NATIONAL UNIVERSITY OF SINGAPORE

FINAL ASSESSMENT FOR
CS2105 – INTRODUCTION TO COMPUTER NETWORKS

(Semester 2: AY2018/2019)

Time allowed: 2 hours

INSTRUCTIONS TO CANDIDATES

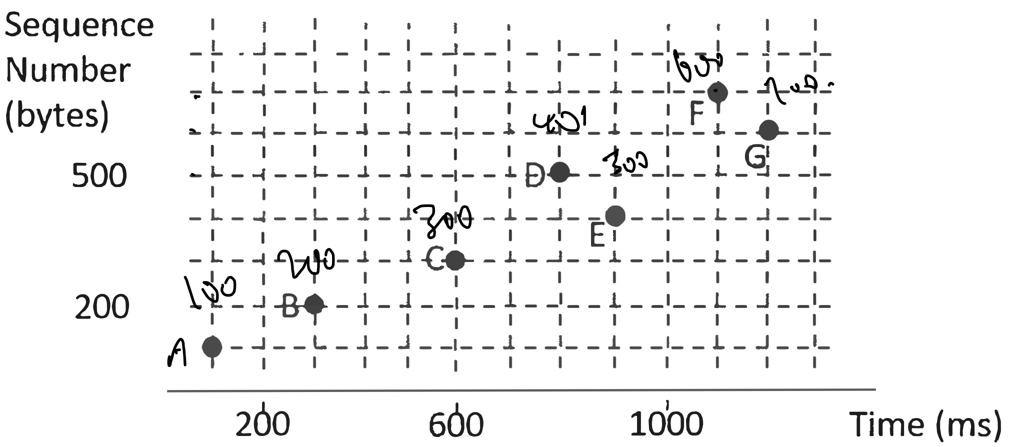
1. This assessment paper contains **FIVE** questions and comprises **FOURTEEN** printed pages.
2. This is an **OPEN BOOK** assessment.
3. Calculators are allowed, but not laptops, PDAs, or other electronic devices.
4. There is no need to show your working in each question.
5. Fill in your student number clearly below. Do not write your name.

STUDENT NO:

For examiners' use only						
Question	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Total**
Max	**20**	**10**	**10**	**9**	**6**	**55**
Score						

Q2. **[Total: 10 marks]**

(a) **[4 marks]** The following graph shows a sequence of TCP segments sent from host X to host Y. Each dot represents a TCP segment, plotting its sequence number versus the time it is received by Y. Each segment carries exactly 100 bytes of payload. The segments labelled with A and G are the first and last segments sent by X, respectively. Assume that no segment is corrupted during transmission and Y buffers out-of-order segments for eventual delivery to the application.



i. **[1 mark]** How many out-of-order segments are received by Y?

2.

ii. **[1 mark]** What is the ACK number in the last ACK segment sent by Y?

800.

iii. **[2 marks]** For each ACK segment sent by Y, fill in the following table by stating when it is sent and what the value of ACK is.

Upon receiving segment	Value of ACK
A	100
B	
C	
D	
E	
F	
G	
H	

(b) **[2 marks]** Host A has 6 segments ready to be sent to Host B. Go-Back-N protocol is used for transmission and sender's window size is 2. Assume that transmission delay of each segment is negligible, timeout value is larger than 2 RTT and no segment is corrupted during transmission. However, the first ACK and the fifth data segment are lost. In the end, all 6 segments are correctly received by Host B. How many segments has Host A sent in total and how many ACKs has Host B sent in total?

Host A:

Host B:

(c) **[4 marks]** Suppose we want to design a stop-and-wait, NAK-free, reliable protocol for the communication between a sender and a receiver over a channel with the following characteristics:

- Packets may be lost or corrupted but won't be re-ordered.
- RTT between the sender and the receiver is a constant that is known to both the sender and the receiver. All other kinds of delay can be omitted.

Comment if the following statements about this reliable protocol are true. Briefly justify your answer.

i. **[1 mark]** If the sender set the timer properly, the receiver won't receive duplicate packets.

ii. **[1 mark]** Instead of the sender, the protocol can let the receiver maintain a timer for the ACK sent. If no packet arrives before timer expires, the receiver should retransmit the ACK.

iii. **[2 marks]** In a feedback packet, receiver must explicitly include the sequence number of the data packet being acknowledged.

Q3. Keep your answers accurate and succinct. **[Total: 10 marks]**

(a) **[1 mark]** Given one reason a stop-and-wait protocol would have low throughput over a satellite communication link.

(b) **[2 marks]** Why Internet checksums are used in the transport layer and network layer while CRCs are used in the link layer?

(c) **[2 marks]** Briefly explain why CSMA has better performance than pure ALOHA? Similarly, explain why CSMA-CD outperforms CSMA?

(d) **[5 marks]** Suppose Alice wants to send a message m to Bob. Bob has a public-private key pair (K_B^+, K_B^-) and Alice is aware of Bob's public key. But Alice does not have a public, private key pair. Alice, Bob and the entire world share the same hash function $H(.)$.

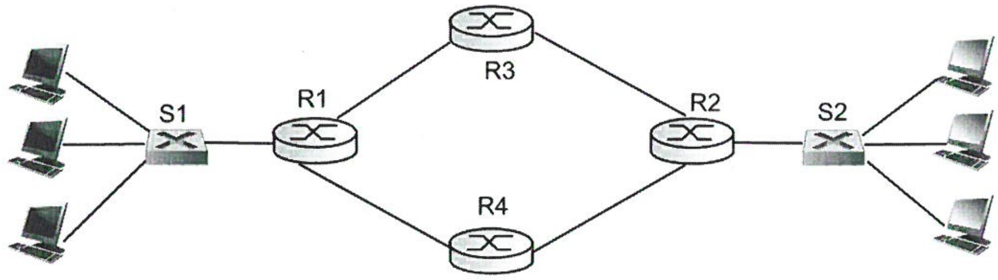
i. **[1 mark]** Is it possible to design a scheme that provides confidentiality for sending m from Alice to Bob? Briefly justify your answer.

ii. **[2 marks]** Is it possible to design a scheme so that Bob can verify that a correctly received message m is indeed created by Alice but not a third party? Briefly justify your answer.

iii. **[2 marks]** Further suppose that Alice and Bob shares an authentication key s that is known to themselves only. Alice sends $H(s \oplus m) \oplus K_B^+(m)$ to Bob. Outline what Bob has to do to verify that m is indeed created by Alice and has not been tampered with during transmission.

Q4. **[Total: 9 marks]**

(a) **[3 marks]** The following diagram shows a network in which six hosts are connected by two Ethernet switches (S1 and S2) and four routers (R1, R2, R3 and R4). All nodes (i.e. hosts, routers and switches) are in working condition.



i. **[1 mark]** How many subnets are there in this network?

ii. **[1 mark]** How many IP addresses need to be assigned to this network?

iii. **[1 mark]** How many nodes in this network have ARP table(s)?

(b) **[2 marks]** Combine the following three blocks of IP addresses into a single block. Write down the address of the aggregated block in CIDR format.

```
172.16.24.208/31
172.16.24.212/30
172.16.24.210/31
```

(c) **[2 marks]** The following shows a forwarding table in a router that uses longest prefix matching and 6-bit addressing. The prefix in each row is distinct.

Prefix Match	Output Interface
10	0
X	1
0	2
otherwise	3

Suppose an IP datagram with destination address 100100 is forwarded through interface 1, list down all the possible values of **X**.

(d) **[2 marks]** An MP3 file of 5 million bytes is to be transmitted over UDP. UDP adds 8 bytes of header to each segment. Each UDP segment is then encapsulated into an IP datagram that has a 20 bytes IP header. Each IP datagram is further encapsulated in to a link layer frame which adds another 18 bytes of header/trailer. Suppose link MTU is 1,500 bytes.

i. **[1 mark]** What will be the value of MSS?

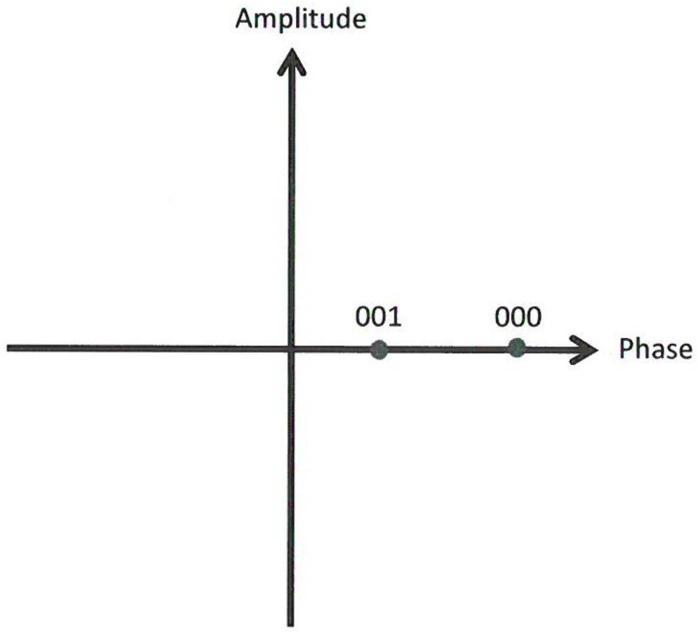
ii. **[1 mark]** What is the minimum number of Ethernet frames needed to transmit this MP3 file?

Q5. **[Total: 6 marks]**

(a) **[3 marks]** A modem uses a QAM technique described by the following table.

Bit values	Amplitude of generated signal ($A_1 > A_2$)	Phase of generated signal
000	A_1	0^0
001	A_2	0^0
010	A_1	90^0
011	A_2	90^0
100	A_1	180^0
101	A_2	180^0
110	A_1	270^0
111	A_2	270^0

i. **[1 mark]** Complete the following signal constellation diagram for the modem.



ii. **[2 marks]** The modem transmitted 216,000 bytes of data in a minute. What is the baud rate of the modem?

(b) **[2 marks]** Consider a packet-switching network of n nodes (n > 10). Among the shortest paths between all pairs of nodes, what is the length of the longest path (in terms of the number of links) if the network is structured as follows?

i. **[1 mark]** A bidirectional token ring

ii. **[1 mark]** A fully interconnected mesh with a wire from every node to every other node

(c) **[1 mark]** What is the probability that x out of n bits ($n > x > 0$) are corrupted during transmission, given that each bit has an independent corruption probability p?

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Do **NOT** use it for your rough work.
Use it ONLY if you need extra space for your answer, in which case please indicate the **question number clearly**.

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