CITY UNIVERSITY OF HONG KONG

Course code & title : CS5222 Computer Networks & Internets

Session : Semester A 2021/22

Time allowed : Two hours

This paper has EIGHT pages (including this cover page).

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1. This paper consists of 8 questions in total.
2. Answer ALL questions.
3. Exam paper not to be taken away.

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*This is an **open-book** examination.*

Candidates are allowed to use the following materials/aids:

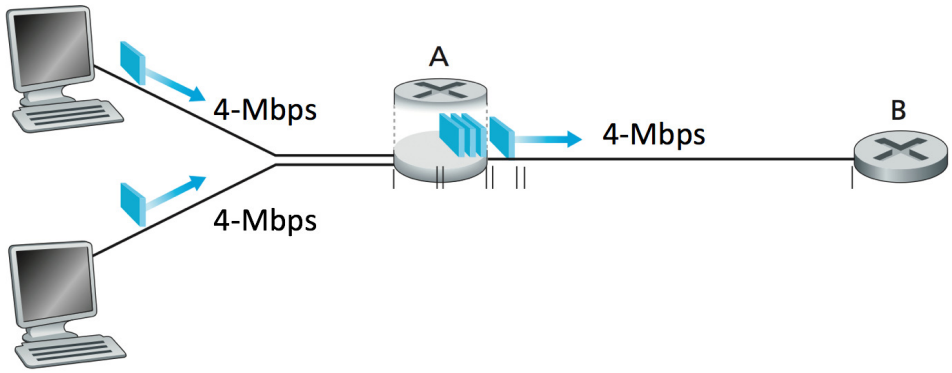
- *Approved Calculator*
- *All hard-copy teaching materials downloadable from the Canvas course website, which include Lecture notes, Tutorial questions and solutions, Assignment questions and solutions (Note: Textbook is not allowed.)*
- *Self-prepared material (Note: Cannot include printed segment of the textbook.)*

Materials/aids other than those stated above are not permitted. Candidates will be subject to disciplinary action if any unauthorized materials or aids are found on them.

1. Delay calculations

a) (7 marks) Consider a user who needs to transmit 1.5 GBytes of data to a server. The user lives in a small town where only 56-Kbps dial-up access to the Internet is available. A bus visits the small town once a day from the closest city, located 150 km away, and stops in front of the user's house. The bus has a 100-Mbps WiFi connection with a local storage device. It can first collect data from users in rural areas (i.e., the user uploads the data through WiFi to the storage device on bus). The bus then transfers data to the server on the Internet through a 1 Gbps link once it gets back to city. Suppose the average speed of the bus is 60 km/h. Which is the faster way the user can transfer the data to the server, by bus or by the dial-up access? Please explain. (Note: 1G = 1000,000,000, 1M=1000,000, and IK = 1000. Assume that in the worst case it takes one day for the user to wait for the bus to arrive in town).

b) (7 marks) Consider the network illustrated in the following Figure. Assume the two hosts on the left of the figure start transmitting packets of 1500 Bytes at the same time towards Router B via Router A. Suppose the link rates between the hosts and Router A is 4-Mbps. One link has a 6-ms propagation delay and the other has a 2-ms propagation delay. Suppose the link rate between Router A and B is also 4-Mbps, and its propagation delay is 10 ms. Will queuing delay occur at Router A? Please explain. (Note: 1M = 1000,000 in this question)



2. Protocols

(10 marks) For each sub-question below, name the protocol that supports the function. (Abbreviation of protocol name is acceptable.)

a) Translates an IP address into a MAC address in a local area network.
b) Allows a newly arriving host to obtain an IP address automatically in a network.
c) A transport layer protocol that ensures reliability for file transfer.
d) A medium access control (MAC) protocol used by the Ethernet.
e) An application layer protocol used to transfer messages from senders' mail servers to the recipients' mail servers in electronic mail.

3. Peer-to-peer (P2P) file distribution

Consider distributing a file of F = 10 GBytes to N = 10 peers. The server has an upload rate of u_s=10 Mbps, and each peer has a download rate of d_i=2 Mbps and an upload rate of u_i= 200 Kbps. Assume 1M = 1000 K, 1 G = 1000 M. 1Byte = 8 bits.

a) (3 marks) What is the minimum distribution time for client-server distribution? Show your steps.

b) (4 marks) What is the minimum distribution time for P2P distribution? Show your steps.

c) (2 marks) What is the high-level reason that the P2P architecture can achieve a higher scalability than the client-server architecture?

d) (2 marks) In BitTorrent protocol, how can the peers obtain the IP addresses of one another for file distribution?

4. TCP Congestion Control and Sequence Number

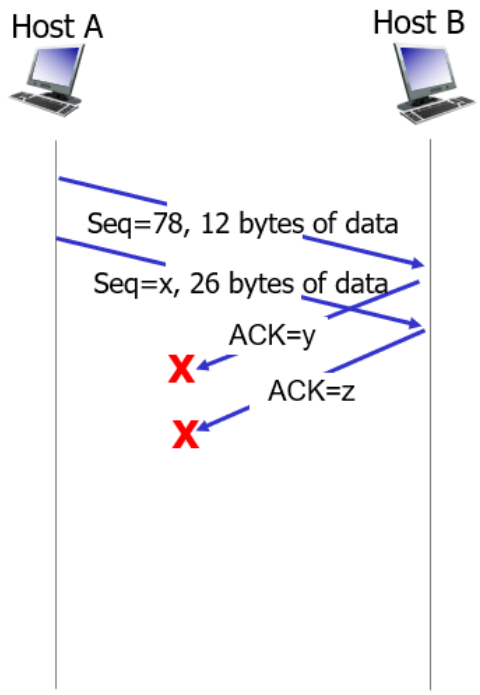
TCP starts with a small congestion window, which is initially set to 1 maximum segment size (MSS), and goes through the slow start phase. The congestion window increases multiplicatively, e.g., 2 MSSs, 4 MSSs, 8 MSSs, ..., for every round trip time, until the slow start threshold is reached and the congestion avoidance phase is entered. Suppose you open a web browser and try to download a webpage of 70 MSSs. Assume that 1 MSS is 1024 bytes.

a) (3 marks) Assuming there is no packet lost, how many RTTs are required in order to download the webpage? (Remember to add up one RTT of handshake to set up the TCP connection.) Please explain.

b) (3 marks) If RTT = 100 ms, what is the average throughput in kbps (kilobits per second)? (Note: We define the throughput as the total amount of transmitted data divided by the time required.)

c) (3 marks) In the slow-start phase, do you expect the throughput of sending a larger-size webpage to be higher than the throughput of sending a smaller-size webpage? Please answer either yes or no and explain.

d) (6 marks) Host A and B are communicating over a TCP connection, and Host B has already received from Host A all bytes up through byte 77. As shown in the figure below, suppose Host A then sends two segments to Host B back-to-back. Host B sends an acknowledgment whenever it receives a segment from Host A. Unfortunately, both the acknowledgments for both segments are lost. What are the values of x, y, and z in the figure?



5. Forwarding and Routing

a) (4 marks) What is the difference between forwarding and routing in the network layer?

b) (12 marks) Consider a datagram network using 8-bit host addresses. Suppose a router uses longest prefix matching and has the following forwarding table:

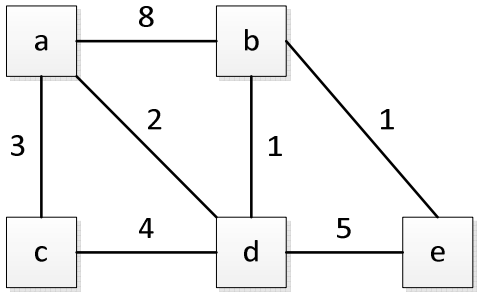
Prefix Match	Interface
1	0
10	1
111	2
otherwise	3

For each of the four interfaces, give the associated range of destination host addresses and the number of addresses in the range by filling in the table below. (Please copy the table to your answer sheet.)

Prefix	**Interface**	**Range of destination host addresses**	**Number of addresses**
1	0		
10	1		
111	2		
Otherwise	3		

6. Dijkstra's algorithm

Consider the following network. With the indicated link costs, we aim to use Dijkstra's shortest-path algorithm (i.e., link-state algorithm) to compute the shortest path from "node a" to all network nodes.



a) (10 marks) Draw the following table in the answer book and fill in the details based on Dijkstra's algorithm.

Step	N'	D(b),p(b)	D(c),p(c)	D(d),p(d)	D(e),p(e)
0					
1					
2					
3					
4					

The notations are:

- *D(v)*: cost of the least-cost path from the source node to destination *v* as of this iteration of the algorithm.
- *p(v)*: previous node (neighbor of *v*) along the current least-cost path from the source to v.
- *N'* : subset of nodes; *v* is in *N'* if the least-cost path from the source to *v* is definitively known.

b) (4 marks) Draw the resulting shortest-path tree from "node a" to all the other nodes in the network.

7. ALOHA

Suppose four active nodes—nodes A, B, C, and D—are competing for access to a channel using slotted ALOHA. Assume each node has an infinite number of packets to send. Each node attempts to transmit in each slot with probability p. The first slot is numbered slot 1, the second slot is numbered slot 2, and so on.

a) (2 marks) What is the probability that none of the nodes are transmitting at time slot 2?

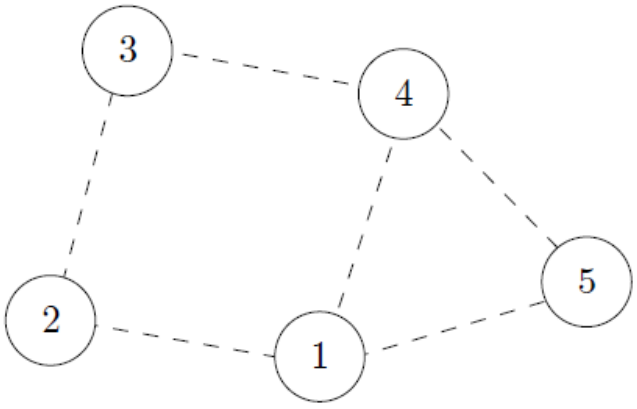
b) (2 marks) What is the efficiency (i.e., the long-run fraction of successful slots) of this four-node system?

c) (4 marks) If we use pure ALOHA instead of slotted ALOHA, do you expect that the efficiency is higher or lower? Why?

8. Wireless MAC protocol

a) (2 marks) What is the "hidden terminal problem" in wireless communications? State one undesirable effect that it will bring to the system.

b) (3 marks) Consider the network in the figure below. A dashed edge between two stations indicates that the stations can transmit to and interfere with each other. Suppose Station 1 is transmitting to Station 4. Which station(s) can cause the hidden terminal problem?



c) (3 marks) Consider the network in the figure again. Suppose Station 1 is transmitting to Station 5. Which station(s) can cause the hidden terminal problem?

d) (4 marks) State a mechanism in IEEE 802.11 that can avoid data frame collisions *completely* even in the presence of hidden terminals. Briefly explain how it works.

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