NAMIBIA UNIVERSITY
OF SCIENCE AND TECHNOLOGY

FACULTY OF COMPUTING AND INFORMATICS

DEPARTMENT OF COMPUTER SCIENCE

QUALIFICATION: BACHELOR OF COMPUTER SCIENCE HONOURS: COMMUNICATION NETWORKS	
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COURSE: BROADBAND NETWORKS	COURSE CODE: BBN810S
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DURATION: 3 HOURS	MARKS: 100

SECOND OPPORTUNITY / SUPPLEMENTARY EXAMINATION QUESTION PAPER	
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INSTRUCTIONS
1. Answer ALL the questions. 2. Write clearly and neatly. 3. Number the answers clearly.

THIS QUESTION PAPER CONSISTS OF 9 PAGES (Including this front page)

Question 1 [10 marks]

The Telecom operator implements an IP / MPLS / Ethernet network whose topology is given in figure. 1. Networks A, B, C, D and E are IP's networks

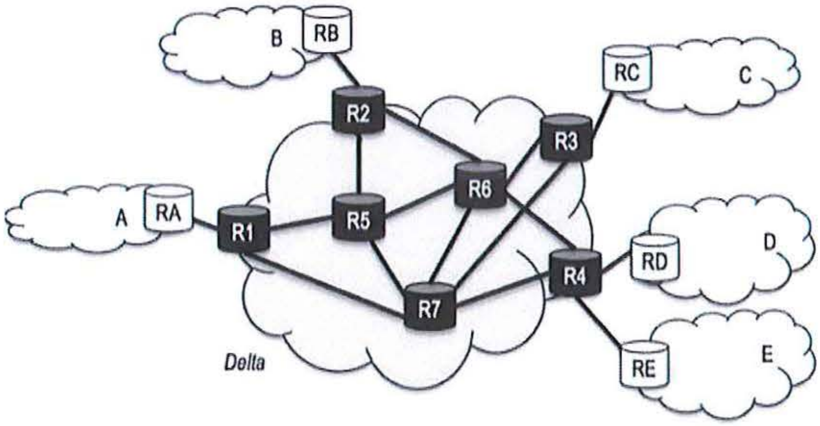


Figure 2. MPLS Network

The routing tables of the routers R1 to R7 are given in the Table 1.

It is assumed that the Telecom network administrator has enabled MPLS on his network. Equipment **R1** to **R7** are Label Switch Routers (LSP). (They switch packets using label. LSPs are built on demand; that is, we wait until the path is necessary to build it. The Delta network does not implement quality of service.

An IP packet is sent from a computer in **Network A** to another computer in **Network D**. The packet is forwarded by router **RA** via the Delta Network Router **R1**with a TTL of 40. Router R1 is the Border Router receiving the packet. It will trigger the creation of the LSP that will route the packets to **network D**. It is assumed that this LSP is the first created in the network.

Table 1. Routing Table

R1 Routing Table		
Dest.	NH	Cost
R2	R5	1
R3	R7	2
R4	R7	2
R5	R5	1
R6	R5	2
R7	R7	1
Network A	RA	1
Network B	R5	3
Network C	R7	4
Network D	R7	3
Network E	R7	3

R2 Routing Table		
Dest.	NH	Cost
R1	R5	2
R3	R6	2
R4	R6	2
R5	R5	1
R6	R6	1
R7	R5	2
Network A	R5	3
Network B	RB	1
Network C	R6	4
Network D	R6	3
Network E	R6	3

R3 Routing Table		
Dest.	NH	Cost
R1	R7	2
R2	R6	2
R4	R6	2
R5	R6	2
R6	R6	1
R7	R7	1
Network	R1	3
Network B	R4	3
Network C	R4	1
Network D	R1	3
Network E	R4	3

R4 Routing Table		
Dest.	NH	Cost
R1	R7	20
R2	R6	10
R3	R6	10
R4	R7	-
R5	R6	10
R6	R7	10
Network A	R7	20
Network B	R6	20
Network C	R6	20
Network D	RD	20
Network E	RE	10

R5 Routing Table		
Dest.	NH	Cost
R1	R1	30
R2	R2	20
R3	R6	20
R4	R6	10
R6	R6	-
R7	R7	20
Network A	R1	20
Network B	R2	10
Network C	R6	30
Network D	R6	40
Network E	R6	10

R6 Routing Table		
Dest.	NH	Cost
R1	R5	30
R2	R2	20
R3	R3	20
R4	R4	10
R5	R5	20
R6	R7	-
Network A	R1	10
Network B	R2	30
Network C	R3	30
Network D	R4	40
Network E	R4	10

R7 Routing Table		
Dest.	NH	Cost
R1	R1	1
R2	R5	2
R3	R3	1
R4	R4	1
R5	R5	1
R6	R6	1
Network A	R1	2
Network B	R5	3
Network C	R3	2
Network D	R4	2
Network E	R4	2

a)	Which router will choose the label to use on the LSP link at the exit of R1 (LSP R1 to R7) towards Network D?	**2 marks**
b)	Which LSR sent the packets to router R4 for the communication from R1 to D?	**2 marks**

c)	Which next hop is associated with these packets in the switching table of R4?	**2 marks**
d)	The switching table in R1 contains the following line: Entry Label | Next host | Release Label D | R7 | 5 In case the IP packet is to leave the Delta network, which router pops the MPLS header?	**2 marks**
e)	If packets leaving router R7 are labelled 9, draw the switching table of router R7.	**2 marks**

Table in d):

Entry Label	Next host	Release Label
D	R7	5

Question 2 [10 marks]

Consider the Figure 2. Suppose that the video is encoded at a fixed bit rate, and thus each video block contains video frames that are to be played out over the same fixed amount of time of 1 second. The server transmits the first video block at t0=0sec, the second block at t=1 sec, the third block at t=2 sec and so on. Once the client begins playout, each block should be played out 1second after the previous block

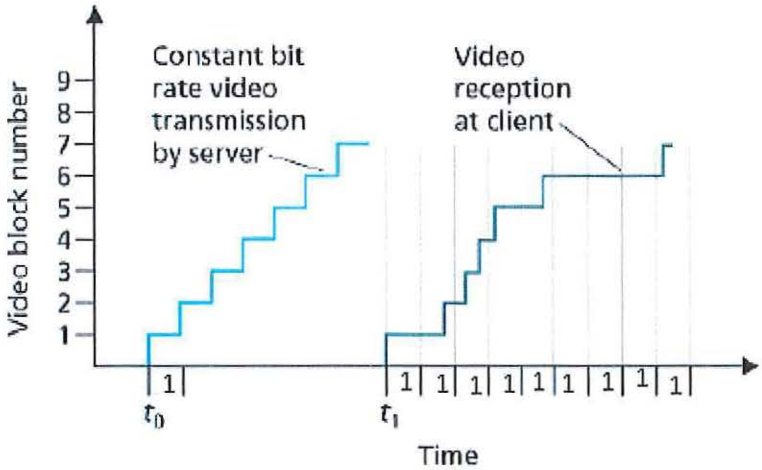


Figure 2. Video streaming transmission

a)	Suppose that the client begins playout as soon as the first block arrives at t1. In the figure below, how many blocks of video (including the first block) will have arrived at the client in time for their playout? Explain how you arrived at your answer.	**3 marks**
b)	Suppose that the client begins playout now at t1+1. How many blocks of video (including the first block) will have arrived at the client in time for their playout? Explain how you arrived at your answer.	**3 marks**

c)	In the same scenario at (b) above, what is the largest number of blocks that is ever stored in the client buffer, awaiting playout? Explain how you arrived at your answer.	**2 marks**
d)	What is the smallest playout delay at the client, such that every video block has arrived in time for its playout? Explain how you arrived at your	**2 marks**

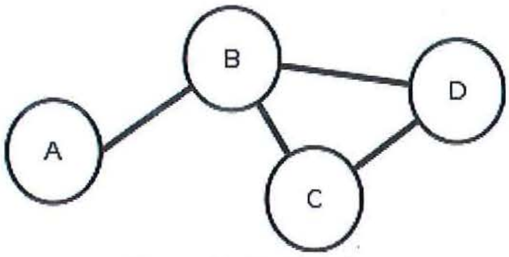
Question 3 [10 marks]		
In TCP the Retransmit Time-Out (RTO) is determined on the basis of RTT observations for arriving ACKs.		
a)	Measured RTT values are subject to considerable fluctuations. List three reasons that explain this phenomenon.	**3 marks**
b)	What is an optimal value of RTO for a TCP connection? Explain	**3 marks**
c)	What are the implications of a RTO that is too large or too small?	**4 marks**

Question 4 [12 marks]		
Compare Go-Back-N (GBN), Selective Repeat, and TCP (no delayed ACK). Assume that the timeout values for all three protocols are sufficiently long such that 5 consecutive data segments and their corresponding ACKs can be received (if not lost in the channel) by the receiving host (Host B) and the sending host (Host A) respectively. Suppose Host A sends 5 data segments to Host B, and the 2nd segment (sent from A) is lost. In the end, all 5 data segments have been correctly received by Host B.		
a)	How many segments has Host A sent in total and how many ACKs has Host B sent in total? What are their sequence numbers? Answer this question for all three protocols	**6 marks**
b)	If the timeout values for all three protocol are much longer than 5 RTT, then which protocol successfully delivers all five data segments in shortest time interval?	**6 marks**

Question 5 [10 marks]		
a)	What percentage of an ATM link's total bandwidth is consumed by the ATM cell headers? [1 mark]	**3 marks**

b)	The IP-datagram for a TCP ACK message is 40 bytes long: it contains 20 bytes of TCP header and 20 bytes of IP header. Assume that this ACK is traversing an ATM network that uses AAL5 to encapsulate IP packets. How many ATM packets will it take to carry the ACK? [2 marks]	**3 marks**
c)	Cell switching methods essentially always use virtual circuit routing rather than datagram routing. Give two arguments why this is so.	**4 marks**

Question 6 [22 marks]		
a)	Consider a TCP connection between Host A and Host B. Suppose that the TCP segments travelling from Host A to Host B have source port number x and destination port number y. What are the source and destination port numbers for the segments travelling from Host B to Host A?	**2 marks**
b)	Suppose two hosts, A and B, are separated by 10,000 kilometers and are connected by a direct link of bandwidth equal to 1 Mbps. Suppose the propagation speed over the link is 2.5x108 meters/sec. What is the maximum number of bits that can be in the link at any given time?	**3 marks**
c)	In packet switching, differentiate between networks with virtual circuits (VCs) and networks with datagram	**2 marks**
d)	What characteristic of the network would you care most about to get good performance for the following activity: hint (jitter, low delay and high bandwidth). Explain your answer (1) ***Navigating a predominantly text-only website.*** ***(2) Downloading a large video file*** ***(3) A remote shell application (such as telnet or SSH).***	**6 marks**
e)	Emerging technologies used for better network survivability include ATM. What does ATM stand for?	**1 marks**
f)	Why does the TCP congestion control mechanism have a "slow-start" and a "congestion avoidance" phase?	**2 marks**

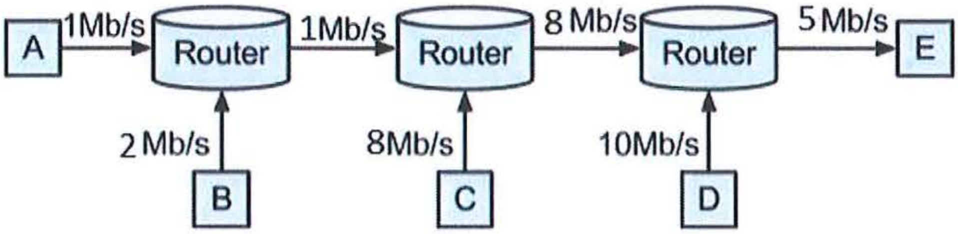
g)	In figure 3, A, B, C and D are Autonomous Systems (AS's) that talk to each other using an external routing protocol.  Figure 3. AS Topology **(A,B)** and **(C,D)** are peering relationships, while B provides transit service to C and D. Which path, traffic from D to B cannot follow to reach autonomous?	**2 marks**
h)	Describe the role and significance of Autonomous System (AS) numbers in the context of internet routing. Detail how AS numbers are assigned and utilized in the operation of Border Gateway Protocol (BGP).	**4 marks**

Question 7 [8 marks]

Suppose that a router has three input flows and one output port. It receives packets continuously as per table below, with all flows beginning at the same time and queues being empty before the arrival of the first packet. Packets order in each separate flow is listed in the table (packets 1 and 2 are the first to arrive). Length represents the number of clock ticks it takes to transmit a packet

Packet ID	Flow	Length	Arrival time
P1	1	1000	0
P2	1	1000	0
P3	2	600	800
P4	2	400	800
P5	2	400	800
P6	3	200	1200
P7	3	200	2100

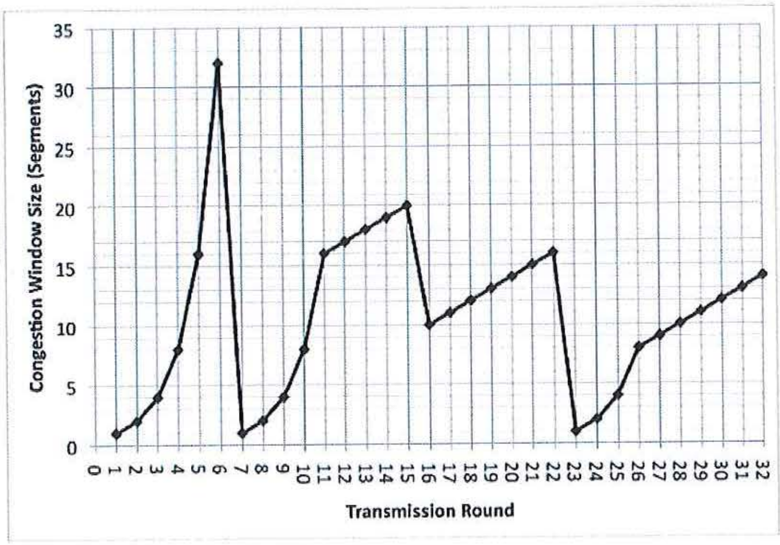
a)	Determine the order in which packets are transmitted by the router if Fair queuing is used.	**4 marks**
b)	Determine the order in which packets are transmitted by the router if weighted Fair queuing is used, with flow 1 has a weight of 2, and flow 2 and 3 each a weight of 1.	**4 marks**

Question 8 [6 marks]	
In the topology in Figure 4, **A, B, C** and **D** are different hosts that all wish to send at the maximum possible rate to host **E**. The arrows are links, and the numbers denote link capacities. The network operator would like to assign to hosts the transmission rates that satisfy the max-min fairness. Note that an allocation is max-min fair if you cannot increase the rate of one flow without decreasing the rate of another flow with lower rate.  Figure 4. Network Topology	
(a) How should transmission rate be assigned to nodes A, B, C and D so as to satisfy the max-min fairness principle?	**4 marks**
(b) You are hired to design a reliable byte-stream protocol that uses sliding window (like TCP). This protocol will run over a 100 Mbps network link. The RTT of the network is 100ms, and the maximum segment lifetime is 60sec.	**2 marks**

Question 9 [8 marks]		
Suppose you are designing a sliding window protocol for a 1 Mbps p-to-p link to the moon, which has a one-way latency of 1.25 seconds. Assuming that each frame carries 1 KB of data		
(a)	Find the window size of the protocol based on the bandwidth-delay product	**4 marks**
(b)	What is the minimum number of bits you need for the sequence number field	**2 marks**
(c)	Calculate the round-trip time (RTT) for transmitting a frame from Earth to the moon and back, considering the given one-way latency of 1.25 seconds.	**2 marks**

Question 10 [14 marks]

The Transmission Control Protocol uses a method called congestion control to regulate the traffic entering the network. The behavior of TCP congestion control can be represented as a graph in which the x-axis indicates the time, and the y-axis indicates congestion window size. Please use the graph shown below to answer the following questions. Note that the graph does not explicitly show timeouts, but you should be able to figure out when timeouts happened based on the events shown.



a)	Give two reasons why slow start is used, and explain why it does a better job than congestion avoidance	**2 marks**
b)	Identify the intervals of time when TCP slow start is operating. For each interval, identify which of the above	**2 marks**
c)	Identify the intervals of time when TCP congestion avoidance is operating. Why congestion avoidance should be used instead of slow	**2 marks**
d)	Identify the intervals of time when TCP fast retransmission is used. Please explain what fast retransmission does	**2 marks**
e)	Identify the intervals of time when TCP fast recovery is operating. What does fast recovery do and explain why is	**2 marks**
f)	Identify the interval(s) of time when fast recovery could have happened, but did not. Identify one specific	**2 marks**
g)	Which version of TCP is represented in this Figure?	**2 marks**

=========================**End of Examination**===================