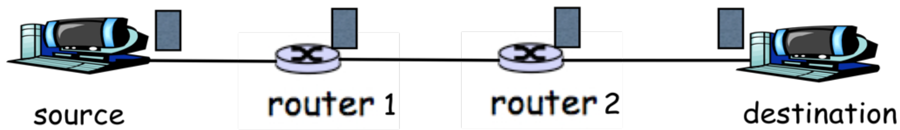


Figure 1

(1) If the file is sent as one large packet, how long does it take to move the file from the source host to the destination host?
(2) The source host segments the file into 10 packets. Suppose each packet sent by the source host is acknowledged by the destination host and the transmission time of an acknowledgement packet is negligible. Assume the sender cannot send a packet until the preceding one is acknowledged (i.e., it runs a stop-and-wait protocol). How long does it take to move the entire file from the source host to the destination host? (From the time the source starts to send the first packet to the time when the sender receives the acknowledge of the last packet in the file).
(3) The source host segments the file into 10 packets and sends packets s=1, 2, …, 10 sequentially. Suppose the source host starts to send packet s+1 when router 1 starts to forward packet s to router 2. We do not consider acknowledgements in this question. How long does it take for the entire file to reach the destination?

2. (10 marks) [DNS, Web application (Learning Outcomes 2, 3)]
Suppose a client clicks a link within her web browser to obtain a web page located at http://www.cs.hku.hk/index.html. The IP address of the local DNS server is configured within the client. Suppose it is the very first time for the client and any other clients using this local DNS server to access www.cs.hku.hk; initially only the authoritative DNS server knows the IP address of the web server hosting the web page, and no name-address mapping has been cached on other servers. After the client or a DNS server learns any name-address mapping,

it caches the mapping for one hour. In Figure 2, the number on a dotted line denotes the time taken for one-way message passing between the two hosts/servers connected by the line. For example, “2” on the line connecting the client and the local DNS server indicates that it takes 2 time units for the client to send a request to the local DNS server and it also takes 2 time units for the local DNS server to send a response to the client. Suppose non-recursive DNS query is used; the HTTP protocol in use is HTTP 1.1; the client finds out the IP address of the web server before sending out respective HTTP requests. We only consider such message passing delays but not any other delays in the network.

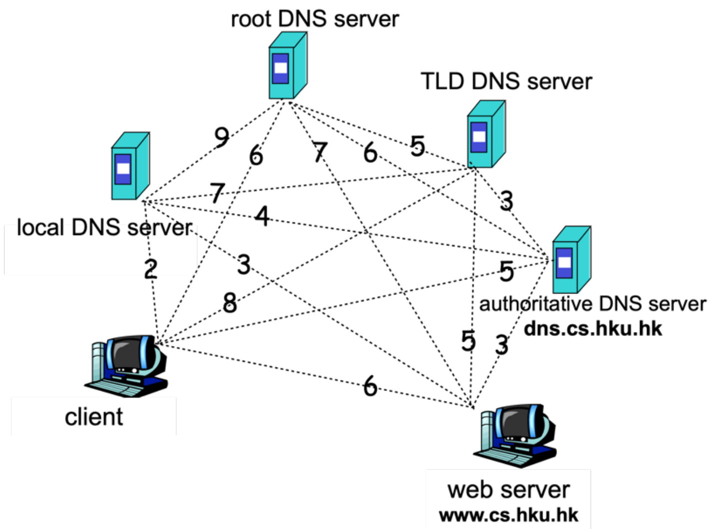


Figure 2

(1) Describe the steps incurred from when the client clicks on the link until the client receives the web page index.html, and compute in total how much time elapses (i.e., total time to complete all those steps).

(2) Suppose the client subsequently clicks a link in the received index.html (within 1 minute after receiving index.html), which links to http://www.cs.hku.hk/images/logo.jpg. Describe the steps incurred from when the client clicks this link until the client receives the image logo.jpg, and compute the total elapsed time for completing these steps.

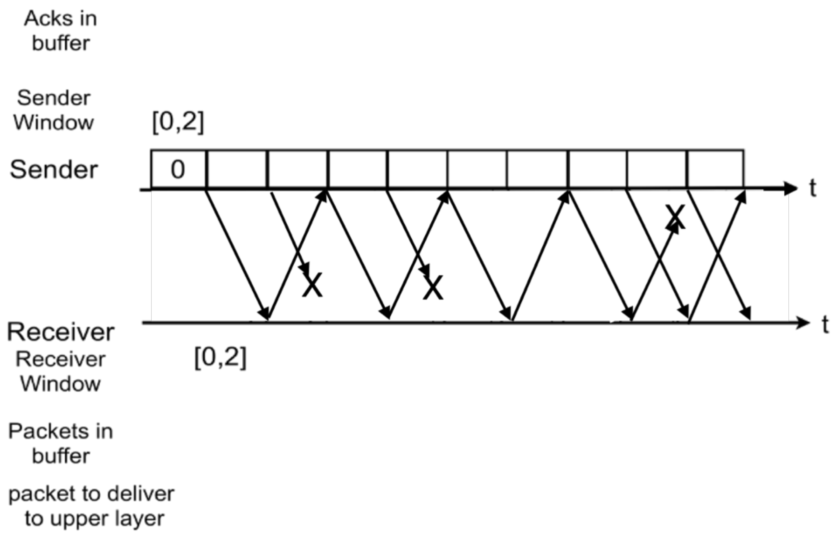
3. (15 marks) [Stop-and-Wait RDT (Learning Outcomes 2, 3)]

Consider the sender FSM and receiver FSM of RDT 3.0. Design an NAK-only protocol that implements the same functionality as implemented by RDT 3.0, by plotting the sender and receiver FSMs. Define variables and functions not included in the FSMs of RDT 3.0.

4. (15 marks) [Selective Repeat RDT (Learning Outcome 3)]

Suppose A and B implement Selective Repeat, with packet/ACK transmissions shown in the figure below. An arrow represents a potential transmission. The cross over a line indicates the loss of the corresponding packet/ACK. There are an unlimited number of packets from the application layer of A, such that a new packet can be sent out whenever the sender window allows. A data message from the receiver to the sender always acknowledges the sequence number of the latest-received packet at the receiver. Each block at the sender indicates a unit time, during which a packet with the sequence number inside the block is being sent (the transmission of each packet takes one unit of time). Assume all arrived packets/ACKs are error free, the sender window size is N=3, the sequence number range is [0,5], and a timer times out 2 units of time after the end of the transmission of the respective packet.

Fill in the figure the following: (1) At the sender: the sequence number of packets sent (in the blocks) (if there are no packets to be sent, fill "—" in the block), and the sender window in the form [x,y] (above the blocks), where x and y are the first and last sequence number in the window respectively, and the sequence number(s) of packet(s) whose ACK has been received (in the row of "Acks in buffer"); (2) At the receiver: receiver window in the form of [x,y], sequence number(s) of out-of-order packet(s) received (in the row of "Packets in buffer"), the sequence number(s) of packets to be delivered to the upper layer. (Note: You only need to indicate the above quantities upon their value changes)



5. (18 marks) [TCP RDT and Congestion Control (Learning Outcomes 2, 3)]

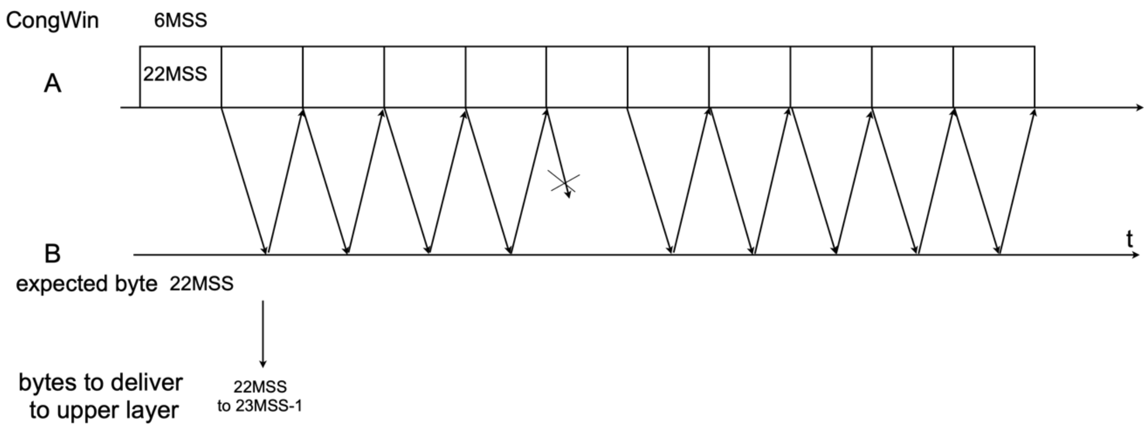
Suppose sender A and receiver B implement TCP RDT and AIMD congestion control, with the following simplified convention: CongWin is increased whenever a new ACK arrives (not when a duplicated ACK arrives) according to CongWin = CongWin + MSS * MSS / CongWin; when a loss is detected based on 3 duplicated ACKs, CongWin is reduced by CongWin=CongWin/2, and the missing segment is retransmitted. Suppose A's upper layer always has data to deliver. We do not consider timers and losses due to timer expiration. Ignore flow control and RcvWindow. The packets are never corrupted. MSS represents Maximum Segment Size.

(1) Suppose at one given time, LastByteACKed at A is 22MSS-1, CongWin is 6MSS, and therefore the largest sender window is [22MSS, 28MSS-1], containing the sequence numbers of bytes that can be sent. After A sends a few segments to B, A receives an ACK with ACK

number 26MSS from B; what will the largest sender window at A become?

(2) Suppose Figure 4 below illustrate the segment/ACK transmissions between A and B. A cross over a line indicates the loss of the corresponding segment. An ACK is immediately sent when a segment arrives, with ACK number set according to TCP RDT protocol. The numbers in the blocks at the sender indicate the sequence numbers of the segments being sent. Assume the range of sequence numbers is unlimited, and each segment has the size of 1MSS. The initial sequence number is 22MSS and the initial CongWin is 6MSS.

Fill in the figure with the following: (1) at the sender: the sequence number of the segment being sent (into the blocks) if there is a segment transmission in a time slot indicated by a block, and the current congestion window size (CongWin); (2) at the receiver: the expected byte (the sequence number of the segment expected), and the bytes to be delivered to upper layer (suppose the receiver buffers out-of-order bytes received). Note: You only need to indicate the CongWin and the expected byte upon their value changes; you can round the numbers to 2 decimal places.



6. (22 marks) [TCP Congestion Control and RTT (Learning Outcomes 2, 3)]
Host A has a file of 49.5Kbytes to send to host C and host B has a file of 70.5Kbytes to send to host D, both using TCP. TCP connection 1 from A to C and TCP connection 2 from B to D share one bottleneck link of 750Kbps in the network, as shown in Figure 5. The file transmissions from host A and from host B start at the same time. The round-trip time (RTT) between A and C and between B and D is both 0.2 seconds (ignore detailed propagation, queueing, and nodal processing delays and just consider the RTT). Suppose time is slotted according to RTT and we start from RTT 1. In both TCP connections: the congestion control process starts with slow start until the slow start threshold (ssthresh) has been reached, and then begins AIMD and reacts to loss events detected by timer timeouts by cutting ssthresh to half and following slow start again. In this question, we do not consider duplicated ACK nor fast recovery, and assume exactly 1MSS is added to a sender's congestion window (CongWin) in each RTT during AIMD (instead of CongWin = CongWin + MSS * MSS / CongWin per new ACK). A receiver sends an ACK immediately after it has received a segment; ignore ACK transmission

time. In this way, batches of segments are sent out from each sender in the M^{th} RTT (M=1,2,...) and ACKs for each batch of segments are received back at the sender in the $(M+1)^{th}$ RTT (M=1,2,...). Suppose each sender's timer expires after 1RTT, the initial ssthresh is 16MSS, and the size of each TCP segment is 1MSS=500bytes.

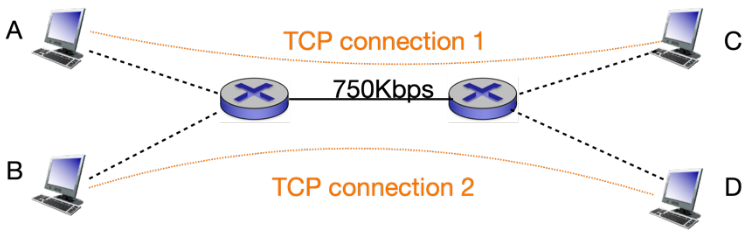


Figure 3

(1) Complete the following table for congestion window sizes and slow start thresholds: fill in CongWin size and ssthresh for TCP connection 1 until the RTT when host A's file transfer is completed; fill in CongWin size and ssthresh for TCP connection 2 until the RTT when host B's file transfer is completed. [**Hints**: consider a loss will occur in each TCP connection in an RTT if the overall data rate in that RTT exceeds the bottleneck link's capacity; compute how many RTTs host A's file transfer takes and how many RTTs host B's file transfer lasts.]

Time (in RTTs)	CongWin of TCP connection 1 (in MSS)	ssthresh of TCP connection 1 (in MSS)	CongWin of TCP connection 2 (in MSS)	ssthresh of TCP connection 2 (in MSS)
1	1	16	1	16
2				
3				
4				
5				
6				
...				

(2) Calculate the average throughput on each of the two TCP connections, for sending the respective file, from the start of file transmission to the end of the RTT in which the last segment of that file is sent.

Submission:

You can write your answers in a word document or other document at your choice. Please convert your answer document to a ***a2-yourstudentid.pdf*** file and submit the PDF file on Moodle before 23:59 Wednesday March 20, 2024:

(1) Login Moodle.
(2) Find "Assignments" in the left column and click "Assignment 2".

(3) Click “Add submission”, browse your .pdf file and save it. Done.
(4) You will receive an automatic confirmation email, if the submission was successful.
(5) You can “Edit submission” to your already submitted file, but ONLY before the deadline.