CLO 1 (Q1 to Q2): **Describe** utilization of network protocol concepts vis-a-vis OSI and TCP/IP stack. **[11+4 = 15 Marks]**

Q1: You are a network analyst at a company tasked with optimizing web performance and email delivery. This question involves calculating delays based on DNS resolution, HTTP requests, and SMTP transactions. Assume negligible transmission, processing, and queuing delays in all cases. Use the following RTTs values:

RTT between user's host and local DNS server: 5 ms
RTT between company's email server and local DNS server: 5 ms (same as above)
RTT between local DNS server and any other DNS server (root, TLD, authoritative): 30 ms
RTT between user's host and web server (for www.company.com): 150 ms
RTT between company's email server and recipient's email server (for example.net): 100 ms
Moreover, assume that the browser uses HTTP/1.1 with persistent connections and pipelining and the company website www.company.com has a homepage with one base HTML file and 10 embedded images.
Answer the following questions for each task: **[2+2+3+2+2 = 11 Marks]**

(I) A user wants to access www.company.com. The user's host does not have the IP address cached. Calculate the total time required for DNS resolution to obtain the IP address of www.company.com. Note that the client sends recursive resolution query to Local DNS, that does iterative queries to find the answer.

(II) After DNS resolution (in (I) above), the browser needs to load the homepage and then all embedded images. Assume the browser does not have any resources cached. Calculate the total time (including DNS resolution time) from when the user clicks the link until all objects are received.

(III) Now assume that the user's local DNS server has the IP address of www.company.com cached, and the browser has the base HTML file cached but not the images. How long does it take to load the page if the browser already had

a. no open TCP connection to the server.
b. an open persistent TCP connection to the server.

(IV) The company's email server needs to send an email to customer@example.net. The email server must resolve the MX record for example.net. Assume the local DNS server has no cached information for example.net. Calculate the time required for DNS resolution to get the MX record.

(V) After DNS resolution, the email server establishes a TCP connection to the recipient's email server and sends the email. Assume the SMTP transaction involves the following steps: HELO, MAIL FROM, RCPT TO, DATA, and QUIT. Each command and response takes one RTT between the email servers. The DATA command involves sending the email content, which takes negligible time. Calculate the total time for the SMTP transaction after DNS resolution.

[2+ 2 = 4 Marks]

Q2: Answer the following questions:

(A) Imagine that Internet works like a **postal service**. Answer the following in the context of postal service.

- What would represent the **hosts (end systems)**?
- What would represent the **communication links**?

(B) Write actual packet name corresponding to a given TCP/IP layer provided in **Layer** column.

Layer	Packet Name
Application Layer	Message
Transport Layer	Segment
Network Layer	Packet
Data Link Layer	Frame

CLO 2 **(Q3 to Q5): Demonstrate** the basics of network concepts using state-of-the-art network tools/techniques. **[3+8+4 = 15 Marks]**

Q3: Host A and Host B are connected via a point-to-point link of capacity **b** bps. A packet of size x bits is sent from A to B. The link propagation delay is **d** seconds. We want to calculate the total time from when Host A starts transmitting the first bit until Host B has received the entire packet. One possible solution goes like this:

- The first bit of the packet takes time equal to 1/b to be put on the wire.
- This bit then takes d seconds to reach B.
- Host B then needs another 1/b second to sense the bit on the link.
- Finally, the rest of the packet (x – 1 bits) takes (x–1)/b seconds to arrive.

Therefore, the total time = $1/b + d + 1/b + (x-1)/b = d + x/b + 1/b$
Do you agree with this reasoning?
If not, explain what's wrong and write the correct total time expression. [3 Marks]

Q4: Answer the following questions: [4 + 4 = 8 Marks]

(A): A campus proxy caches HTTP objects and forwards misses to origin server over a single uplink with bandwidth of 100 Mbps (where 1 Mbps = $1 * 10^6$ bits per second). One way propagation delay = 20 ms. Proxy serves 7200 HTTP requests from clients per hour for three static objects as per below: [2 + 2 = 4 Marks]

- Object A: size = 100 KB, requests = 3600 / hour
- Object B: size = 500 KB, requests = 2400 / hour
- Object C: size = 2000 KB, requests = 1200 / hour (where 1 KB = $1 * 10^3$ bytes.)

The proxy has objects A and B in cache, but C is not cached (thus A & B = hits, C = miss). Moreover, response times are as follows:

7200

Q5: Two hosts are store-and-forward forwarding a pack data are to be tra determine the ti

- Cache hit: proxy → client latency = 10 ms (where 1 ms = $1 * 10^{-3}$ seconds)
- Cache miss: proxy → origin **RTT** + object transmission time over uplink + proxy → client latency.

Your task is to

1. Compute the cache hit ratio (in terms of number of requests).
2. Compute the total bytes saved on the uplink per hour because of caching (answer in MB/hour i.e. Mega bytes per hour saved).

(6) A client establishes a single HTTP/2 connection to a web server. It requests two objects A & B, each of size 10 KB & 15 KB respectively (where 1 KB = $1 * 10^3$ bytes.) The server sends these two objects broken into frames (with the frame size of 5 KB) via two possible scenarios, i.e.

- Scenario 1) No interleaving, i.e. Object 1 frames transmitted first followed by Object 2 frames.
- Scenario 2) Frames of each object are transmitted interleaved.

The link bandwidth is 10 Mbps (where 1 Mbps = $1 * 10^6$ bits per second.) The single HTTP/2 connection is already established (so no RTT required for establishing connection.) Also, consider transmission delay and ignore all other delays. Consider the starting time of transmission to be t = 0 sec, fill in the table below with the appropriate time stamps (in seconds or msec.) **[4 Marks]**

Timeline	Scenario 1 (without interleaving)	Scenario 2 (with interleaving)
1st frame of Object A transmission complete at t =	0.004 s	0.004 s
Entire Object A transmission complete at t =	0.008 s	0.012 s
1st frame of Object B transmission complete at t =	0.012 s	0.008 s
Entire Object B transmission complete at t =	0.02 s	0.02 s

Q5: Two hosts are connected via a packet switch with 10^6 bits per second links. The packet switch implements store-and-forward scheme, and each link has a propagation delay of 20 microseconds. The switch begins forwarding a packet 35 microseconds (time incurred on processing) after it receives that packet. If 10000 bits of data are to be transmitted between the two hosts using a packet size of 5000 bits. Ignoring any queuing delays, determine the time required to receive 10,000 bits at the destination. **[4 Marks]**