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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FIRST OPPORTUNITY 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 13 PAGES (Including this front page)

QUESTION 1 [15 marks]

a) Give an example of an application-level requirement that might take advantage of the drop priority field in an ATM cell? List three reasons explaining your answer. [2 marks]

b) Why will two ISPs at the same level of the hierarchy often peer with each other? [2 marks]

c) How does an IXP earn money? [2 marks]

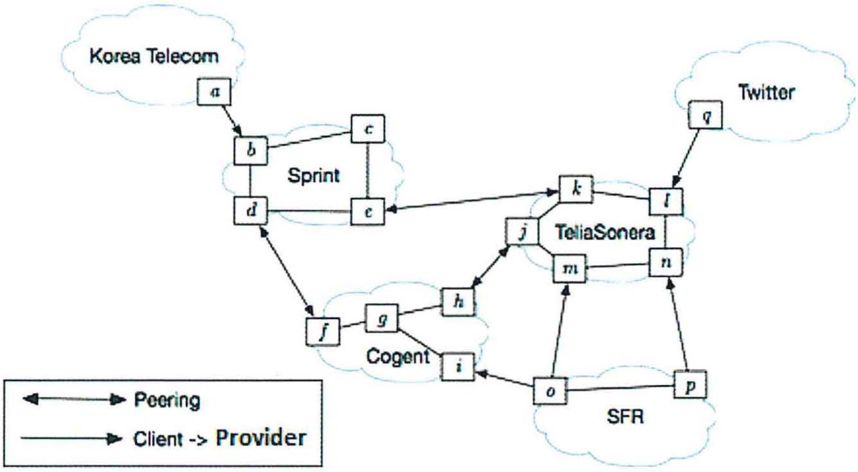
d) Name four features of Multi-Protocol Label Switching explaining your answer. [4 marks]

e) Many Internet companies today provide streaming video, including YouTube, Netflix, and Hulu. What are the three features that characterized streaming video applications? [3 marks]

f) Since 2009, AS numbers are coded using the X.Y format, where X and Y are integer's number coded with 16-bits each. With this representation, how many AS numbers are possible? [2 marks]

QUESTION 2 [8 marks]

We consider a set of autonomous systems as shown in the figure 2. The relationships between these autonomous systems are of the peering or transit type (customer to provider). The letters **a** to **q** represent any IP equipment on the networks of each of these autonomous systems. We assume that only the type of service agreement between autonomous systems governs routing: no other decision criteria are taken into account in the routing selection. Looking at the topology in figure 2, answer the questions below. Note that a question may have more than one answer.



1) Looking at the network topology, and the service agreement between Korea Telecom and Sprint, what can deduct? [2 mark]

Korea Telecom is billed for the volume of traffic sent and received from Sprint.	
Sprint is billed for the volume of traffic sent and received from Korea Telecom.	
Traffic exchanged between Korea Telecom and Sprint is not billed.	
Sprint routes traffic from Korea Telecom to the rest of the Internet.	

2) According to the proposed network topology, and the service agreement between Sprint and TeliaSonera, what can you deduct [2 marks]

Sprint is billed for the volume of traffic exchanged with TeliaSonera.	
TeliaSonera routes traffic from Sprint to Cogent.	
TeliaSonera routes traffic from Sprint to Twitter.	
The exchange of traffic between Sprint and TeliaSonera is not invoiced.	

3) For a communication from Korea Telecom to Twitter, what are the paths that respect the service agreements between the autonomous systems? [2 mark]

Korea Telecom -> Sprint -> TeliaSonera-> Twitter	
Cogent -> Sprint->Cogent->TeliaSonera->Twitter	
Cogent -> Sprint->Cogent->SFR->TeliaSonera->Twitter	
Korea Telecom->Sprint-> TeliaSonera -> Cogent -> Twitter	

4) For a communication from Twitter to Cogent, what is the path that respects the service agreements between the autonomous systems? [2 marks]

Twitter -> TeliaSonera -> Cogent	
Twitter -> TeliaSonera -> Sprint -> Cogent	
Twitter -> TeliaSonera -> SFR -> Cogent	
Twitter -> TeliaSonera -> SFR-> SFR -> Sprint -> Cogent	

QUESTION 3 [6 marks]

The measurements available on the CAIDA AS Rank ranking site reveal the properties of three autonomous systems (ASs), Level3, Renater and Irisa. On the CAIDA web page corresponding to the three ASs (see Table 1), we can identify the number of neighbours under the heading "AS degree" and the term "global". These neighbours can be Internet service providers, AS with a peering agreement, or customers. Looking at the information providing on the table of each of the AS, answer the following questions.

CAIDA DATA FOR Level 3					
AS number	3356				
AS Name	Level3				
Organisation	Level 3 Parent, LLC				
Country	USA				
AS rank	1				
Customer cone	48548 asn	740857 prefix	191119864 address		
AS degree	6322 global	63220 transit	0 provider	67 peer	6255 customer

CAIDA DATA FOR RENATER					
AS number	2200				
AS name	FR-RENATER				
Ogarnisation	RENATER				
Country	European Union				
AS rank	683				
Customer cone	51 asn	296 prefix	1074176 address		
AS degree	81 global	80 transit	4 provider	38 peer	39 customer

CAIDA DATA FOR IRISA					
AS number	1938				
AS Name	FR-RENATER-IRISA				
Ogarnisation	RENATER				
Country	European Union				
AS rank	13236				
Customer cone	1 asn	1 prefix	65536 address		
AS degree	1 global	0 transit	1 provider	0 peer	0 customer

a) In which Tier will you categorize AS Level3? [2 marks]

b) In which AS tier will you categorize AS RENATER? [2marks]

c) In which AS Tier will you categorize AS IRISA? [2 marks]

QUESTION 4 [8 marks]

Consider the figure below. 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.

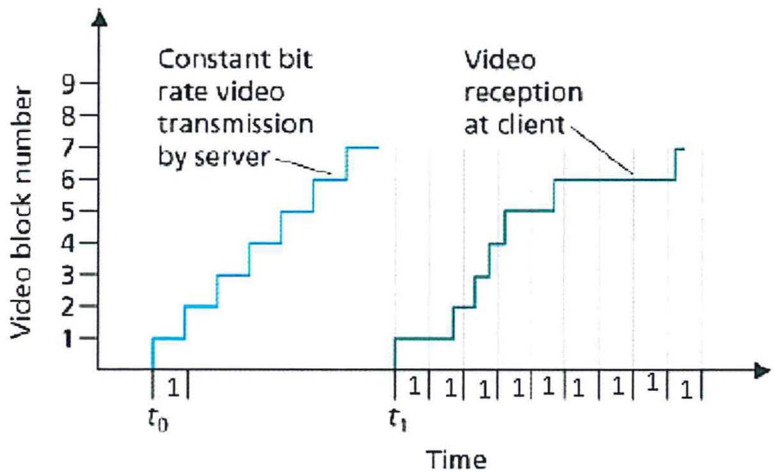


Figure 1. Video streaming transmission

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. [2 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. [2 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 answer. [2 marks]

QUESTION 5 [5 marks]

Suppose that a router has three input flows and one output port. It receives packets continuously as per table 1, with all flows beginning at the same time and queues being empty before the arrival of the first packet. Packets in each separate flow are listed in the order they are received at the router. For example, packets 1, 3 and 6 are the first to arrive. Length represents the number of clock ticks it takes to transmit a packet.

Table 1. Queuing Router

Packet id	Length	Flow
1	200	1
2	200	1
3	160	2
4	120	2
5	160	2
6	210	3
7	150	3
8	90	3

Determine the order in which packets are transmitted by the router if Weighted fair queuing is used, with flow 2 having weight 2, and the other two with weight 1: [5marks]

QUESTION 6 [8 marks]

a) Assume that an application transmits a 100-byte IP to an ATM network over a local loop using the ADSL protocol stack. At the ATM network, if the edge switch that process the packet uses the ATM Adaptation Layer 3/4, how many ATM cells are transmitted? [4 marks]

b) What percentage of an ATM link's total bandwidth, the payload bits consumes in ATM networks? [4 marks]

QUESTION 7 [5 marks]

You are hired to design a reliable byte-stream protocol that uses a sliding window (like TCP). This protocol will run over a 100-Mbps network. The RTT of the network is 100 ms, and the maximum segment lifetime is 60 seconds.

(a) How many bits would you include in the AdvertisedWindow of your protocol header? [3 marks]

(b) How many bits would you include in SequenceNum fields, assuming a minimum packet size of 40 bytes? [2 marks]

QUESTION 8 [11 marks]

The Google network operator implements an IP / MPLS / Ethernet network whose topology is given in figure 2. Networks A, B, C, D and E are IP's networks.

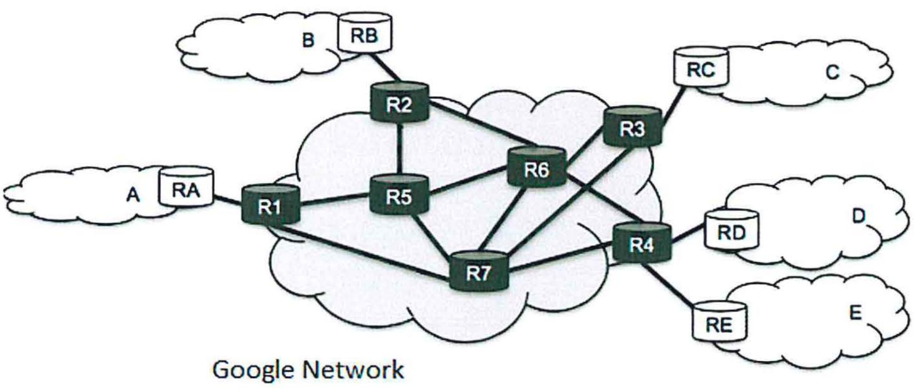


Figure 2. MPLS Network

The routing tables of the routers R1 to R7 are given in the Table 2.

Table 2. 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

It is assumed that the Google network administrator has enabled MPLS on his network. Equipment R1 to R7 are Label Switch Routers (LSP). LSPs are built on demand; that is, we wait until the path is necessary to build it. The Google 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 Google 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.

a) Which router will decide the label to use when a packet exits the LSP link R1 -R7 towards Network D? [2 marks]

b) The switching table in R1 contains the following line: [2 marks]

Entry Label	Next host	Release Label
D	R7	5

In case the IP packet is to leave the Google network, which router pops the MPLS header?

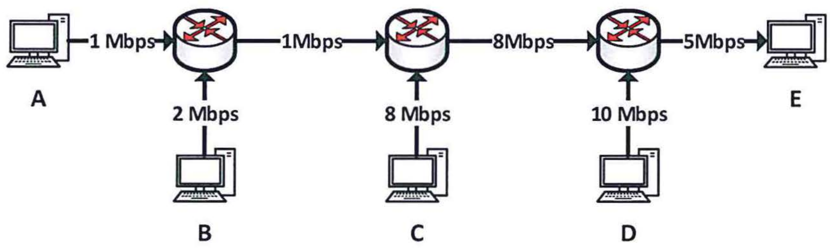
c) Which LSR sent the packets to router R4 for the communication from R1 to D? [2 marks]

d) Which next hop is associated with these packets in the switching table of R4? [2 marks]

e) If packets leaving router R7 are labelled 9, draw the switching table of router R7. [3 marks]

QUESTION 9 [12 marks]

a) In the network topology in figure 3, A, B, C and D are different hosts that all want to send traffic at the maximum possible rate to host E. The arrows are links, and the numbers on the arrows represent the capacities of the links. How should the network administrator allocate the transmission rate to nodes A, B, C and D to satisfy the max-min fairness principle? [Hint: 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. [8 marks]



b) Assume a link of capacity 10 Mbps that is traversed by four flows with arrival rates of 6, 4, 2, and 1 Mbps, respectively. How much bandwidth will each flow get if the max-min principle is applied? (Show all your calculations.) [4 marks]

QUESTION 10 [10 marks]

Using the network in Figure 2, give the virtual circuit tables for all the switches after each of the following connections is established. Assume that the sequence of connections is cumulative; that is the first connection is still up when the second connection is being established and so on. Also assume that the VCI assignment always picks the lowest unused VCI on each link, starting with 0.

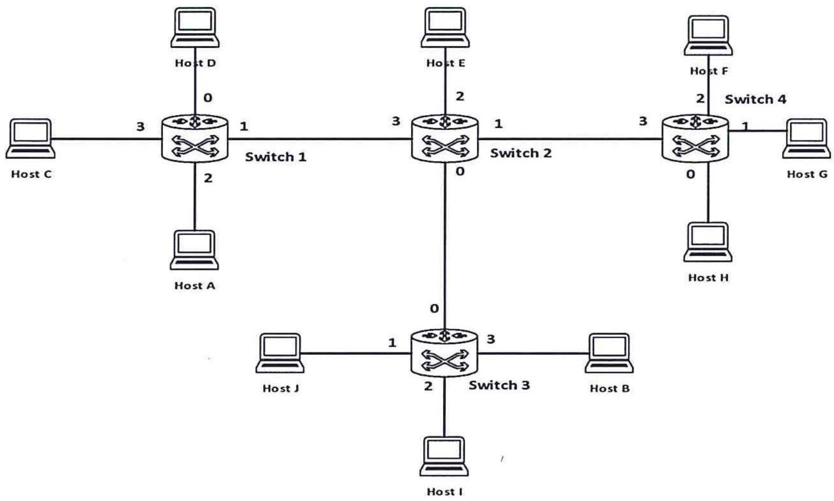


Figure 2. Virtual Circuit Network

1) Host D connects to host H (2 marks)
2) Host B connects to host G (2 marks)
3) Host F connects to host A (2 marks)
4) Host H connects to host C (2 marks)
5) Host I connects to host E (2 marks)

QUESTION 11 [16 marks]

Consider two hosts A and B that communicate via a router R. The link **(A, R)** has infinite bandwidth: packets experience no delay on this link. The link **(R, B)** has finite bandwidth: the packet transmission rate on the **link (R, B)** is 1 packet per second. However, acknowledgements from **B** to **R** are sent instantaneously, as are ACKs from R to A. Host A sends data to host B over a TCP connection using slow start but with an arbitrarily large window size. Router R has a queue size of 1 packet in addition to the packet that router R is transmitting on the outbound link (R, B). Consider the timeline illustrated in the Table 1. Time advances in units of 1 second. At each second the sender first processes any arriving ACKs and then responds to any timeouts. Assume that the timeout period T is 2 seconds. Figure 1 shows the items sent and received during the period T = 1, 2. . . 7 seconds.

Note that in this table, it is assumed that when TCP encounters a timeout it reverts to stop-and-wait as the outstanding lost packets in the existing window are re-transmitted one at a time, and that the slow start phase will begin again only when the existing window is fully acknowledged. Note too that once a timeout and re-transmission is pending, subsequent timeouts of later packets are ignored until their earlier acknowledgment is received.
Answer the following questions concerning the timeline illustrated in Table 1. [16 marks].

Table 1. TCP Timeline

Time T	A receives	A sends	R sends	cwnd
0		data0 (slow start)	data0	1
1	ack0	data1, data2	data1	2
2	ack1	data3, data4 (data4 dropped)	data2	3
3	ack2	data5, data6 (data6 dropped)	data3	4
4	ack3 (timeout data4)	data4	data5	1
5	ack3 (timeout data5, data6)		data4	1
6	ack5	data6	data6	1
7	ack6	data7, data8 (slow start)	data7	2

a) At time T = 2: why is packet data4 dropped? [2 marks]

b) At time T = 2: why are only 2 packets data3 and data4 sent even though cwnd=3? [2 marks]

c) At time T = 3: why are only 2 packets data5 and data6 sent even though cwnd=4? [2 marks]

d) At time T = 3: why is data6 dropped? [2 marks]

e) At time T = 4: why does a timeout occur? [2 marks]

f) At time T = 5: why does A receive ack3 even though data5 was received at B at the previous step? [2 marks]

g) At time T = 5: why do 2 timeouts occur? [2 marks]

h) At time T = 6: why does A receive ack5 even though data4 was received at B at the previous step? [2 marks]

Question 12 [6 marks]

a) A client initiates a TCP connection setup with a server by sending a SYN message, and immediately dies (crashes). A while later, the SYN message reaches the server, and it sends a SYNACK in response. Is the TCP connection now established from the server's point of view? Explain. [2 marks]

b) What is the difference between the flow control and congestion control mechanisms provided by TCP? [2 marks]

c) Why does the TCP congestion control mechanism have a "slow-start" and a "congestion avoidance" phase? [2 marks]

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