NATIONAL UNIVERSITY OF SINGAPORE

EXAMINATION FOR

(Semester II: 2019/2020)

EE4204 - COMPUTER NETWORKS

April/May 2020 - Time Allowed: 2 Hours

INSTRUCTIONS TO CANDIDATES:

1. This paper contains **4** questions and comprises **12** 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** cut-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.
9. Write your matriculation number on every page.
10. Scan in each page and compile into one PDF file in the given order: cover page, signed declaration form, and your answers.
11. Name your file: <matric number>-<module code>.pdf (e.g.: A1234567R-EE4204.pdf).
12. Upload the combined PDF file to the LumiNUS folder labeled "EE4204 Final Exam Submission Group_X", where X is your Final Exam Group Number.

Q.1(a)

(i) Calculate the total time required to transfer a 1000000-Byte file over a 10-Mbps link with an RTT of 1 ms assuming error-free communication. The file is transferred as batches of eight 1000-Byte packets. Every batch is acknowledged upon receiving the last packet in the batch. Upon receiving the acknowledgement of the current batch, the next batch is sent. The transfer is said to be complete when the acknowledgement for the last batch is received.

(ii) Briefly explain how the above batch transfer compares with packet-by-packet transfer when the packet size is 8000 Bytes for the cases of error-prone and error-free communication. (10 marks)

Q.1(b) A receiver receives a frame with data bit stream 1000100110. Determine if the receiver can detect an error using the generator polynomial $C(x)=x^2+x+1$. (5 marks)

Q.1(c) Suppose that 12 hosts are connected to a store-and-forward packet switch through 1-Mbps links that use statistical time division multiplexing. Each host transmits 20 percent of the time but requires 1 Mbps when transmitting. All the hosts contend for an output link of capacity 10 Mbps. Is there any possibility of the excess traffic getting queued up at the switch? If yes, find the probability of occurrence of such an event. If no, explain why it cannot happen. (5 marks)

Q.1(d) If a 10-Mbps link with the propagation delay of 10 ms can hold 10 frames, how many frames can be held on a 100-Mbps link with the propagation delay of 100 ms?

(5 marks)

Q.2(a) Consider a sliding window-based flow control protocol that uses a 3-bit sequence number and a window of size 7. At a given instant of time, at the sender, the current window size is 5 and the window contains frame sequence numbers {1,2,3,4,5}. What are the possible RR frames that the sender can receive? For each of the RR frames, show how the sender updates its window.

(5 marks)

Q.2(b) Node A detects an idle link in an 802.11 network that uses MACA and sends an RTS frame to node B. But node A does not receive a CTS frame in response to its RTS frame. Explain what could be the possible reasons for this. (5 marks)

Q.2(c) Suppose that node A sends frames to node B using the sliding window-based Go Back N ARQ protocol. Assume that the size of the window is 7 and the sequence number of frames is in the range of 0 to 7. Node A sends frames labeled 0 through 5, i.e., F_0 through F_5. Node B receives all these frames and sends an acknowledgement frame RR_6. Suppose that node A sends frame F_6 before RR_6 is received. Also suppose that frames RR_6 and F_6 are lost. Explain how node A and node B will behave and what actions will be taken by them. (5 marks)

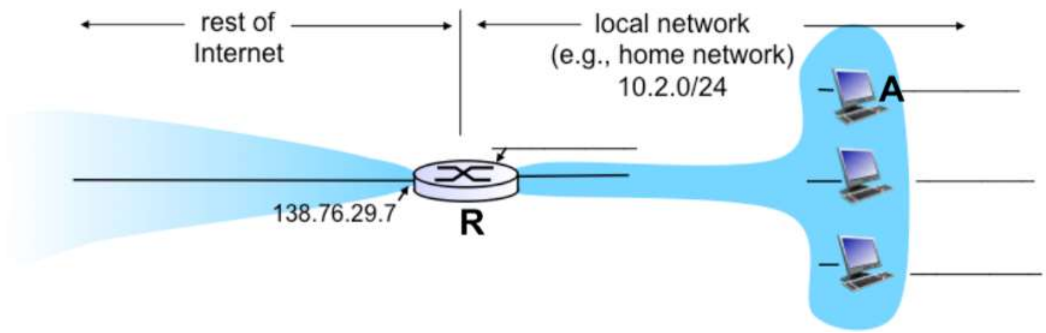
Q.2(d) A learning-bridge, which was initially empty, receives four frames, F_1 through F_4, whose source nodes are A, B, C, and D, respectively. The destination nodes for these frames are all distinct, but among nodes A, B, C, and D. Out of these four frames, only two frames are forwarded by the bridge. Explain the reason by choosing a possible set of destination nodes and ports for the above four frames. (5 marks)

Q.2(e) Two hosts A and B attempt to transmit on an Ethernet. Each host has a steady queue of frames ready to send. At an instant of time, the two hosts attempt to send their frames simultaneously and collision occurs. We say that the hosts enter into a backoff race. It is given that the probability of none wins the race is 1/16. If this is the first collision for A, what is the collision number of B in this race? Explain. (5 marks)

Q.3(a) A LAN is assigned an IP address block that has a starting IP address of 114.44.23.128 and an ending address of 114.44.23.255. (10 marks)

(i) How many IPv4 addresses does this block represent?
(ii) What is the CIDR representation of the subnet with this address block?
(iii) How many bits are there in the subnet and host parts of this network?
(iv) What are the subnet mask and broadcast address (in dotted decimal notation)?
(v) Can you divide this subnet into 3 subnets, each with at least 35 hosts?

Q.3(b) Consider the network shown below in which Router R is a NAT router and Host A is a host inside the local network. (5 marks)



(i) In the table below, specify IP addresses for the router and Host A in the local network. Also assign MAC addresses to these interfaces.

Please reproduce the following table in your written answers.

Node	IP Address	MAC Address
NAT Router		
Host A		

(ii) Now assume that Host A sends an HTTP request to http://www.nus.edu.sg (IP addr: 137.132.5.148) and the local port for the TCP connection for this HTTP request is 7000. Fill out the NAT table below with the information that would be entered in that table after the HTTP request has been forwarded from the NAT router into the WAN.

Please reproduce the following table in your written answers.

WAN side address, Port	LAN side address, Port

Q.3(c) Consider the directed network shown in Fig. 3.1. Suppose w = 1. (i) Using *Dijkstra's algorithm*, find the shortest path spanning tree (Tree 1) from S to all other nodes. In the table below, put an 'X' when an edge is in Tree 1. (ii) State the order in which edges are added in Dijkstra's algorithm, e.g., put a 1, 2 in the row for the edge. (iii) Find all values of 'w' for which Dijkstra's algorithm finds the correct shortest path spanning tree.

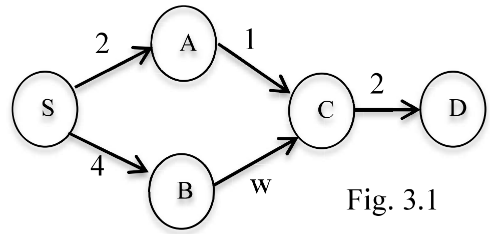


Fig. 3.1

(5 marks)

Please reproduce the following table in your written answers.

Edge	(i) Tree 1	(ii) Order of edges	(iii)
S-A			
S-B			
A-C			
B-C			
C-D			

Q.3(d) Consider the undirected network shown in Fig. 3.2. Suppose we are routing with the *distance vector algorithm*. Explain if removing the following edges will result in the count-to-infinity problem and explain your answer.

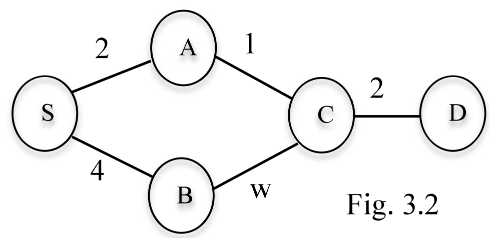


Fig. 3.2

Please reproduce the following table in your written answers. (5 marks)

(i) Removing Edge S-A	(ii) Removing Edge C-D

Q.4(a) TCP uses two different signals to infer congestion: Timeout at the Sender and Reception of triple duplicate acknowledgements at the Sender. Both events will trigger a retransmission of a certain packet. (5 marks)

(i) In each case, which packet is retransmitted?
(ii) Give one reason why TCP uses duplicate acknowledgements to trigger retransmissions instead of simply waiting for timeout.
(iii) Is it advisable to remove the timeout mechanism and use triple duplicate acknowledgements as the only way to trigger retransmissions? Explain briefly.

Q.4(b) You are designing a wireless multihop network that can tolerate 5% packet loss, meaning that 95% of the packets must be delivered to the destination. (5 marks)

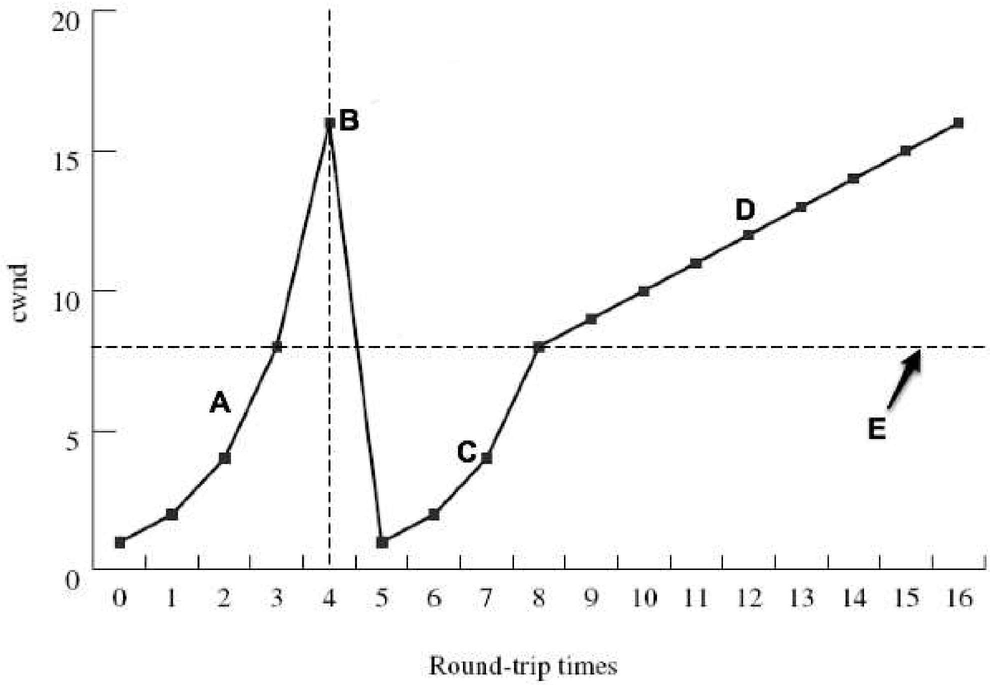
(i) Would you recommend using TCP or UDP at the transport layer and why?
(ii) Design an efficient protocol that meets the stated requirements using the least amount of resources.

Q.4(c) Suppose there are two different Zoom calls, flow X and flow Y, using TCP. Suppose that the RTT for flow X is 100ms and the RTT for flow Y is 200ms. Assume that each flow has an MSS value of 1460 bytes and a slow-start threshold value of 8. Assume each flow has been running for a long time over links with similar properties. (10 marks)

(i) Which flow do you expect to have a higher throughput? Explain briefly.
(ii) At some time in the future, say time t = 100 seconds, both flows experience a timeout, and set their congestion window size to 1. Calculate the average throughput (in bytes per second) over the next 1 second (counting the starting and ending points) for each flow. Assume that the packet transmission time is negligible, and that there are no packet drops for either flow in the next few seconds.

Q.4(d) The figure below shows the evolution in time of the TCP congestion control window as a function of round-trip time. Identify the 5 points (A, B, C, D, and E) indicated in the figure using the terms in the set shown below. Note that not all terms will be used, and a term may be used more than once. Please give your answer in the table shown below.

(5 marks)



{ Slow-start threshold, Timeout, Three-way handshake, Multiplicative decrease, Exponential backoff, Flow control window, Fast retransmit, Additive Increase, Slow start, Sliding window }

Please reproduce the following table in your written answers.

A	
B	
C	
D	
E	

END OF PAPER