**Full Marks: 30**                                                                    **Time: 1 hour**

*All parts of the same question must be answered together*
*Be precise in your answers, and state any assumptions made*

Question 1 [5(2.5+1.5+1)+3+3 = 11 marks]

(a) You are asked to design an application-level protocol to be used between an automatic teller machine and a bank's centralized computer. Your application should allow a user's card and pin to be verified, the account balance (maintained at the centralized computer) to be queried, and money withdrawal to be made. You also need to handle the case when there is not enough money to cover the withdrawal. Explain your protocol by listing the messages that need to be exchanged between the automatic teller machine and the centralized computer. Can you create a common message format to cover all these messages and potentially generalize to additional use cases? What would be your underlying end-to-end transport service, and why?

(b) Consider an application that transmits data at a steady rate N bit per second and once started, it continues running for a relatively long period of time. Which among a packet-switched network or a circuit-switched network be more appropriate for this application? Why? If the sum of all application data rates is less than the capacities of every link, will some form of congestion control be needed? Why?

(c) Host A is sending real-time voice to Host B over a packet-switched network (VoIP). Host A converts analog voice to a digital 64 kbps bit stream on the fly, and then groups the bits into 56-byte packets. As soon as Host B receives a packet, it converts the packet's bits to analog voice signal. These packets travel over three links, connected by two packet switches. If the propagation speed on all three links is $2.5 \times 10^8$ m/s, the transmission rates of all three links are 2.5 Mbps, the packet switch processing delay is 3 msec, the length of the first link is 5000 km, second link is 4000 km and the last link is 1000 km, what is the end-to-end delay for a packet to travel from Host A to Host B? Show all calculation steps.

Question 2 [3+3+3 = 9 marks]

(a) Consider the Go Back N protocol with sender window size of 8 and sequence number range of 512. At time t, the next in-order packet that the receiver is expecting has a sequence number of k. Assume that the medium does not reorder messages. What are the possible sets of sequence numbers inside the sender's window at time t? Justify your answer.

(b) Akamai is a content delivery network. It places its content servers inside the networks of regional ISPs. An ISP like Airtel may have an Akamai server inside its network, and similarly Jio may also have an Akamai server inside its network. Suppose a content provider like Facebook wants to use Akamai services. How can Facebook indicate to clients to download content from the content delivery network instead of Facebook servers? Explain the steps clearly.

(c) Two applications in Host A and B are communicating over a TCP connection. Suppose that Host B has already received from A all bytes till byte 56. Host A then sends two segments to Host B back-to-back. The first and

second segments contain 44 and 62 bytes of data, respectively. In the first segment, the sequence number is 57, source and destination port numbers are 23968 and 35092. Host B sends an acknowledgment whenever it receives a segment from Host A.

 i. In the second segment sent from Host A to B, what will be the sequence number, source port number, and destination port number?

 ii. If the first segment arrives before the second segment, in the acknowledgment of the first arriving segment, what is the acknowledgment number, the source port number, and the destination port number?

 iii. If the second segment arrives before the first segment, in the acknowledgment of the first arriving segment, what is the acknowledgment number?

Question 3 [3+2+3+2 = 10 marks]

(a) Your IP address is 100.100.100.100. A wireshark output indicates that you have received an HTTP packet on port 34262 from IP address 200.200.200.200 with a remaining TTL value of 35. The application data is "HTTP/1.1 200 OK\r\n Content-Length: 31\r\n <html><p>Hello There!</p></html>". Using all these information, fill in the appropriate header fields below.

| Network Layer | Transport Layer | Application Layer |
|---|---|---|
| | | |

(b) Consider a datagram network using 12-bit host addresses. Suppose a router uses longest prefix matching and has the following forwarding table. For each of the four interfaces, give the associated range of destination addresses and number of addresses in the range.

| Prefix Match | Interface |
|---|---|
| 01 | 1 |
| 010 | 2 |
| 0101 | 3 |
| otherwise | 0 |

(c) Consider an instance of TCP's congestion control algorithm where the initial window size is set as 2 MSS and the threshold at the start of first transmission is 8 MSS. Assume that a timeout occurs during the fifth transmission. What would be the congestion window size at the end of tenth transmission? Show all intermediate steps.

(d) Consider a router that interconnects 3 subnets: Subnet 1, Subnet 2, and Subnet 3. Suppose all interfaces in each of these three subnets are required to have the prefix 223.1.17. Also suppose that Subnet 1 is required to support at least 60 interfaces, Subnet 2 is to support at least 90 interfaces, and Subnet 3 is to support at least 12 interfaces. Provide three network addresses (of the form a.b.c.d/x) that satisfy these constraints.