NATIONAL UNIVERSITY OF SINGAPORE

EXAMINATION FOR

(Semester II: 2021/2022)

EE4204 - COMPUTER NETWORKS

April/May 2022 - Time Allowed: 2 Hours

INSTRUCTIONS TO CANDIDATES:

1. This paper contains four questions and comprises twelve pages.
2. Each question carries 25 marks.
3. Answer all questions in the spaces provided.
4. You are allowed to bring one A4 size sheet. No other material is allowed.
5. Programmable calculators are not allowed.
6. Write your matriculation number in the space provided below.

MATRICULATION NUMBER:

A0214561M

QUESTION NUMBER	MARKS	MAX. MARKS
1		25
2		25
3		25
4		25
TOTAL		100

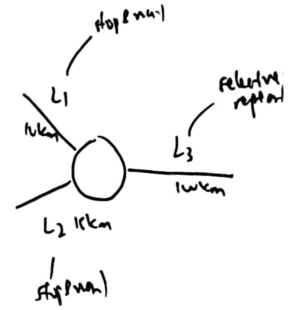
Q.1(a) Consider a node with three links L_1, L_2, and L_3. Frames of size 1250 Bytes are received from L_1 and L_2 and are sent out through L_3. The lengths of the links L_1, L_2, and L_3 are 10 km, 15 km, and 100 km, respectively. Each link operates at the data rate of 100 Mbps. The propagation delay on each link is 5µs per km. On link L_1 and L_2 stop-and-wait ARQ is used and on link L_3 selective-repeat ARQ is used. Assume error-free frame transmission.

(i) Determine the total number of frames received at the node in one second.

(ii) Determine the minimum window size needed in order not to flood the buffer at the node.

(10 marks)

i)



100Mbps each

5µs/km each

L1

$T_p = 10km \times 5\mu s/km = 50\mu s$

$T_f = \frac{1250 \times 8 \text{ bits}}{100Mbps} = 100\mu s$

$\alpha = \frac{50}{100} = \frac{1}{2}$

stop and wait $\Rightarrow$ $U = \frac{1}{1+2\alpha} = \frac{1}{2}$

1 frame every 200µs $\Rightarrow$ 5000 frames / second

L2

$T_p = 15km \times 5\mu s/km = 75\mu s$

$\alpha = \frac{3}{4}$

$T_f = 100\mu s$

stop and wait $\Rightarrow$ $U = \frac{1}{1+2\alpha} = \frac{2}{5}$

1 frame every 250µs $\Rightarrow$ 4000 frames / second

9000 frames received at the node in 1 second

ii)

L3

$T_p = 100km \times 5\mu s/km = 500\mu s$

$\alpha = 5$

$T_f = 100\mu s$

selective repeat $\Rightarrow$ $w \geq 1+2\alpha \Rightarrow U = 1$

$w < 1+2\alpha \Rightarrow U = \frac{w}{1+2\alpha}$

error free

To not flood buffer

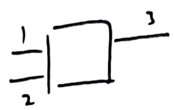
at least 9000 frames need to be transmitted in 1 second

$U = \frac{9}{10}$

$\frac{w}{1+2\alpha} \geq \frac{9}{10} \Rightarrow \frac{w}{11} \geq \frac{9}{10} \Rightarrow w \geq 9.9$

$\underline{w \geq 10}$

Q.1(b) Consider a packet switch with four 100-Mbps ports, that uses statistical time division multiplexing. Suppose that there is a continuous flow of packets with an average data rate of 80 Mbps each at port 1 and port 2 and all of them need to leave through port 3. The switch has a buffer of size 10 Gigabits for packet queueing. Assume that there is no flow control mechanism used at link level. Is there a possibility of congestion? If so, determine the time when the congestion starts to occur. If not, explain why congestion cannot happen. (5 marks)



100Mbps

There is a possibility of congestion as the rate data flows in through port 1 and 2 is 80+80 = 160 Mbps which is higher than the rate it can leave through port 3 at 100Mbps given that port 4 does not participate.

There is an excess of 60 Mbits per second at the switch hence with a buffer of 10Gbits, congestion occurs at

$$\frac{10\text{ Gbits}}{60\text{ Mbit/s}} = \underline{166.6667\text{ s}}$$

Q.1 (c) Determine the CRC bits generated to send the bit stream 10111001 using the divisor polynomial x^3+x^2+x+1. (5 marks)

k= 3

```
         11101011
1111 ) 10111001000
       1111
        1001
        1111
         1100
         1111
          1101
          1111
           1000
           1111
            1110
            1111
               1
```

CRC bits generated is $\underline{001}$

Q.1 (d) Consider five nodes A, B, C, D and E in an 802.11 network that uses the MACA protocol. The communication reach between the nodes is represented as an edge in the graph format A-B-C-D-E-A. For each of the three different scenarios below, state if simultaneous transmissions can take place or not, and justify your answer using RTS/CTS messages.

- Scenario 1: B → C and A → E ✓
- Scenario 2: B → C and D → E ×
- Scenario 3: A → C and D → E ×

(5 marks)

① B transmits RTS seen by A and C
C transmits CTS after seeing RTS from B, seen by B and D
since A only sees RTS but not CTS, it can still transmit
A transmits RTS seen by B and E
E transmits CTS after seeing RTS from A, seen by D and A
since B only sees RTS but not CTS, it can still transmit

YES

② B transmits RTS seen by A and C
C transmits CTS seen by B and D
Since D sees CTS, it cannot transmit else collision with B and C

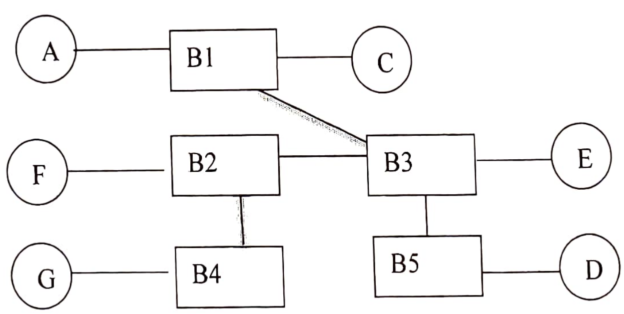
NO ×

③ A transmits RTS seen by E and B, cannot reach C
D transmits RTS seen by C and E
E transmits CTS seen by A and D
A cannot transmit since it sees CTS

NO ×

Q.2 (a) Consider the arrangement of learning bridges B1-B5 with six hosts A, C, D, E, F, and G as shown below. Assuming that all the forwarding tables are initially empty, list the forwarding table entries below, for each of the bridges after the following transmissions that happen in that order.

(i) C sends to D (ii) A sends to C (iii) D sends to A and (iv) A sends to D



(10 marks)

Bridge B1

Host	Port
C	B1 ↔ C
A	B1 ↔ A
D	B1 ↔ B3

Bridge B2

Host	Port
C	B2 ↔ B3
D	B2 ↔ B3

Bridge B3

Host	Port
C	B3 ↔ B1
D	B3 ↔ B5
A	B3 ↔ B1

Bridge B4

Host	Port
C	B4 ↔ B2
D	B4 ↔ B2

Bridge B5

Host	Port
C	B5 ↔ B3
D	B5 ↔ D
A	B5 ↔ B3

Q.2(b) Consider a link that implements an ARQ for frame transfer. It is given that 1020 frame transmissions take place on average, while sending a message with 1000 frames due to errors on the link.

(i) Determine the frame error probability.
(ii) Calculate the probability that a given frame is transmitted exactly three times (one original transmission and two retransmissions) due to errors.

(5 marks)

i) 1020 frames transmitted on average for message with 1000 frames

20 frames retransmitted

frame error probability $P_f = \frac{20}{1000} = \underline{0.02}$

ii) frame is transmitted 3 times if 2 errors occur for same frame

probability $= (0.02)^2$

$= \underline{0.0004}$

Q.2(c) Can congestion occur in a circuit-switched network? Justify your answer. You can assume that there are no network component failures. (5 marks)

No. Since there are dedicated bandwidth allocated for each circuit, there is no buffering & congestion within the circuit switched network. However, that means the input rate and output rate of the network has to be the same.

Q.2(d) How does a host recognize that the Ethernet frame received carries an ARP packet, but not the data packet? (5 marks)

There is a type field in the header of the Ethernet frame which tells the host what type of information is carried in the body of the frame

Q.3(a) (i) How many physical hosts are there in a network with CIDR prefix 137.132.128.0/21?
(ii) What is the CIDR prefix for the following range of network addresses: 137.132.16.1 through 137.132.31.255? Please fill in the table and explain below.
(iii) Show how we can divide the subnet 137.132.128.0/21 into 3 subnets (call them A, B and C) such that each subnet has the maximum possible number of hosts. (8 marks)

(i) Number of physical hosts in subnet 137.132.128.0/21	→ 2046
(ii) CIDR aggregation of 137.132.16.1 through 137.132.31.255	→ 137.132.16.0/20
(iii) Division of 137.132.128.0/21	
• Subnet address of original subnet	→ 137.132.128.0/21
• Subnet address of subnet A	→ 137.132.128.0/22
• Subnet address of subnet B	→ 137.132.132.0/23
• Subnet address of subnet C	→ 137.132.134.0/23

i) 8 16 17 18 19 20 21 22 23 24
137.132.10000000.00000000

#address for hosts = 2^{32-21} = 2048

physical hosts = 2048 - 2 (1 for broadcast, 1 for network ID)
= 2046

ii) 17 18 19 20
137.132.00010000.00000001
137.132.00011111.11111111
} CIDR = 137.132.16.0/20

iii) subnets can only be created by increasing # bits used for subnet part
3 subnets => 2 bits => 4 partitions each with 2^{32-23} - 2 = 510 hosts
✓ combine 2 partitions for A

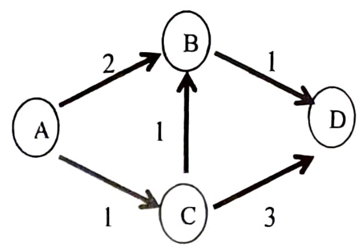
17 18 19 20 21 22 23 24
137.132.10000~~0~~00.0
10/
11/

{ 137.132.128.0/22
137.132.132.0/23
137.132.134.0/23

Q.3(b) Consider a network in which node A receives a packet with destination address Node D. For each of the following actions, determine if Node A performs that action and indicate TRUE/FALSE. Complete the following table. (5 marks)

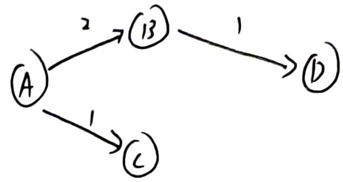
(i) Node A sends a routing protocol update message to its neighbors.	F
(ii) Node A calculates the least cost path to Node D using several routing algorithms and take the average cost.	F
(iii) Node A looks up Node D in its forwarding table and forwards the packet on the associated interface.	T
(iv) Node A may discard the packet.	T
(v) Node A sends a ping message to Node D using ICMP to determine if Node D is reachable by Node A.	F

Q.3(c) Consider the 4-node directed network shown to the right. The labels on the links represent the weight of that link.
(i) Using Dijkstra's algorithm, find and draw the shortest path spanning tree (SPST) from Node A to all other nodes.
(ii) State the forwarding table at Node A.
(iii) Show that the SPST from Node A is not unique by showing another SPST.
(7 marks)



(i)

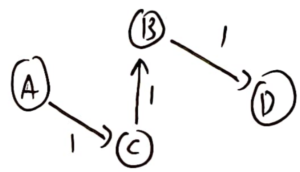
	B	C	D
A	2,A	1,A	∞
AC	2,A	-	4,C
ACB	-	-	3,B



(ii)

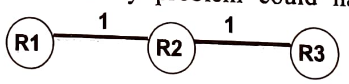
Dest Node	Next Hop
B	B
C	C
D	B

(iii)



tie between
A→B
& A→C→B

Q.3(d) The count-to-infinity problem arises in the context of network routing and usually happens because of a routing loop. (i) What routing protocols does the count-to-infinity problem affect? (ii) Describe how the count-to-infinity problem could happen in the 3-node network shown here.



(5 marks)

(i)

count to infinity affect Distance vector routing protocols such as RIP

BGP does not have count to infinity problem as it has AS-PATH attribute to list full path

(ii)

If the link between R2 and R3 is broken

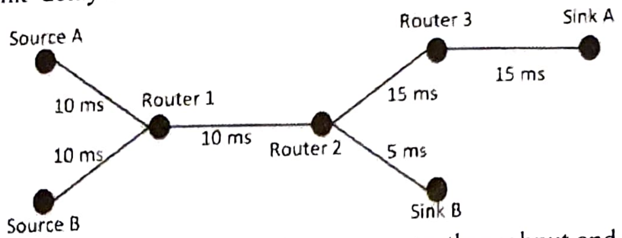
R2 updates its table by taking $\underbrace{R2 \to R1}_{1} \underbrace{\to R2 \to R3}_{2} = 3$

R1 then updates its table by using $\underbrace{R1 \to R2}_{1} \underbrace{\to R3}_{3} = 4$

this routing loop keeps going until ∞

since distance from R2 to R3 using direct link is ∞ so path via R1 always used for update

Q.4(a) Consider the network shown below in which there are two parallel TCP sessions. TCP Session 1 is from Source A to Sink B and TCP Session 2 is from Source B to Sink A. The labels on each link represent the delay on that link, so the round-trip time (RTT) is the sum of the individual link delays. Assume that there are no other causes of delay in the network.



B→A
50ms
100ms RTT
A→B
25ms
50m RTT

(i) Which TCP session do you expect to have larger average throughput and why?
(ii) Assume Session 1 is TCP Reno and Session 2 is TCP Tahoe and the initial value of *ssthresh* for both sessions are 32. Suppose that a triple duplicate ack is detected for Session 1 and Session 2 at time t1=650 ms and t2=900 ms respectively. Draw the congestion window for the two TCP sessions in the figure below and label the sessions.
(iii) State two actions you could take to improve the throughput of TCP Session 1.

(10 marks)

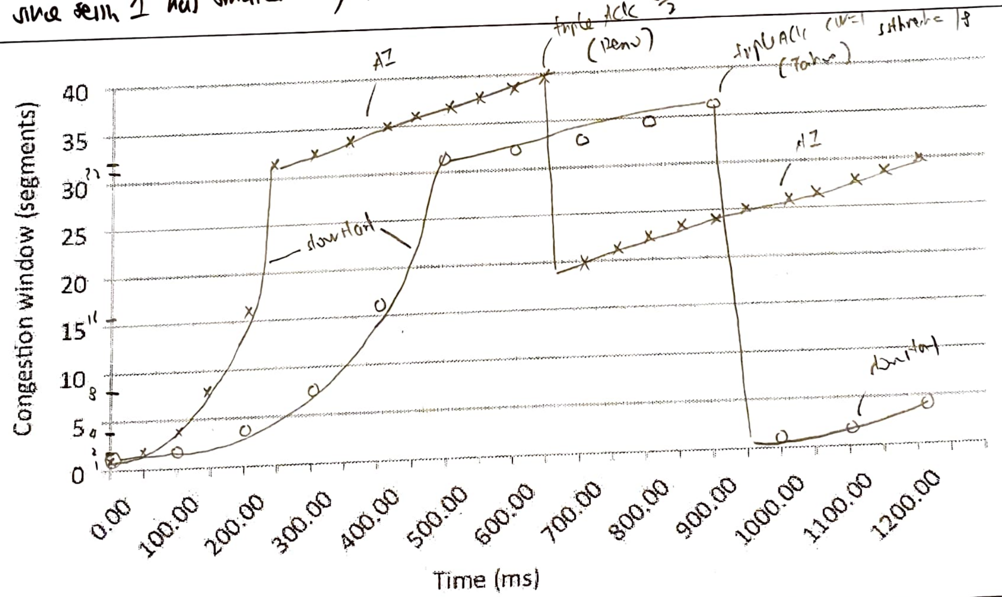
(i) Session 1 : RTT = (10+10+5)×2 = 50ms

Session 2 : RTT = (10+10+15+15)×2 = 100ms

since TCP is fair with equal distribution, with both sharing link between Router 1 and 2 throughput is determined by inverse relationship with RTT

since session 1 has smaller RTT, it has higher throughput

(ii)



x session 1
o session 2

(iii) ① increase the window size of TCP session 1

② open more connections between source A and sink B

Q.4(b) Consider a class of 125 NUS students joining a remote learning session hosted on campus. Each student initiates a TCP connection to the NUS and therefore shares a common bottleneck link. Assume that NUS has set up a fractional T1 line with a capacity of 800 Mbps. Assume that all packet loss occurs at just the bottleneck link. The round-trip times, RTT, for all sessions are approximately the same and no other sessions are using the bottleneck link. Assuming the sessions have been running for a long time, what is the approximate throughput (in Mbps) of each of the TCP sessions? Briefly explain.

(5 marks)

Approximate throughput for each TCP session $= \frac{800 \text{ Mbps}}{125} = \underline{\underline{6.4 \text{ Mbps}}}$

Since TCP uses AIMD, hosts with higher share lose more proportionately when congestion occurs and throughput halved while all hosts increase throughput equally afterward.

Hence, in the long term, equilibrium will be reached where all hosts share resources equally.

Q.4(c) TCP and UDP provide very different service models.
(i) Name a service that both UDP and TCP provide.
(ii) Name a service that TCP provides but UDP does not provide.
(iii) Suppose an application does not want to use TCP at the transport layer. For example, the application may want reliable message transfer but not congestion control. How would you implement such customized service for the application?

(5 marks)

(i) Video streaming / conferencing

TCP behaviour becoming more current-like

(ii) File transfer where errors cannot be tolerated

(iii) Set window size to be minimum, don't change dynamically based on congestion

retransmit using stop and wait protocol

Q.4(d) Students S1 & S2 are connected to two different WiFi access points, and they are both using the same IP address.

(i) How can both students use the same IP address and how did they get that IP address?

(ii) Suppose S1 wants to connect to S2 using S2's MAC address. What protocol can S1 use to do this?

(iii) S1 and S2 are able to successfully initiate a network connection to each other. Explain how they could have done this. (5 marks)

(i)

IP address is allocated dynamically by server with DHCP

If S1 and S2 are both hiding behind 2 different NAT routers they may be assigned the same IP address in their LAN

There is no conflict since the address becomes unique after translation at NAT router to outside.

(ii)

Address resolution protocol ARP

(iii)

They could have done this through relaying so that connection can be made even without knowing local address,

THIS PAGE INTENTIONALLY LEFT BLANK

END OF PAPER