Q1
A multiplexer combines five 400 kbps channels A, B, C, D, E (see Figure 1 below). Each frame has 1 synchronisation bit added to the beginning of the frame and has slot size of 5 bits. Synchronous time division multiplexing will start from Channel A, then B, C, D, E and then back to channel A, then B, C, D, E and so on...

A. Draw a diagram to show the content of the first two frames of the output for the inputs as shown in Figure 1. In your diagram, for each frame, show all the slots containing bits of each channel and the synchronisation bit. **(2 marks)** (It is up to you to choose what sync bit for each frame, as long as there is 1 sync bit at the beginning of each frame. The data generated by each channel is shown in Figure 1)

B. What is the frame rate (frame per second) **(1 mark)** and the frame duration (in microsecond)

C. What is the bit rate (bps) of the MUX output link?

Q2

i. suppose frame are 600bytes long which includes 47 bytes of overhead, also assume that ACK is 78 bytes long

a. The transmission uses Stop-and-Wait ARQ. Let the transmission rate of the system be R where R = 1.5 Mbps. For convenience calculation, the Processing Times at each end is 1.2 ms. Calculate the efficiency of the system if RTT takes the following values: 1.5 ms, 13 ms, 117 ms, and 1.25 seconds.

b. Repeat if R = 1.5 Gbps. **(4 marks)**

[Note: this question can give some very small numbers. Round your results up to 5 decimal places if possible] 1 Mbps = 1,000,000 bps 1 Gbps = 1,000,000,000 bps

II. Three ARQ protocols are covered in this course. Discuss how each ARQ protocol will respond when it detects a frame with errors? Explain how recovery is achieved.

III In a Stop-and-Wait ARQ system, the bandwidth of the line is 512 kbps, and 1 bit takes 37 ms to make a round trip.

a. What is the bandwidth-delay product?

b. If the system data frames are 128 bytes in length, what is the utilization percentage of the

link as estimated from the BDP in (a).

c. What is the utilization percentage of the link if the link uses Go-Back- N ARQ with window

size of 9?

Q3

I. **Assumption**: Network is in good condition and diameter has been calculated accurately.
Yes flooding the network with the packets having a TTL or Hop Count of the diameter will ensure the packet reaches its destination at least once, however if the longest path has been calculated incorrectly or a node is down, it is possible that the packet may not reach its destination

II. Consider the network shown in Figure 2

a. Using Dijkstra's algorithm, compute the shortest paths from node H to all other network nodes showing your work in a table

H	G	B	F	D	E	A	C
0	5|H	10|H	∞	∞	∞	∞	∞
0	5|H	7|G	11|G	9|G	∞	∞	∞
0	5|H	7|G	11|G	9|G	∞	14|B	8|B
0	5|H	7|G	11|G	9|G	10|C	12|C	8|B
0	5|H	7|G	11|G	9|G	10|C	12|C	8|B
0	5|H	7|G	11|G	9|G	10|C	12|C	8|B
0	5|H	7|G	11|G	9|G	10|C	12|C	8|B
0	5|H	7|G	11|G	9|G	10|C	12|C	8|B

b. Using Bellman-Ford algorithm, compute the shortest paths from H to all network nodes showing your work in a table.

	H	G	B	F	D	E	A	C
Iteration 1	0	5|H	10|H	∞	∞	∞	∞	∞
Iteration 2	0	5|H	7|G	11|G	9|G	∞	∞	∞
Iteration 3	0	5|H	7|G	11|G	9|G	14|D	17|B	8|B
Iteration 4	0	5|H	7|G	11|G	9|G	12|F	17|B	8|B
Iteration 5	0	5|H	7|G	11|G	9|G	12|F	17|B	8|B
Iteration 6	0	5|H	7|G	11|G	9|G	12|F	17|B	8|B
Iteration 7	0	5|H	7|G	11|G	9|G	10|C	12|C	8|B

Q4

a) What is the maximum number of stations, N, that can be supported by the current design in Figure 3?

Operating Rate x 0.(Efficiency) = Effective Rate
Effective Rate/R = Number of Stations

270Mbps x 0.33 = 89.10Mbps
89.10Mbps / 4Mbps = 22 Stations (22.275 Stations)

b) To increase the number of nodes on the network, it is proposed to reduce R by half and re-design the network. The new proposed design is shown in Figure 4. Calculate the number of nodes N that can be supported.

270Mbps x 0.33 = 89.10Mbps
89.10Mbps / 2Mbps = 44 Stations (44.55 Stations)

c) The Accountant thinks he knows a bit about data networking and can see a way to redesign the network re-use existing equipment, saving money. He claims that in his solution, R remains the same thereby saving even more money. Analyse his design shown in Figure 5 and calculate how many nodes can be supported.

Q5

i. Consider an application that transmits data at a steady rate (for example, the sender generates an N-bit unit of data every k time units, where k is small and fixed). Also, when such an application starts, it will continue running for a relatively long period of time. Answer the following questions briefly justifying your answer:

a. *Would a packet-switched or circuit-switched network be more appropriate for the application? Why?*

Packet Switched network would be beneficial, circuit switched networks require a dedicated circuit between the sender and receiver, even if data is not being sent, if the connection is open. However, packet switched would pass the data to where it's needed without wasting resources by keeping a circuit open when data is not being transmitted

Should the data being sent not utilise all of the bandwidth on a particular circuit that available bandwidth cannot be used by another signal, with packet switching this would not be the case.

b. *Suppose that a packet-switched network is used and the only traffic in this network comes from such applications as described above. Furthermore, assume that the sum of the application data rates is less than the capacities of each and every link. Is some form of congestion control needed? Why?*

In this situation, congestion control probably wouldn't be needed as, each link is capable of supporting the entire network traffic, however it would still be recommended, if something was to go wrong such as line/equipment degradation or the data being sent or even the number of data lines increased, there could be issues.

ii. Recall that ATM uses 53-byte packets consisting of five header bytes and 48 payload bytes. 53 bytes is unusually small for fixed-length packets; most networking protocols (IP, Ethernet, Frame Relay etc.) use packets that are, on average, significantly larger. One of the drawbacks of a small packet size is that a large fraction of link bandwidth is consumed by overhead bytes; in case of ATM, almost 10% of the bandwidth is "wasted" by the ATM header. In this question, we investigate why such a small packet size was chosen.

The first question asks you to construct a formula for Packetization delay.

a. Let the payload of a cell/packet be P bytes. Consider a digitally encoded voice source encoded at a constant rate of 32 kbps. Assume each cell/packet is entirely filled before the cell/packet is sent into the network. Derive a formula for calculating the packetization delay in millisecond, in terms of P.

Packetization Delay = Packet Size / Transmission Rate (bits/s)

D = P/R (bits/s)

b. Use the formula derived in part (a) to determine the packetization delay in millisecond for

i. P = 1,500 bytes (corresponding to a large Ethernet packet payload)

Rate 32kbps = 4000 bytes/sec

Delay = 1500bytes/4000 bytes/sec

= 0.37 5 seconds

= 375 milliseconds

ii. P = 48 bytes (corresponding to an ATM cell payload)

Delay = 48bytes/4000bytes/sec

= 0.012 seconds

= 12 milliseconds

c. A transmission link has a data rate of R=189 Mbps. Calculate the transmission delay in microsecond for:

Rate 189Mbps = 23 625 000

i. L = 1,500 bytes

Delay = 1 500/23 625 000
= 0.0000634920634920635 seconds
= 63.492 microseconds

ii. L = 48 bytes

Delay = 48/23 625 000
= 0.00000203174603174603 seconds
= 2.032 microseconds

d. *Comment on the advantages of using a small ATM cell.*

Using small ATM cell, provides a uniform frame size making reshuffling easy, because of its small size individual packets are transported a lot faster, both of these allow for greater speed and flexibility.