NATIONAL UNIVERSITY OF SINGAPORE

EXAMINATION FOR

EE4204 - COMPUTER NETWORKS

(Semester II: 2020/2021)

Time Allowed: 2 Hours

INSTRUCTIONS TO CANDIDATES:

1. This paper contains **4** questions and comprises **6** pages.
2. Each question carries **25** marks.
3. Programmable calculators are **NOT** allowed.
4. The Final Exam is open book. You **MAY** use any of the materials handed out in class and refer to any textbook. You **MAY** refer to your notes on the computer or tablet.
5. You **MAY** consult Internet sources as a reference for technical concepts only. You are **NOT** allowed to communicate with anyone else about the Exam via forum, email, bulletin board, or any other electronic communication method.
6. You should **NOT** consult with any other person about the Exam or during the Exam. You may **NOT** copy-and-paste from the Internet or any other sources. All answers must be yours and in your own words.
7. Please abide by the Code of Student Conduct (http://nus.edu.sg/osa/resources/code-of-student-conduct).
8. Write your answers on fresh sheets of A4-size paper. Please start each question (Q1, Q2, Q3, and Q4) on a new page. Clearly indicate the part, e.g., Q1(a) on the left margin. Typewritten or handwritten answers on tablets or any electronic devices are NOT acceptable.
9. Write your Student Number on every page. You should not write your name.
10. Scan/Photograph each page and combine into one PDF file in the given order: cover_page, signed declaration form, and your answers.
11. Name your file: STUDENT_NUMBER-EE4204.pdf (e.g.: A1234567R-EE4204.pdf).
12. Upload the combined PDF file (cover_page + declaration form + answers) to the LumiNUS Files Folder labeled “Exam Group X Submission”, where X is your Final Exam Group Number.

Q.1(a) Host A is connected to host B via a store-and-forward switch S. The bandwidth of the links A→S and S→B is 100 Mbps and 10 Mbps, respectively. The propagation delay on each link is 100 μs. Host A transmits a message in two packets, each of size 10,000 bits one after another without any time gap left between them. Host B sends an acknowledgement to host A immediately after receiving each packet. The message transfer is said to be complete when host A receives an acknowledgement for the second packet from host B. Assume that communication is error-free and acknowledgement frame transmission time is negligible. Calculate (i) time when the second packet is completely transmitted at switch S (ii) message transfer time and (iii) throughput.

(10 marks)

Q.1(b) Determine the CRC bits when the data bit stream 10101010 is transmitted using the divisor polynomial $C(x)=x^2+ x+1$. (5 marks)

Q.1(c) Calculate the frame size, frame time, and data rate of a SONET OC-12 frame, given that OC-1 frame carries 810 bytes.

. (5 marks)

Q.1(d) Sam has 1-Gbps network service subscription for his home network. He downloaded a game of size 50 billion bytes from a remote server to a game console connected to his home network in 1 hour and 20 minutes.

(i) What is the minimum possible transfer time in the ideal case?
(ii) Give any two factors which probably would have caused longer transfer time when compared to the ideal case. (5 marks)

Q.2(a) A data-link layer uses selective-repeat ARQ protocol with a window of size 10 for transferring data from node A to node B through a 100-Mbps link which is 100-km long. It is required to transfer a message of 200 frames each of size 1000 bytes, but, due to an error, 210 frames are transmitted. The propagation speed is assumed to be1 km per 5 μs.

(i) Calculate the time taken to transfer the message?
(ii) For what range of the window size, the transfer time is minimum?
(iii) Calculate the message transfer time for the window size range chosen in part(ii) above.

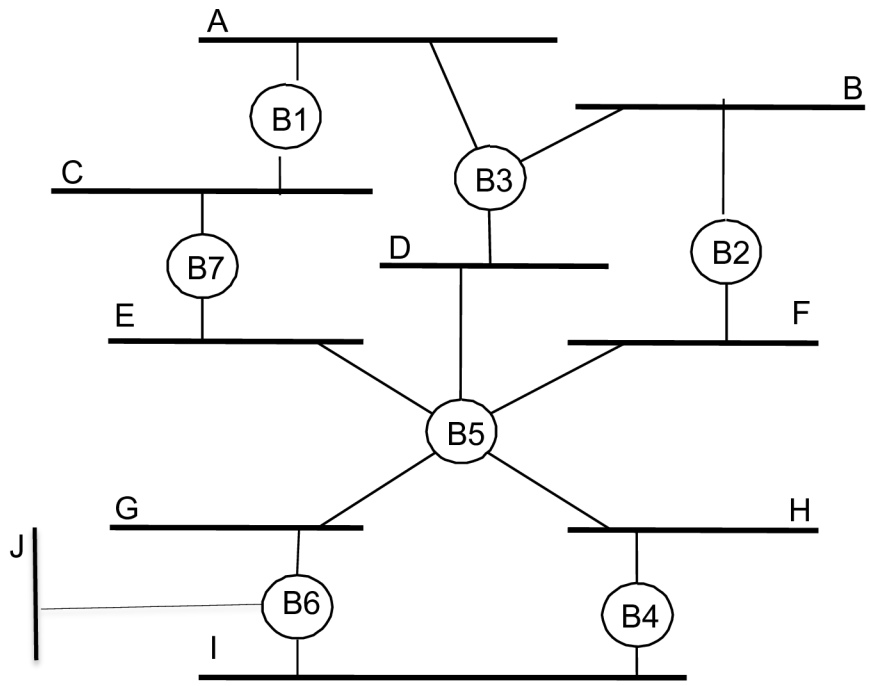
(10 marks)

Q.2(b) Two hosts A and B attempt to transmit on an Ethernet. Each host has a steady queue of frames ready to send. The frames sent by A are numbered A_1, A_2, A_3, and so on. The frames sent by B are numbered B_1, B_2, B_3, and so on. The sequence of frames sent and collisions (C) are given by A1, A2, B1, C, B2, C, C. What is the probability that host A wins the current collision race?

(5 marks)

Q.2(c) Consider the extended LAN with seven bridges labeled B1 through B7 and ten LANs labeled A through J as shown in the figure below. Draw the spanning tree generated by the distributed spanning tree algorithm by removing the ports that are not part of the tree.

(5 marks)



Q.2(d) Consider four nodes A, B, C, and D in an 802.11 network that uses MACA. Node A needs to send a frame to node B and node D needs to send a frame to node C. The RTS frame sent by node A can be heard by node B and D, while that is sent by node D can be heard by node A and C. Node A and node D simultaneously send RTS frames. Can the two transfers <A,B> and <D,C> can take place simultaneously? Explain.

(5 marks)

Q.3 Consider the six-node packet-switched network shown in Figure 3 below with edge costs as indicated in the diagram. All the following parts of this question refer to this network.

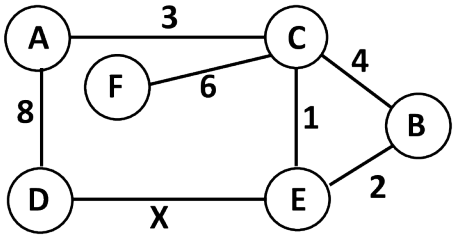


Figure 3: Network for Problem Q.3

Q.3(a) Assume that X=1. Compute the least cost paths by inspection and determine the forwarding table at all nodes in the network. As an example, the forwarding table at node F is given in the table at the right. Please determine the forwarding tables at the other nodes (A, B, C, D, and E) in the same format. (5 marks)

Node F:	
Destination	Next Hop
A	C
B	C
C	C
D	C
E	C

Q.3(b) Suppose node A receives a packet with destination address E. For each of the following actions, determine if node A performs that action and indicate TRUE/FALSE. Please reproduce the following table in your answer booklet. (5 marks)

(i) A sends a routing protocol update message to its neighbours.	
(ii) A looks up E in its forwarding table to find the interface to forward the packet.	
(iii) A calculates the least cost path to destination E.	
(iv) A may discard the packet.	
(v) A sends a ping message to E using ICMP to determine if E is accessible to A.	

Q.3(c) Suppose the given network has subnet address 192.168.100.192/28, represented in CIDR notation. Suppose that Node A wants to send a broadcast packet to all other nodes. What is the IPv4 address that node A will put in the destination address field? What is the subnet mask? (5 marks)

Q.3(d) Suppose that the nodes in the network are running the link state routing algorithm (via Dijkstra's algorithm). The catch is that all the nodes are not using the same edge costs. Suppose that node E is computing least cost routes using the edges costs shown. Suppose that node B is computing shortest hop routes, i.e., the minimum number of hops. Assume X=18 and that link C-E breaks. Determine the forwarding tables at Nodes B and E. Show that the network now contains a routing loop. (5 marks)

Q.3(e) Suppose that the nodes in the network are running the distance vector routing algorithm (not path vector). Assume X=1. Choose a link to break so that the resulting network has a routing loop. State explicitly which link you would break and clearly explain the routing loop. (5 marks)

Q.4 Suppose we have the following network (shown in Figure 4 below) with hosts A, B, D, X, Y, and Z connected to routers R1, R2, and R3 via access links. Assume that the access links have no capacity constraints. Assume that the link between R1 and R2 has link capacity C1 (in Mbps) and the link between R2 and R3 has link capacity C2 (in Mbps). All the following parts of this question refer to this network.

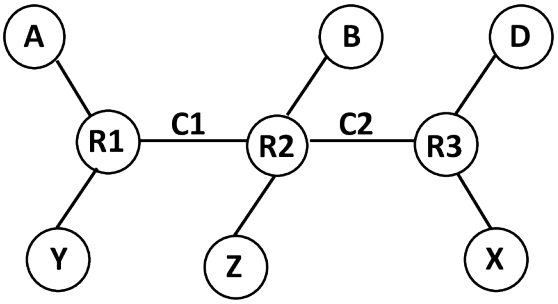


Figure 4: Network for Problem Q.4

Q.4(a) In the network given, suppose we have four TCP flows (as shown to the right). Assume that all sources have a large amount of data to send and that the round trip times (RTT) for all four flows are the same. What is the approximate throughput of each of these four TCP flows? Explain your answer briefly. (5 marks)

Flow 1 from A to Z
Flow 3 from Y to B
Flow 2 from B to A
Flow 4 from Z to Y

Q.4(b) In the network given, suppose we have three TCP flows (as shown to the right). Assume that C1=C2=C and that all sources have a large amount of data to send. Express your answers in terms of C.

Flow 1 from A to X
Flow 2 from Y to B
Flow 3 from Z to D

(i) What is the max-min fair allocation of throughputs for each flow? What is the total system throughput for this max-min fair allocation?

(ii) What is the allocation of throughputs for each flow such that the system throughput is maximized? What is the total system throughput for this allocation?

(iii) Notice that Flow 1 is using two links while Flows 2 and 3 are using only one link. With this observation, design another throughput allocation that is proportionally fair? What is the total system throughput for this allocation?

(10 marks)

Q.4(c) Suppose we have two TCP flows in the network. Flow 1 is from A to B and uses TCP Reno. Flow 2 is from Y to X and uses TCP-Tahoe. The initial value of *ssthresh* for both TCP flows is equal to 32. Assume that the access links have negligible delay and all other links have a delay of 25 ms. The round-trip time (RTT) of a flow is the sum of the delays on the links in the round-trip path. Assume that all other delays in the network are negligible.

(i) What is <u>one</u> advantage of TCP Reno as compared to TCP Tahoe? Explain briefly.

(ii) For TCP flow 1 and TCP flow 2, assume that a packet loss (via triple duplicate ack) is detected at time t=650ms and t=900ms, respectively. Draw the resulting congestion window for the <u>two</u> TCP flows up to time 1200 milliseconds using the figure below (see Figure 5). Please label your figure with the different characteristics of TCP: *ssthresh*, Slow-start, AIMD, triple dup ack. Please clearly explain how you derived your plots. Please reproduce the figure in your answer booklet.

(10 marks)

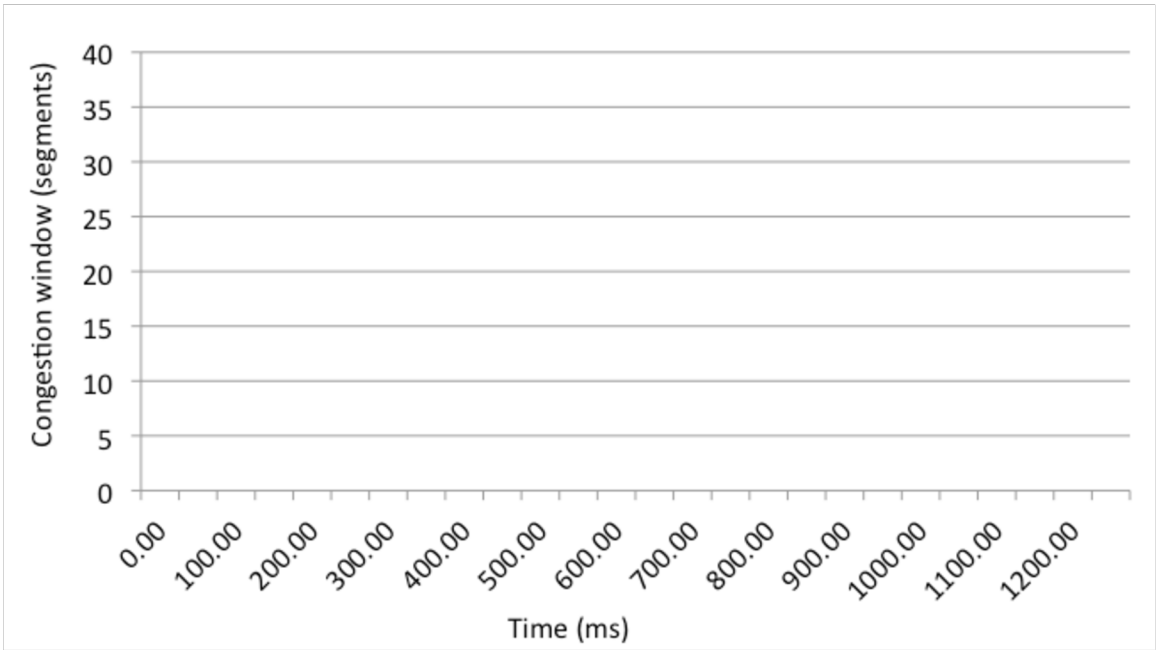


Figure 5: Use this figure to write your answer for Q.4(c). Reproduce this figure in your answer booklet.

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