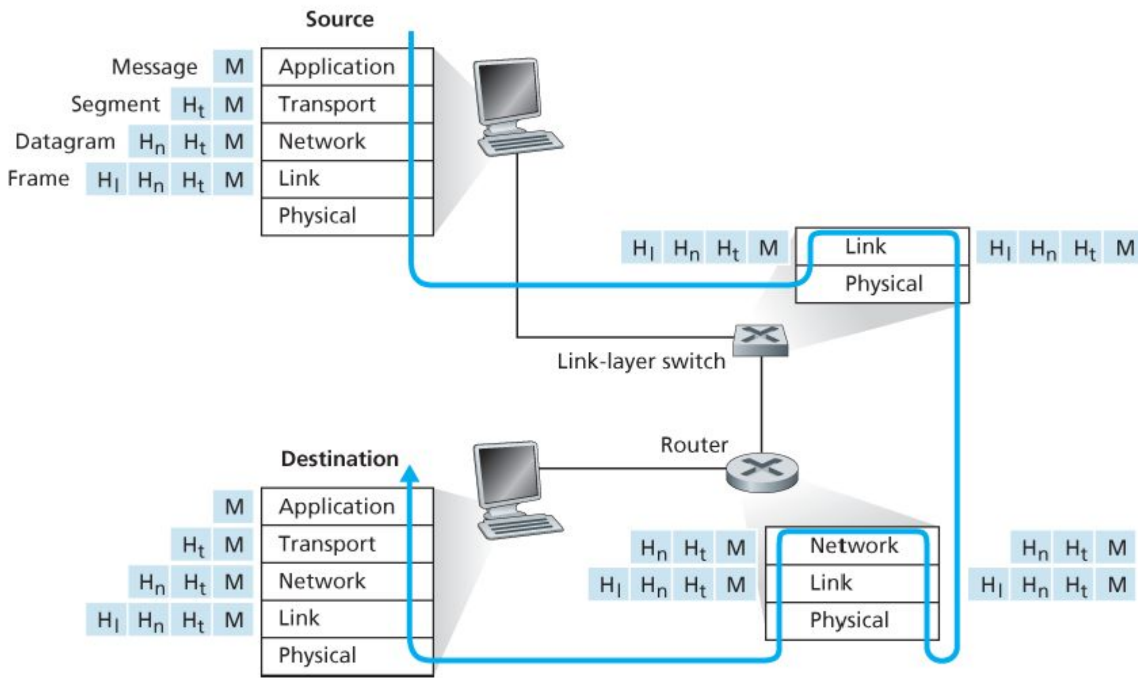
1. The figure shown below shows the physical path that data takes down a sending end system's protocol stack, up and down the protocol stacks of an intervening link-layer switch and router, and then up the protocol stack at the receiving end system. A link-layer switch is similar to a router in terms of functioning, i.e., they forward packets received through a link to the neighboring router. However, Hosts, routers, and link-layer switches; each contains a different set of layers, reflecting their differences in functionality **Marks: 1 + 1 + 3 + 1**



Answer the following:

a. Consider the source system. From the figure, explain briefly what happens when the data passes through different layers **in the source system.**

b. Consider the destination system. Explain briefly what happens when the data arrives at the destination.

c. What do the symbols Ht, Hn, Hl represent.

d. From the figure, which layer reference model do the devices follow and why?

Solution

a. In the source system,an application-layer message M is passed to the transport layer.The transport layer takes the message and appends additional information (so-called transport-layer header information, Ht).The application-layer message and the transport-layer header information together constitute the transport-layer segment. The transport-layer segment thus encapsulates the application-layer message. The added information might include information allowing the receiver-side transport layer to deliver the message up to the appropriate application, and error-detection bits that allow the receiver to determine whether bits in the message have been changed in route. The transport layer then passes the segment to the network layer, which adds network-layer header information (Hn) such as source and destination end system addresses,creating a network-layer datagram. The datagram is then passed to the link layer, which will add its own link-layer header(HI)information and create a link-layer frame.

b. In the destination system,the process de-encapsulation begins.The application layer message M is extracted by removing headers from each of the layers as data passes.The H_t is removed in the transport layer thus getting information about error detection and checking if the message is delivered.. The H_n is removed in the network layer to get the ip addresses. The H_l is removed in the data link layer thus getting information about the frames.The process works exactly in reverse order as of the source system.

c. Ht - Transport layer header
   Hn- Network layer header
   HI- Link layer header

d. TCP/IP since there are 5 layers. It cannot be OSI because OSI model has 7 layers.

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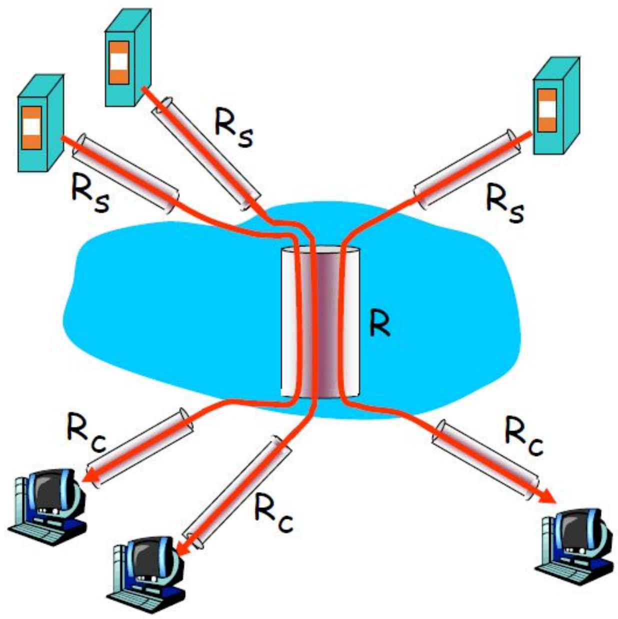
2. Consider the figure shown below where **10 servers and 10 clients** connected to the core of the computer network (which has a shared link having transmission rate R).
Marks: 2 + 1



In such a case, there are **10 simultaneous downloads taking place, involving 10 client-server pairs**. The shared link in the core is traversed by all 10 downloads. Suppose that these 10 downloads are the only traffic in the network at the current time. **All server access links have the same rate (or capacity) Rs, all client access links have the same rate (capacity) Rc, and the transmission rates of the one common link in the core has a rate R which is much larger than Rs and Rc**. Suppose Rs = 2 Mbps, Rc = 1 Mbps, and R = 5 Mbps and the common link divides its transmission rate equally among the 10 downloads. What will be the end-to-end throughput of each download? In such a scenario, which link will act as the bottleneck link. Explain the answer using proper expressions.

Solution:

End-to-end throughput = min(Rs, R/10, Rc)

5/10 = 0.5 Mbps or 500kbps

The bottleneck is the shared link in the core, which only provides each download with 500 kbps of throughput.

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3. Match the following descriptions (in the first column) to the corresponding terms used to describe them (no explanation needed):

Marks: 4

Description	Term
1. To Control the flow of packets between a fast sender and receiver	a. IP Address
2. Conversion of binary data to analog signals	B. Protocol
3. Control the access to shared channel	C. Routing
4. Set of rules that define the format, order, and action to be taken once the messages are sent.	D. MAC Address
5. The address of a given process running within a host	E. Flow control
6. Permanent address of a host	F. Medium access control
7. Temporary address of a host	G. Modulation
8. Mechanism that guides the data along the correct path from source to destination	H. Port number

Solution: 1-e, 2 - g, 3 - f, 4 - b, 5 - h, 6 - d, 7 - a, 8 - c

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4. Match the following functions to the corresponding layers of OSI model (Hint: A layer may have more than one functions) (no explanation needed) **Marks: 4.5**

Function	Layer
1. Responsible for node-to-node communication	a. Physical Layer
2. Responsible for Host-to-host communication	b. Data link Layer
3. Responsible for process-to-process communication	C. Network Layer

4. Encryption and decryption of data	D. Transport layer
5. Congestion control	E. Application Layer
6. Flow control	F. Presentation Layer
7. Routing	G. Session Layer
8. Medium Access control	
9. Multiplexing	

Solution - 1-b, 2-c, 3 - d, 4-f, 5 - c and d, 6 - b and d, 7 - c, 8 - b, 9 - a

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5. Match the protocols to the corresponding layers they belong to (Hint: A layer can have multiple protocols) (no explanation needed) **Marks: 4**

Protocol	**Layer**
1. Ethernet	a. Physical Layer
2. WiFi	b. Application Layer
3. Bluetooth	c. Transport Layer
4. TCP	d. Session Layer
5. UDP	e. Presentation Layer
6. HTTP	f. Data link Layer
7. DNS	g. Network Layer
8. IP	

Solution - 1-f, 2-f, 3 - f, 4-c, 5-c, 6-b, 7-b, 8-g

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6. Why do we need layering in computer networks? **Marks: 2**

Solution

Dealing with complex systems:

- explicit structuring allows identification, understanding the relationship of complex system's pieces and how they work with each other.
- Similar to Divide and Conquer approach
- modularization eases maintenance, updating of system
- change of implementation of layer's service transparent to rest of system

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7. **Marks:1+ 1 + 2**

Suppose Host A wants to send a large file to Host B. The path from Host A to Host B has three links, of rates R1 = 500 Mbps, R2 = 100 Mbps, and R3 = 50 Mbps.

a. Assuming no other traffic in the network, what is the throughput for the file transfer?

b. Suppose the file is 4 million bytes. Dividing the file size by the throughput, roughly how long will it take to transfer the file to Host B?

c. Repeat (a) and (b), but now with R2 reduced to 20 Mbps.

(Explain your answer)

Solution

a)

The throughput for the file transfer=min{R1,R2,R3}

=min{500 Mbps, 100 Mbps, 50 Mbps}

=50 Mbps

So, the throughput for the file transfer=50 Mbps

b)

Consider given data:

The file size= 4 million bytes

Convert million bytes to bits

=32000000 bits.

From (a), Throughput for the file transfer=500 Mbps

=500000000 bps

Dividing the file size by the throughput,roughly how long will it take to transfer the file to Host B:

=file size/throughput for the file transfer

=32000000 bits/500000000 bps

=0.064 seconds

c)

Consider the given data:

Repeat (a) and (b), but now with R2 reduced to 20 Mbps.

That means R2=20 Mbps , R1 = 500 Mbps, and R3 = 50 Mbps

The throughput for the file transfer=min{R1,R2,R3}

=min{500,20,50}

=20 Mbps

So, the throughput for the file transfer=20 Mbps

Dividing the file size by the throughput,roughly how long will it take to transfer the file to Host B:

=file size/throughput for the file transfer

=32000000 bits/20000000 bps

=1.6 seconds

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8. **Marks: 2**
How long does it take a packet of length 1,000 Kbytes to propagate over a link of distance 1,500 km, with propagation speed being 3 x 10^8 m/s, and transmission rate 5 Mbps?

(Explain your answer)

Solution

L = 1000K.B = 1000*1000*8 bits

R = 5Mbps = 5 * 10^6 bps

Transmission Delay = L/R = 1.6 seconds

Propagation Delay = (1500*10^6)/(3*10^8)=5ms or 0.005sec

Total Delay = Transmission Delay + Propagation Delay

= 1.6 + 0.005 = 1.605 seconds

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9. **Marks: 2**

Consider the queuing delay in a router buffer. Let T denote traffic intensity; that is, **T = La / R**, where **a** denote the rate of packets arriving at a link in packets/sec, **R** is the transmission rate and **L** denotes the size of the packet. Suppose that the queuing delay takes the form for **TL/R(1-T)** for **T < 1**. Provide a formula for the total delay, that is, the queuing delay plus the transmission delay.

Solution :

a. propagation delay and switching delay in a queue are ignored.

Calculate the Total delay by using the below formula,
Total delay = Queuing delay + Transmission delay

$$\begin{aligned}\text{Total delay} &= d_{queue} + d_{trans}\\ &= \frac{IL}{R(1-I)} + \frac{L}{R}\\ &= \frac{L}{R}\left[\frac{I}{1-I} + 1\right]\\ &= \frac{L}{R}\left[\frac{I+1-I}{1-I}\right]\\ &= \frac{L}{R}\left[\frac{1}{1-I}\right]\text{sec}\end{aligned}$$

b.
Let us assume that the transmission is represented by x.

So, the transmission delay $x = \frac{L}{R}$

Traffic intensity $I = \frac{La}{R} = xa$

Hence, the total delay= $\frac{x}{1-xa}$

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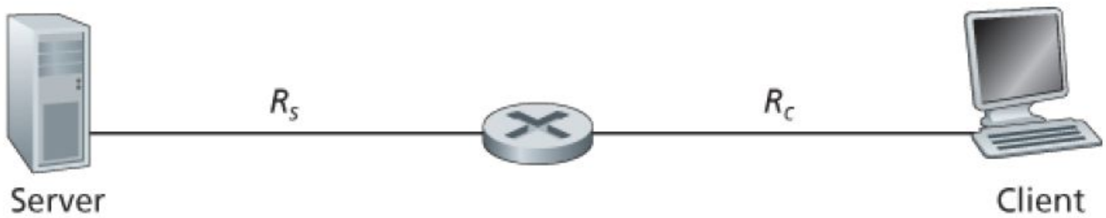
10. **Marks: 2 + 2**

Consider the figure shown below.



Assume that we know the bottleneck link along the path from the server to the client is the first link with rate **Rs** bits/sec. Suppose we send a pair of packets back to back from the server to the client, and there is no other traffic on this path. Assume each packet of size **L bits**, and both links have the same propagation delay **dprop**.

a. What is the packet inter-arrival time at the destination? That is, how much time elapses from when the last bit of the first packet arrives until the last bit of the second packet Arrives? Explain

b. Now assume that the second link is the bottleneck link (i.e., **Rc < Rs**). Is it possible that the second packet queues at the input queue of the second link? Explain. Now suppose that the server sends the second packet **T** seconds after sending the first packet. How large must **T** be to ensure no queuing before the second link? Explain.

Solution :

a) If the bottleneck link is the first link, then packet B is queued at the first link waiting for the transmission of packet A. So the packet inter-arrival time at the destination is simply L/Rs.

b) If the second link is the bottleneck link and both packets are sent back to back, it must be true that the second packet arrives at the input queue of the second link before the second link finishes the transmission of the first packet.

That is, $L/Rs + L/Rs + dprop < L/Rs + dprop + L/Rc$

The left hand side of the above inequality represents the time needed by the second packet to arrive at the input queue of the second link (the second link has not started transmitting the second packet yet). The right hand side represents the time needed by the first packet to finish its transmission onto the second link.

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11. **Marks = 2+2**

Consider a packet of length **L = 1500 bytes** that begins at end system **A and travels over three links to a destination end system B**. These three links are connected by two packet switches. **The length (d1) of the first link = 5000 Km, length (d2) of the second link = 4000 Km and the length (d3) of the third link = 1000 Km. The propagation speed on all three links is 3 x 10^8 m/sec and the transmission rates of all three links = 2 Mbps**. The packet switch delays each packet by **dprocess = 3 msec** . There are no queuing delays. What is the total end to end delay for the packet? (Derive the answer step by step)

Solution :

First link transmit packet = L/R1
= 1500*8/2*10^6
= 0.006sec

First Propagates of link = d1/s1
= 5000*10^3/3*10^8
= 0.0166sec

Second link transmit packet = L/R2
= 1500*8/2*10^6
= 0.006sec

Second Propagates of link = d2/s2
= 4000*10^3/3*10^8
= 0.0133sec

Third link transmit packet = L/R3
= 1500*8/2*10^6
= 0.006sec

Third Propagates of link = d3/s3
= 1000*10^3/3*10^8
= 0.0033sec

Delay time dproc=3ms or 0.003 sec

End-to-End delay=L/R1+L/R2+L/R3+d1/s1+d2/s2+d3/s3+dproc+dproc
= 0.006+0.006+0.006+0.0166+0.0133+0.0033+0.003+0.003
=0.0572 sec

Therefore, the end-to-end delay =0.0572 seconds

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12. Marks = 2.5

Consider the following set of operations that take place whenever you try to access a website (www.iitdh.ac.in). The steps are not in the correct order. Your task is to arrange the steps given below in the right sequence of execution

a. Use routing procedure and determine the next hop IP address. Construct the network layer packet.
b. Use DNS to get the IP address of the server - DNS returns 74.125.224.72
c. Determine the MAC address of the destination machine corresponding to the destination IP address. Construct the link layer frame.
d. Construct an HTTP GET Request – GET 74.125.224.72/index.html HTTP/1.1.
e. Construct the transport layer packet (TCP packet). Determine the source and destination port.

Solution - b,d,e,a,c
