1. Answer all the questions. [2x5]

a) What is the length of the data in the UDP header given in hexadecimal format CBS40050001F001F?

The UDP header length can be found from the header. The length field in the UDP header is included in the hexadecimal sequence. In this case, the length is given as 00F0 (in hexadecimal), which equals 240 bytes.

b) What is the destination port number in the UDP header CBS40050001F001F?

The destination port number is given by the second 16-bit field in the UDP header. In this hexadecimal sequence, the destination port is 0001, which is 1 in decimal.

c) Consider 2 computers x and y connected by a single line of bandwidth 512 Mbps. Let the propagation speed be 2x10^8 meters per second. If the packet length is 1 KB, calculate the distance between x and y if the propagation delay is the same as the transmission delay.

The transmission delay can be calculated using the formula:

$$\text{Transmission Delay} = \frac{\text{Packet Length}}{\text{Bandwidth}} = \frac{1\ \text{KB}}{512\ \text{Mbps}} = \frac{8192\ \text{bits}}{512 \times 10^6\ \text{bits/sec}} \approx 16\ \text{microseconds}$$

Since the propagation delay is the same as the transmission delay:

$$\text{Distance} = \text{Propagation Speed} \times \text{Propagation Delay} = 2 \times 10^8\ \text{m/sec} \times 16 \times 10^{-6}\ \text{sec} = 3.2\ \text{km}$$

d) Why does TCP use a 32-bit sequence number in the TCP header? In TCP, how many sequence numbers are consumed by each of the following segments: ACK, SYN + ACK, FIN?

TCP uses a 32-bit sequence number to allow for a large number of unique sequence numbers to handle long-lived connections and ensure reliable data transfer.

- ACK: 0 sequence numbers are consumed.
- SYN + ACK: 1 sequence number is consumed.
- FIN: 1 sequence number is consumed.

e) Given a TCP header with a header length field value of 0111, calculate the actual length of the TCP header in bytes. How many bits of optional data are added with the header in this case?

The header length field value 0111 (binary) is 7 in decimal. The length is:

$$\text{TCP Header Length} = 7 \times 4 = 28 \text{ bytes}$$

The standard TCP header length is 20 bytes, so:

$$\text{Optional Data} = 28 - 20 = 8 \text{ bytes} = 64 \text{ bits}$$

f) In a network using the Go-Back-N protocol with m = 3 and the sending window size of 7, the values of variables are $S_{\square}$ = 62, S_1 = 66, and R_x = 64. Assume that the network does not duplicate or reorder the packets. What are the sequence numbers of data packets in transit?

For Go-Back-N protocol, the sequence numbers of data packets in transit are from:

$$S_n = 62 \text{ to } S_n + \text{window size} - 1 = 62 + 7 - 1 = 68$$

Thus, the sequence numbers in transit are 64, 65,

g) Station B needs to send a message consisting of 9 packets to Station C using a sliding window (window size 3) and Go-Back-N error control strategy. All packets are ready and immediately available for transmission. If every 5th packet that B transmits gets lost (but no ACKs from C ever get lost), then what is the number of packets that B will transmit for sending the message to C?

In the worst case, every 5th packet is lost, and the sender must retransmit starting from that packet. For 9 packets, the sender will:

Summary of Packets Sent:

1. **First transmission: P1, P2, P3 → 3 packets**
2. **Second transmission: P4, P5 (lost), P6 → 3 packets**
3. **Retransmission: P5, P6, P7 → 3 packets**
4. **Fourth transmission: P8 (lost), P9 → 2 packets**
5. **Retransmission: P8, P9 → 2 packets**
6. **Final adjustment due to retransmission of lost P9: 1 additional packet**

Total packets sent = 16.

h) What are the minimum functionalities that should be implemented by a transport protocol over and above the network protocol?

The transport protocol should implement:

1. Error Detection and Correction
2. Flow Control
3. Data Sequencing
4. Connection Establishment and Termination

i) A client uses UDP to send data to a server. The data is 16 bytes long. Calculate the efficiency of transmission at the UDP level.

The UDP header is 8 bytes. Therefore, the total size of the UDP packet is:

$$\text{Total Size} = \text{Data Size} + \text{UDP Header Size} = 16 + 8 = 24 \text{ bytes}$$

Efficiency of transmission:

$$\text{Efficiency} = \frac{\text{Data Size}}{\text{Total Size}} = \frac{16}{24} \approx 66.67\%$$

j) What would be the type of resource record (RR) that contains the canonical name of the host?

The type of resource record that contains the canonical name of the host is a CNAME (Canonical Name) Record.

k) In a client-server architecture, why is it necessary to keep the server always on whereas?

A server needs to be always on to respond to incoming requests and provide continuous service. If the server were off, clients would not be able to connect or get responses.

l) Consider an HTTP client that wants to retrieve a Web document at a given URL. The IP address of the HTTP server is initially unknown. What transport and application-layer protocols besides HTTP are needed in this scenario?

The necessary protocols are:

- Transport Layer Protocol: TCP
- Application Layer Protocol: DNS (Domain Name System)

m) “There are applications where using UDP is better than using TCP”. True or false? Justify your answer.

True. UDP is better for applications requiring low latency and where occasional data loss is acceptable, such as real-time applications (e.g., VoIP, live streaming) because it has lower overhead and no connection setup or maintenance.

n) If the value of the HLEN field is 1111, how many bytes of options are included in the TCP segment?

The HLEN field value 1111 (binary) is 15 in decimal. The length of the TCP header is:

$$\text{TCP Header Length} = 15 \times 4 = 60 \text{ bytes}$$

Options:

$$\text{Options} = 60 - 20 = 40 \text{ bytes}$$

o) Consider a TCP client and a TCP server running on two different machines. After completing data transfer, the TCP client calls close to terminate the connection and a FIN segment is sent to the TCP server. Server-side TCP responds by sending an ACK which is received by the client-side TCP. As per the TCP connections state diagram, in which state does the client-side TCP connection wait for the FIN from the server-side TCP?

The client-side TCP connection waits in the FIN-WAIT-1 state for the FIN from the server-side TCP.

p) Can a machine with a single DNS Name have multiple IP Addresses? How could this occur?

Yes, a single DNS name can have multiple IP addresses. This occurs through DNS load balancing where multiple IP addresses are associated with a single DNS name to distribute the load among different servers.

q) Write four types of records maintained by DNS. Write only one line about each.

1. A Record: Maps a domain name to an IPv4 address.
2. AAAA Record: Maps a domain name to an IPv6 address.
3. MX Record: Specifies the mail server responsible for receiving email.
4. CNAME Record: Alias for another domain name, providing the canonical name.

r) What is HTTP Cache? How is it helpful in addressing the stateless issue of HTTP?

HTTP Cache stores responses to HTTP requests to reduce load times and bandwidth usage. It helps address the stateless issue of HTTP by allowing the client and server to reuse previously retrieved responses.

s) What is In-band and out-of-band communication in FTP? Write the well-known ports used in FTP.

- In-band Communication: Data transfer occurs within the same connection used for control commands (port 21 for control).
- Out-of-band Communication: Data transfer occurs on a separate connection (port 20 for data).

t) In Go-Back-N protocol with m=6, the sending machine is in the ready state with S=10 and S_1=15. An ACK with ACKNo. =13 arrives. What are the next values of S□, S_1, and R_x?

For Go-Back-N protocol, the next values are:

$$S_n = \text{ACKNo.} = 13$$

$$S_1 = S_n + \text{Window Size} - 1 = 13 + 63 - 1 = 75$$

$$R_x = \text{Next Expected Sequence Number} = 14$$

u) If the value of the HLEN field in TCP is 1101, how many bytes of options are included in the segment? If this value is used in the total length field in UDP, how much data in bytes does the segment carry?

The HLEN value 1101 (binary) is 13 in decimal. The length of the TCP header is:

$$\text{TCP Header Length} = 13 \times 4 = 52 \text{ bytes}$$

Options:

$$\text{Options} = 52 - 20 = 32 \text{ bytes}$$

If this value (13) is used in the total length field in UDP, it refers to the length of the UDP packet:

$$\text{Total Length} = 13 \text{ bytes}$$

v) With a nonpersistent connection between the browser and the origin server, is it possible for a single TCP segment to carry a complete HTTP request message? Explain your answer.

Yes, it is possible. A single TCP segment can carry a complete HTTP request message if the message fits within the maximum segment size (MSS) of the TCP connection.

Long Question :
2023:
Q2 . [5+5 Marks]
A) A user is suppose to access a Web page. The IP address for the associated URL is not known to the Jocal host, so a DNS lookup is carried out to obtain the IP address. Suppose, n DNS servers are visited before your host receives the IP address from DNS; the successive visits incur an RTT of RTT1, .. , | RTTn. Further suppose that the Web page associated with the link contains exactly one object, consisting of a small amount of HTML text. Let RTTO denote the RTT between the local host and the server containing the object. Calculate the time elapses from when the client clicks on the link until the

client receives the object?
Ans :

A) To calculate the total time elapsed from when the client clicks on the link until the client receives the object, consider the following steps:

1. DNS Lookup Time:
○ The client needs to perform DNS lookups to resolve the IP address. If n DNS servers are visited, the time taken for these lookups will be the sum of the Round-Trip Times (RTTs) for each server.
○ Total DNS lookup time = RTT1 + RTT2 + ... + RTTn
2. Time to Fetch the Web Page Object:
○ After resolving the IP address, the client sends an HTTP request to the server and waits for the server's response.
○ This RTT is denoted as RTTO (Round-Trip Time between the client and the server).

The time elapsed from the client clicking the link until the client receives the object is therefore:

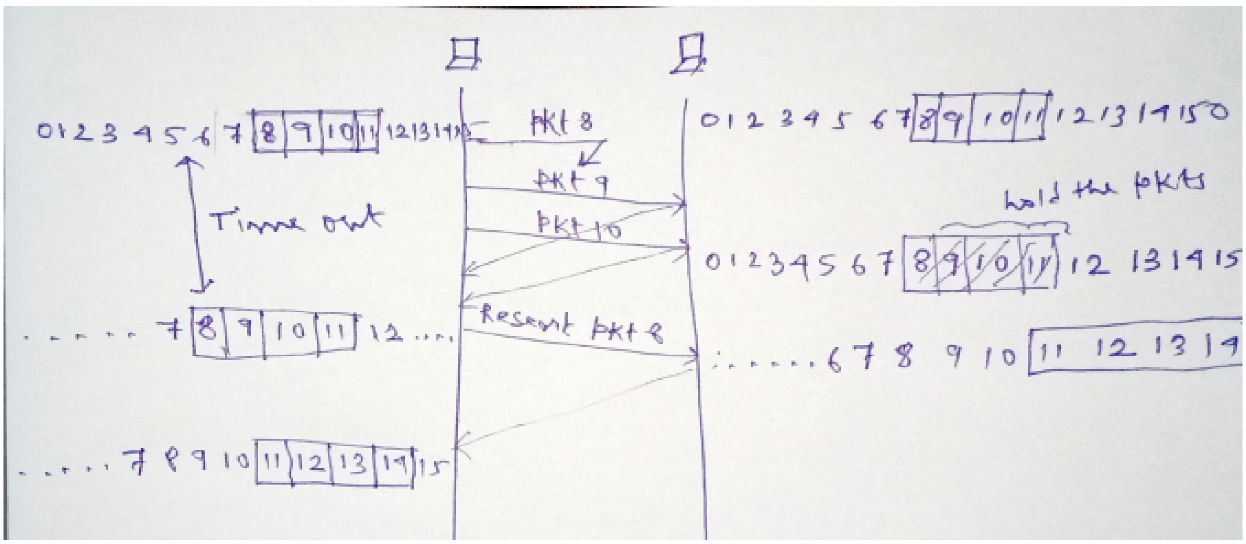
$$\text{Total Time}=(\text{RTT1}+\text{RTT2}+\cdots+\text{RTTn})+\text{RTTO}$$

B) Explain Email protocols in detail (SMTP, MIME and POP3). |
Ans : B) Email Protocols

1. SMTP (Simple Mail Transfer Protocol):
○ Purpose: SMTP is used for sending and relaying emails from a client to a server or between servers.
○ How It Works: When a user sends an email, SMTP establishes a connection with the email server to relay the message. SMTP works over TCP port 25 and follows a request-response model for communication.
○ Example Commands: HELO, MAIL FROM, RCPT TO, DATA, QUIT.
2. MIME (Multipurpose Internet Mail Extensions):
○ Purpose: MIME extends the format of email messages to support text in character sets other than ASCII, attachments, and multimedia content.
○ How It Works: MIME defines how emails are structured into different parts, including headers (Content-Type, Content-Disposition) and body sections (e.g., text, images, audio).
○ Example Headers: Content-Type: text/html; charset=UTF-8, Content-Disposition: attachment; filename="document.pdf".
3. POP3 (Post Office Protocol version 3):
○ Purpose: POP3 is used by email clients to retrieve emails from a server. It allows users to download messages from the server to their local device.
○ How It Works: POP3 works over TCP port 110. It downloads the emails from the server and usually deletes them from the server (depending on configuration). This protocol is simple and is used for offline access to emails.

○ Example Commands: USER, PASS, LIST, RETR, DELE, QUIT.

3. A) Consider a network using the Selective Repeat protocol for reliable data transmission. The sender's window size is 4 and the receiver's window size is also 4. The sequence numbers are 0 to 15. The sender bas sent packets up to sequence number 10, and all acknowledgments up to sequence been received by the sender
[
|1) illustrate the sender's and receiver's window positions on & the sequence number line.
11) If the receiver has received packets up to 10 sequence number 9 correctly but packet with sequence number 8 was lost, explain how the receiver and sender will respond
ANS:
Refer Text book for diagram



Sender's and Receiver's Window Positions:

- The sender's window size is 4. This means the sender can send up to 4 packets before needing an acknowledgment.
- The receiver's window size is also 4. This means the receiver can receive up to 4 packets before sending an acknowledgment.

Let's denote the sequence numbers in the window:

- Sender's Window: Includes packets 10, 11, 12, 13 (assuming the sender has sent up to 10).
- Receiver's Window: The receiver's window would start from the last correctly received packet plus one and cover the range up to the next 4 packets.

Lost Packet Handling:

- The receiver has received packets up to sequence number 9 correctly but packet with sequence number 8 was lost. The receiver will keep waiting for packet 8 and will send an acknowledgment for the last correctly received packet (9 in this case).
- The sender will timeout waiting for an acknowledgment for packet 8 and will retransmit packet 8 and possibly any packets after 8 (10 and 11, if not yet acknowledged)

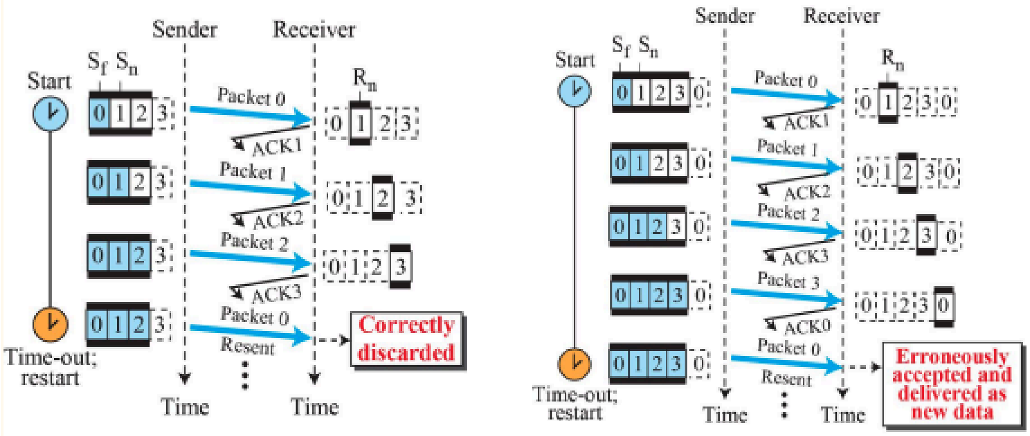
B) Why does the Selective repeat protocol use the maxim window size 2™' and Go-Back-N protocol, Justify your answer with appropriate examples

ANS: Maximum Window Size Justification:

○ Selective Repeat Protocol: Uses a window size of 2m−12^m - 12m−1 because it allows each packet to be acknowledged independently. For example, with a window size of 4, packets 0, 1, 2, and 3 can be sent and acknowledged independently.

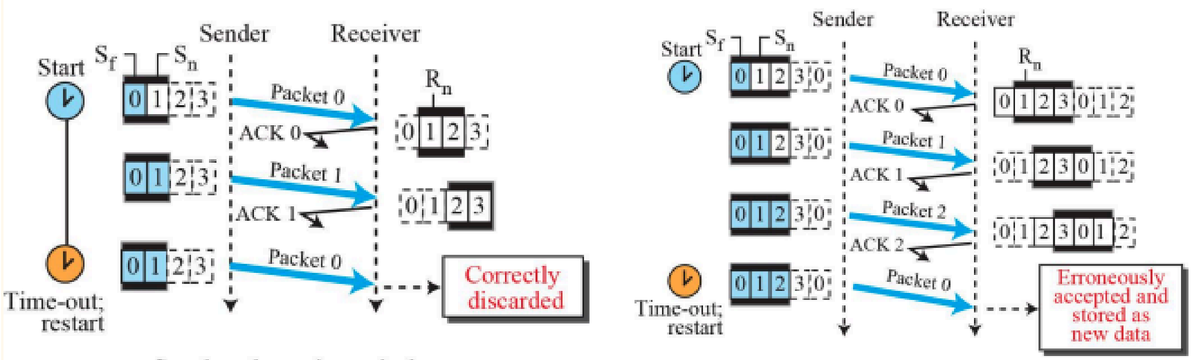
○ Go-Back-N Protocol: Uses a window size of 2m−12^{m-1}2m−1 because the receiver only acknowledges packets up to the last correctly received packet. This limits the number of unacknowledged packets that can be in transit. For example, with a window size of 4, packets 0 to 3 can be sent, but if packet 1 is lost, all packets from 1 will need to be retransmitted.

ANS: Go-Back-N [2.5 Marks]



a. Send window of size < 2^m b. Send window of size = 2^m

Selective repeat [2.5 Marks]



a. Send and receive windows of size = 2^{m-1} b. Send and receive windows of size > 2^{m-1}

4. A) Consider a scenario where Host A is establishing a TCP connection with Host B. Host A initiates the connection by sending a TCP segment with the SYN flag set to 1 and the Sequence Number set to 1000. Host B responds with a TCP segment with both the SYN and ACK flags set to 1, Acknowledgment Number set to 1200, and Sequence Number set to 2000.

1) Explain the significance of the SYN and ACK flags in the initial connection setup. |

ANS: SYN and ACK Flags in Connection Setup:

- SYN Flag: Initiates a connection request from Host A to Host B. It indicates that Host A wants to establish a connection and includes the initial Sequence Number (1000).
- ACK Flag: Responded to by Host B. It acknowledges the receipt of the SYN packet from Host A and includes its own SYN flag set (for initiating its connection request) and an Acknowledgment Number (1200) indicating that it received Host A's SYN.

(Time diagram or FSM) -> Refer Text Book

11) What is the next expected Sequence Number that Host A should use when sending data to Host B?
ANS: We can consider both the answer as 1001 or 1201 [1 Marks]
III) If Host A wants to terminate the connection after exchanging data, in what way would the FIN flag be used?
ANS:Using FIN Flag for Connection Termination:

- Host A will send a segment with the FIN flag set to initiate the termination of the connection. Host B will then respond with an ACK for the FIN and send its own FIN segment to Host A, which Host A will acknowledge. This completes the connection termination process.

Connection termination using FIN. (Time diagram or FSM){ Refer book for digram}

B)B) Imagine you are designing a network application that will use TCP for reliable data transmission. Provide a comprehensive explanation of the various components and fields present in a TCP segment.

"Your explanation should cover the purpose and significance of each components of TCP segment. |

TCP Segment Components:

- Source Port: The port number of the sender.
- Destination Port: The port number of the receiver.
- Sequence Number: Used for ordering data and tracking packets.
- Acknowledgment Number: Indicates the next expected sequence number.
- Data Offset (HLEN): Length of the TCP header.
- Flags (Control Bits): Includes SYN, ACK, FIN, etc., indicating the state of the connection.
- Window Size: Specifies the amount of data the sender is willing to receive.
- Checksum: Ensures data integrity of the TCP segment.
- Urgent Pointer: Indicates if there is urgent data.
- Options: Used for various TCP options such as window scaling.
- Data: Contains the payload being transmitted.

5.
A) Suppose host A is sending a large file to host B over a TCP connection. The two end hosts are 10 ms apart (20 ms RTT) connected by a | Gbps link. Assume that they are using a packet size of 1000 bytes to transmit

the file. For simplicity ignore ack packets. Atleast how big would the window size (in |packets) have to be for the channel utilization to be greater than 80% ?

1. **Transmission Time:**
   - Packet Size: 1000 bytes.
   - Link Bandwidth: 1 Gbps = 10^9 bits/sec.
   - Transmission Time (per packet) = $\frac{1000 \text{ bytes} \times 8 \text{ bits/byte}}{10^9 \text{ bits/sec}} = 8 \text{ microseconds.}$
2. **Propagation Time:**
   - Distance: 10 ms (RTT = 20 ms).
   - Propagation Delay (one-way) = 10 ms.
3. **Channel Utilization Formula:**
   - Utilization (U) = $\frac{\text{Transmission Time}}{\text{Transmission Time+Propagation Time}}$.
   - Required Utilization > 80%, thus:

$$0.8 < \frac{8 \text{ microseconds}}{8 \text{ microseconds} + 10 \text{ milliseconds}}$$

$$0.8 < \frac{8 \text{ microseconds}}{8 \text{ microseconds} + 10 \text{ milliseconds}} = \frac{8 \text{ microseconds}}{10 \text{ milliseconds}}$$

   Rearranging, the window size needed:

$$\text{Window Size} > \frac{\text{Propagation Time}}{\text{Transmission Time}} = \frac{10 \text{ milliseconds}}{8 \text{ microseconds}} = 1250$$

   So, the minimum window size must be at least 1250 packets to ensure channel utilization greater than 80%.

B) What is the difference between centralized P2P network and decentralized P2P network? In a DHT-based network, assume m = 4. If the hash of a node identifier is 18, where is the location of the node in the DHT space?

Centralized P2P Network vs. Decentralized P2P Network:

- Centralized P2P Network: A central server or node maintains the directory of all peers, and peer interactions go through this central node.

- Decentralized P2P Network: There is no central node. Instead, peers interact directly with each other, and the network maintains a distributed directory.

DHT-Based Network (m = 4):

- In a DHT (Distributed Hash Table) with m = 4, the space is divided into $2^4=16$ partitions.
- If the hash of a node identifier is 18, the node's location in the DHT space would be:

$\text{Location}=18 \bmod 16=2$ Therefore, the node with identifier 18 would be located at position 2 in the DHT space.