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Review Questions & Answers
Problems & Answer

Chapter1

Computer Networks and the Internet

Chapter1 : Computer Networks and the Internet

1.What is the difference between a host and an end system? List several different types of end systems. Is a Web server an end system?

Answer:

Host is Computer or a device connected to a network which provide information, resources or services to users or other host in a network.

End Systems are termed as they are at the edge of internet which does not interact with the users but provide various services. For example, web servers and e-mail servers which does not interact with users directly but provide resources.

End System are considered same as hosts but with no direct interaction with the user and Web Server is an end system.

2. The word protocol is often used to describe diplomatic relations. How does Wikipedia describe diplomatic protocol?

Answer:

- The heads of countries (or) heads of nations represents the diplomatic protocol.
- The word protocol contains set of rules to deals with other nations/countries.
- It is a special type of art to guiding interaction between the different nations/countries.

3. Why are standards important for protocols?

Answer:

The reason behind the standards are important for protocols:

- Protocols means set of rules. Protocols is used to sending and construing information in the same order and manner for communicate computers always.

4. List six access technologies. Classify each one as home access, enterprise access, or wide-area wireless access

Answer:

Technologies	**Classification**
1. Dial-up modem over telephone line	Residential Access
2. Hybrid fiber-coaxial cable	Residential Access
3. 100 Mbps switched Ethernet	Enterprise Access
4. Wireless LAN	Home and Enterprise Access
5. Digital subscriber Line	Residential Access
6. 3G , 4G services	wide-area wireless access

5. Is HFC transmission rate dedicated or shared among users? Are collisions possible in a downstream HFC channel? Why or why not?

Answer:

- HFC means Hynrid Fiber Coaxial cable. Its combines coaxial cable and fiber optical.
- **HFC transmission rate shared among users.**

No. Collisions are not possible in a downstream HFC channel.

Reason behind this, the head end contains single source is sent by the every packet. This is
travel downstream on every link.

6. List the available residential access technologies in your city. For each type of access, provide the advertised downstream rate, upstream rate, and monthly price.

Answer:

The available residential access technologies in city mainly as:

- Dial-up
- DSL

- Cable modem
- Fiber-to-the-home

7. What is the transmission rate of Ethernet LANs?

Answer:

The transmission rates of Ethernet LANs are 10 Mbps, 100 Mbps, 1 Gbps and 10 Gbps.

8. What are some of the physical media that Ethernet can run over?

Answer:

Ethernet most commonly runs over twisted pair copper wire. It also can run over fibers optic links.

9. Dial-up modems, HFC, DSL and FTTH are all used for residential access. For each of these access technologies, provide a range of transmission rates and comment on whether the transmission rate is shared or dedicated.

Answer:

Dial-up modems:

- Transmission rate: 56 Kbps
- Broad cast medium device.

HFC(Hybrid fiber-coaxial cable):

- Transmission rate: 10 Mbps to 30 Mbps.
- Shared broad cast medium.

DSL(Digital subscriber line):

- Transmission rate: <5Mbps
- Dedicated broad cast medium.

FTTH(Fiber To The Home):

- Transmission rate: Approximately 20Mbps
- Shared broad cast medium.

10. Describe the most popular wireless Internet access technologies today. Compare and contrast them.

Answer:

The comparison between above mentioned wireless Internet access technologies are:

- These two technologies are called computer networks. It is using for wireless data connections.
- WLAN will covers short distance and Wide-area wireless access networks will covers long distance.
- These two networks will used in mobile technology via internet connection.

Contrast between Wireless Local Area Network and Wide-area wireless access network:

Wireless Local Area Network	Wide-area wireless access network
In Wireless LAN, data will transmit through radio transmissions.	In Wide-area wireless access network, data will transmit or receive through wireless infrastructure to use for cellular telephony.
In a wireless LAN, wireless users transmit (or) receive packets to (or) from a base station or wireless access point within a radius of few tens of meters. The base station is typically connected to the wired Internet and thus serves to connect wireless users to the wired network.	In Wide-area wireless access network, data will transmit within a radius of tens of kilometres from the base station to users.
Wireless LAN is used in small business, schools, universities and homes etc.	Wide-area wireless access network technology can be used in mobile.
Wireless LAN is called as Wi-Fi.	Wide-area wireless access network is called as 3G and 4G.

11. Suppose there is exactly one packet switch between a sending host and a receiving host. The transmission rates between the sending host and the switch and between the switch and the receiving host are R1 and R2, respectively.
Assuming that the switch uses store-and-forward packet switching, what is the total end-to-end delay to send a packet of length L? (Ignore queuing, propagation delay, and processing delay.)

Answer:

Consider the data:
R1= Transmission rates between the sending host and the switch
R2= Transmission rates between the switch and the receiving host
L= Packet of length
Therefore, total end-to-end delay to send a packet of length L=L/R1+L/R2

12. What advantage does a circuit-switched network have over a packet-switched network? What advantages does TDM have over FDM in a circuit-switched network?

Answer:

Advantages of a circuit-switched network have over a packet-switched network:

- Circuit switched network is used for voice/video calls, but packet-switched network is not possible do this.
- Circuit switched network's bandwidth is limited, but packet-switched network's bandwidth is not limited. So, packets transfer is time taken in packet-switched network.

Advantages of TDM have over FDM in a circuit-switched network:

- TDM means Time Division Multiplexing. FDM means Frequency Division Multiplexing.
- In TDM, same frequency operate all connections, but In FDM, different frequencies operate all connections.

13. Suppose users share a 2 Mbps link. Also suppose each user transmits continuously at 1 Mbps when transmitting, but each user transmits only 20 percent of the time.

a) **When circuit switching is used, how many users can be supported?**
b) **For the remainder of this problem, suppose packet switching is used. Why will there be essentially no queuing delay before the link if two or fewer users transmit at the same time? Why will there be a queuing delay if three users transmit at the same time?**
c) **Find the probability that a given user is transmitting.**
d) **Suppose now there are three users. Find the probability that at any given time, all three users are transmitting simultaneously. Find the fraction of time during which the queue grows.**

Answer:

a) 2 users can be supported because each user requires half of the link bandwidth.
b) Since each user requires 1Mbps when transmitting, if two or fewer users transmit simultaneously, a maximum of 2Mbps will be required. Since the available bandwidth of the shared link is 2Mbps, there will be no queuing delay before the link. Whereas, if three users transmit simultaneously, the bandwidth required will be 3Mbps which is more than the available bandwidth of the shared link. In this case, there will be queuing delay before the link.
c) **Probability that a given user is transmitting = 0.2**
d) Probability that all three users are transmitting simultaneously $= \binom{3}{3} p^3 (1-p)^{3-3} = (0.2)^3 = 0.008$
Since the queue grows when all the users are transmitting, the fraction of time during which the queue grows (which is equal to the probability that all three users are transmitting simultaneously) is 0.008.

14. Why will two ISPs at the same level of the hierarchy often peer with each other? How does an IXP earn money?

Answer:

- Using the intermediate ISP provider to carry the traffic by the two ISPs.
- It is an extra burden to the two ISPs.
- If hierarchy often peer with each other then reduces the cost for two ISPs to avoid intermediate ISP provider.

So, the t wo ISPs at the same level of the hierarchy often peer with each other.

- IXP means Internet exchange Point. Its contains multiple ISPs to exchange traffice in internet.
- Then charge the money to each ISP that connects to it.

So, an IXP earn money.

15. Some content providers have created their own networks. Describe Google's network. What motivates content providers to create these networks?

Answer:

Google's network:

- This network provides global data.
- It is used to transfer content within the Google servers.
- Its contains some Tier-1 ISP and interconnect with TCP/IP.

Motivates:

- It is used to save money by transfer data and less time to travel content.
- Content providers to control over the services.

16. Consider sending a packet from a source host to a destination host over a fixed route. List the delay components in the end-to-end delay. Which of these delays are constant and which are variable?

Answer:

List the delay components in the end-to-end delay:

- Processing delay
- Transmission delay
- Propagation delay
- Queuing delay.

The processing delay, transmission delay, and propagation delay are constant. Reason is that, time taken to transmit data bits.
The queuing delay is variable. Reason is that, only single packet transfer in queue process and waiting time depends on packet size.

17. Visit the Transmission Versus Propagation Delay applet at the companion Web site. Among the rates, propagation delay, and packet sizes available, find a combination for which the sender finishes transmitting before the first bit of the packet reaches the receiver. Find another combination for which the first bit of the packet reaches the receiver before the sender finishes transmitting.

Answer:

Given the Transmission Versus Propagation Delay applet at the companion Web site:

s=Propagation speed = $2.8*10^8$ m/s
E=End-to-End delay = 3.620 *ms*
L=Packet length=1 KBytes
d=link length=1000 km
R=Transmission rate=10Mbps

18. How long does it take a packet of length 1,000 bytes to propagate over a link of distance 2,500 km, propagation speed 2.5 *10^8 m/s, and transmission rate 2 Mbps? More generally, how long does it take a packet of length L to propagate over a link of distance d, propagation speed s, and transmission rate R bps? Does this delay depend on packet length? Does this delay depend on transmission rate?

Answer:

Transmission delay = L/R
= 8 bits/byte * 1,000 bytes / 2,000,000 bps
= 4 ms

Propagation delay = d/s
= 2,500 / 2.5×105
= 10 ms

Therefore, the total time = 4ms + 10 ms = 14 ms

No, the delay depend on packet length is not true.
No, the delay depend on transmission rate is not true.

19. 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 kbps, R2 = 2 Mbps, and R3 = 1 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 100 kbps.**

Answer:

a)
Consider given data:R1 = 500 kbps, R2 = 2 Mbps, and R3 = 1 Mbps
The throughput for the file transfer=min{R1,R2,R3}
=min{500 kbps, 2 Mbps, 1 Mbps}
=500 kbps

So, the throughput for the file transfer=500 kbps

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 Kbps
=500000 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/500000 bps
=64 seconds
c)
Consider the given data:
Repeat (a) and (b), but now with R2 reduced to 100 kbps.
That means R2=100 kbps , R1 = 500 kbps, and R3 = 1 Mbps
The throughput for the file transfer=min{R1,R2,R3}
=min{500 kbps, 100 kbps, 1 Mbps}
=100 kbps
So, the throughput for the file transfer=100 kbps
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/100000 bps
=320 seconds

20. Suppose end system A wants to send a large file to end system B. At a very high level, describe how end system A creates packets from the file. When one of these packets arrives to a packet switch, what information in the packet does the switch use to determine the link onto which the packet is forwarded? Why is packet switching in the Internet analogous to driving from one city to another and asking directions along the way?

Answer:

Consider given data:
Suppose end system A wants to send a large file to end system B.
The following steps to end System A creates packets from the file at very high level:

- Divide file into chunks.
- Create a packet by attach header to chunk.
- Each packet maintain an address of the destination.

The following information in the packet does the switch use to determine the link onto which the packet is forwarded:

- Switch uses the destination address.
- It is easy to find which packet is forward to the header.

The following the packet switching in the Internet analogous to driving from one city to another and asking directions along the way:

- Each packet maintain an address of the destination.
- Reaching packet, packet display outgoing link which road to take to forwarded.

21. Visit the Queuing and Loss applet at the companion Web site. What is the maximum emission rate and the minimum transmission rate? With those rates, what is the traffic intensity? Run the applet with these rates and determine how long it takes for packet loss to occur. Then repeat the experiment a second time and determine again how long it takes for packet loss to occur. Are the values different? Why or why not?

Answer:

Consider to visit the Queuing and Loss applet at the companion **Web site**:
The maximum emission rate =500 packets/s
The minimum transmission rate=350 packets/s
The traffic intensity=500/350
=1.42

22. List five tasks that a layer can perform. Is it possible that one (or more) of these tasks could be performed by two (or more) layers?
Answer:

The following list five tasks that a layer can perform:

1. Flow control
2. Error control
3. Segmentation and reassembly
4. Multiplexing
5. Connection setup

23. What are the five layers in the Internet protocol stack? What are the principal responsibilities of each of these layers?
Answer:

The following are the five layers in the Internet protocol stack:

1. Application layer
2. Transport layer
3. Network layer
4. Data link layer
5. Physical layer.

Principal responsibilities:

Application layer: HTTP, SMTP, and FTP protocols are used in application layer. it is used to send data over multiple end systems.
Transport layer: Transfer the content between two endpoints mainly. TCP and UDP protocols are used in transport layer.
Network layer: Move the packets between any two hosts in the network. IP protocol is used in network layer.
Data link layer: Move the packets from one node to the next another node. Point-to-point protocol (ppp) used in data link layer.
Physical layer: Transfer the individual bits from one node to the next node with in the frame.

24. What is an application-layer message? A transport-layer segment? A network layer datagram? A link-layer frame?

Answer:

Application layer message: HTTP, SMTP, and FTP protocols are used in application layer. it is used to send data over multiple end systems.
Transport layer segment: Transfer the content between two endpoints mainly. TCP and UDP protocols are used in transport layer.
Network layer datagram: Move the packets between any two hosts in the network. IP protocol is used in network layer.
link-layer frame: Move the packets from one node to the next another node. Point-to-point protocol (ppp) used in data link layer.

25. Which layers in the Internet protocol stack does a router process? Which layers does a link-layer switch process? Which layers does a host process?

Answer:

The layers in the internet protocol stack which does router processes are: -

- Physical layer
- Link layer
- Network layer

The layer which does a link layer switch process are: -

- Physical layer
- Link layer

The layer which does a host process are all the five layers which are: -

- Physical layer
- Link layer

- Network layer
- Transport layer
- Application layer

26. What is the difference between a virus and a worm?

Answer:

Virus	Worm
A virus is a software program that can replicate itself, and can enter the system through pen drives, disk drives, email attachments as well as downloaded files	Worms are self-replicating files that reside in the memory of an infected computer. It often disguises itself as system files to avoid detection.
Viruses spread to different systems through executable files.	Worms use Computer Networks to spread itself
Spreading speed of a Virus is slow.	Spreading speed of a Worm is faster
The virus tends to destroy damage or alter the files of target computers.	Worms does not modify any file but aims to harm the resource files.
A virus requires some form of human interaction to spread. Classic example: E-mail viruses.	Worm doesn't require human interaction

27. Describe how a botnet can be created, and how it can be used for a DDoS attack.

Answer:

The following steps to create a botnet:

- Prepare host systems to find the vulnerability attacker tries.
- Using the Trojan to fight against attackers or compromises the host system.
- This process is called botnet.

DDoS attack:

- DDoS means Distributed Denial-of-Service.
- The host systems can scan the environment and control the systems from the attacker.

28. Suppose Alice and Bob are sending packets to each other over a computer network. Suppose Trudy positions herself in the network so that she can capture all the packets sent by Alice and send whatever she wants to Bob; she can also capture all the packets sent by Bob and send whatever she wants to Alice. List some of the malicious things Trudy can do from this position.
Answer:

Consider the given data:

- Alice and Bob are sending packets to each other over a computer network.
- Trudy positions herself in the network so that she can capture all the packets sent by Alice and send whatever she wants to Bob

The following steps to list some of the malicious things Trudy can do from this position:

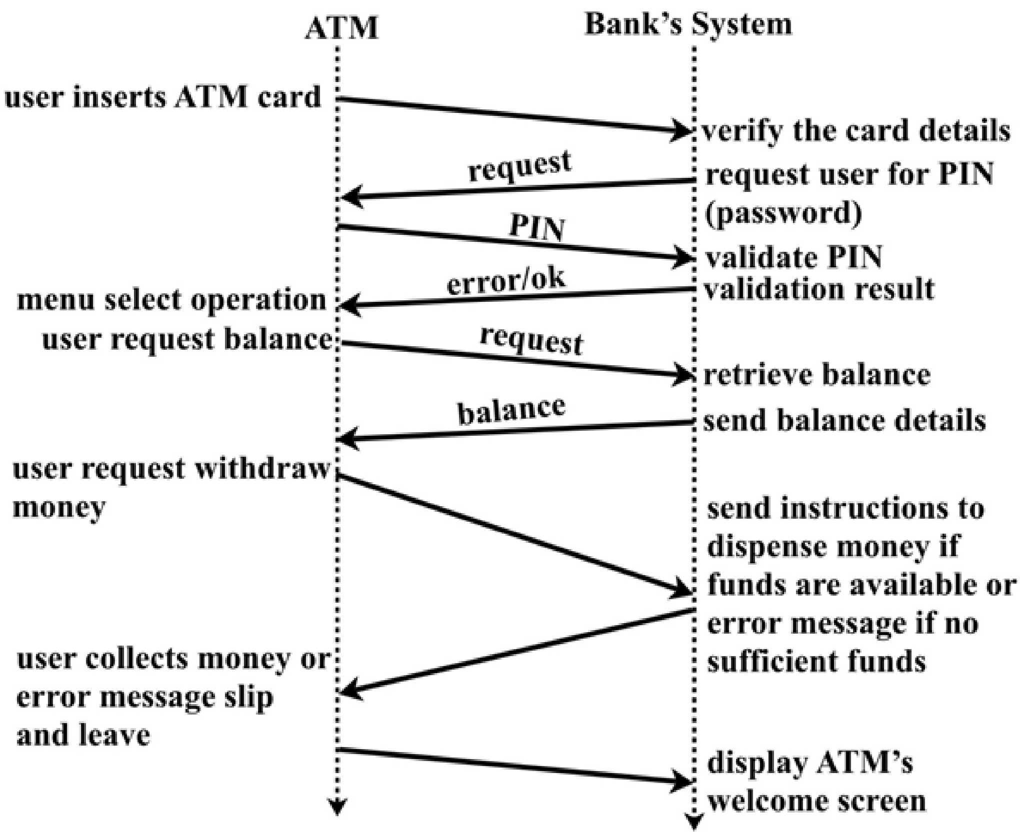
- She can observe the contents of all the packet and possibility to modify content of packets and sent appropriate receiver.
- Trudy is chance to drop the packets from Alice to Bob or from Bob to Alice.

Problems

1.**Design and describe an application-level protocol to be used between an automatic teller machine and a bank's centralized computer. Your protocol should allow a user's card and password to be verified, the account balance (which is maintained at the centralized computer) to be queried, and an account withdrawal to be made (that is, money disbursed to the user). Your protocol entities should be able to handle the all-too-common case in which there is not enough money in the account to cover the withdrawal. Specify your protocol by listing the messages exchanged and the action taken by the automatic teller machine or the bank's centralized computer on transmission and receipt of messages. Sketch the operation of your protocol for the case of a simple withdrawal with no errors, using a diagram similar to that in Figure. Explicitly state the assumptions made by your protocol about the underlying end-to-end transport service.**

Answer:

The diagram shows the sequence of communication between an ATM and a bank's centralized computer.



2. Equation dend-to-end=NLR gives a formula for the end-to-end delay of sending one packet

<u>Answer:</u>

of length *L* over *N* links of transmission rate *R*. Generalize this formula for sending *P* such packets back-to-back over the *N* links.

Consider the given data

N = Total number of links

R = Transmission rate

L = Packet length

P = packets that transmit over the *N* link

The following is the formula of back-to-back delay of sending *P* packets, each of length *L* over *N* links of transmission rate $R = d_{back-to-back} = PN\left(\frac{L}{R}\right)$

3. Consider an application that transmits data at a steady rate (for example, the sender generates an *N*-bit unit of data every *k* time unit, 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 network or a circuit-switched network be more appropriate for this application? Why?**
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?**

<u>Answer:</u>

a)

Circuit-switched network is the more appropriate for this application.

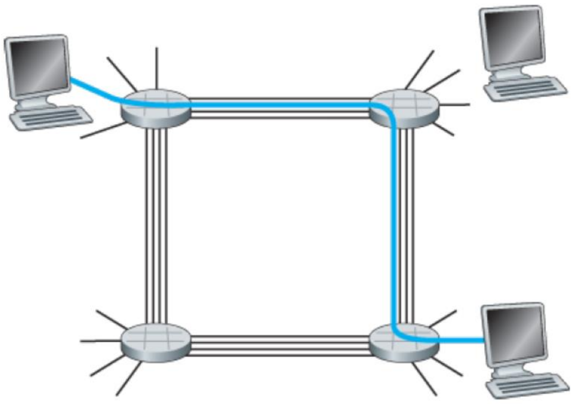
Reason: Fixed bandwidth and long sessions involved.

b)

Consider 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. In that time congestion control is needed. **The reason is that sufficient bandwidth of the link is enabled to completed the task of application.**

4. **Consider the circuit-switched network in Figure . Recall that there are 4 circuits on each link. Label the four switches A, B, C and D, going in the clockwise direction.**

a) **What is the maximum number of simultaneous connections that can be in progress at any one time in this network?**
b) **Suppose that all connections are between switches A and C. What is the maximum number of simultaneous connections that can be in progress?**
c) **Suppose we want to make four connections between switches A and C, and another four connections between switches B and D. Can we route these calls through the four links to accommodate all eight connections?**



Answer:

a) Between the switch in the upper left and the switch in the upper right we can have 4 connections. Similarly, we can have four connections between each of the 3 other pairs of adjacent switches. Thus, this network can support **up to 16 connections.**
b) We can 4 connections passing through the switch in the upper-right-hand corner and another 4 connections passing through the switch in the lower-left-hand corner, giving a total of 8 connections.
c) Yes. For the connections between A and C, we route two connections through B and two connections through D. For the connections between B and D, we route two connections through A and two connections through C. In this manner, there are at most 4 connections passing through any link.

5. **Assume a propagation speed of 100 km/hour.**

a) **Suppose the caravan travels 150 km, beginning in front of one tollbooth, passing through a second tollbooth, and finishing just after a third tollbooth. What is the end-to-end delay?**

b) **Repeat (a), now assuming that there are eight cars in the caravan instead of ten.**

Answer:

a)
Suppose the caravan travels 150 km, beginning in front of one tollbooth, passing through a second tollbooth, and finishing just after a third tollbooth.
Assume a propagation speed of 100 km/hour.
Delay time=total distance/propagation speed
=150/100km/hr
=1.5 hrs
Time for taken by 3 tollbooths to reach 10 cars= 2*3=6 minutes.
So, end-to-end delay = 1hr 30 minutes + 6 minutes
= 1hr 36minutes.
b)
assuming that there are 8 cars in the caravan instead of 10.
Time for taken by 3 tollbooths to reach 8 cars= 96*3=288 minutes=4 minutes 48 seconds.
So, end-to-end delay = 1hr 30 minutes + 4 minutes 48 seconds
= 1hr 34 minutes 48 seconds

6. **This elementary problem begins to explore propagation delay and transmission delay, two central concepts in data networking. Consider two hosts, A and B, connected by a single link of rate R bps. Suppose that the two hosts are separated by m meters, and suppose the propagation speed along the link is s meters/sec. Host A is to send a packet of size L bits to Host B.**
a. Express the propagation delay, d_{prop}, in terms of m and s.
b. Determine the transmission time of the packet, d_{trans}, in terms of L and R.
c. Ignoring processing and queuing delays, obtain an expression for the end-to-end delay.
d. Suppose Host A begins to transmit the packet at time $t = 0$. At time $t = d_{trans}$,where is the last bit of the packet?
e. Suppose d_{prop} is greater than $d_{trans.}$ At time $t = d_{trans}$, where is the first bit of the packet?
f. Suppose $d$prop is less than d_{trans}. At time $t = d_{trans}$, where is the first bit of the packet?

g. Suppose *s* = 2.5 · 108, *L* = 120 bits, and *R* = 56 kbps. Find the distance *m* so that d_{prop} equals d_{tr}

<u>Answer:</u>

a) The propagation delay, d_{prop}=m/s sec
b) The transmission time of the packet, d_{trans}=L/R sec
c) The end-to-end delay=(L/R+m/s) sec
d) Suppose Host A begins to transmit the packet at time $t = 0$. At time $t = d_{trans}$.
Then, the last bi of the packet $t = d_{trans}$
e) Suppose d_{prop} is greater than $d_{trans.}$ At time $t = d_{trans}$
Thus, the first bit of the packet is $d_{prop} > d_{trans}$.
f)Suppose *d*prop is less than d_{trans}. At time $t = d_{trans}$,
Thus, the first bit of the packet is $d_{prop} < d_{trans}$.

7.In this problem, we consider sending real-time voice from Host A to Host B over a packet-switched network (VoIP). Host A converts analog voice to a digital 64 kbps bit stream on the fly. Host A then groups the bits into 56- byte packets. There is one link between Hosts A and B; its transmission rate is 2 Mbps and its propagation delay is 10 msec. As soon as Host A gathers a packet, it sends it to Host B. As soon as Host B receives an entire packet, it converts the packet's bits to an analog signal. How much time elapses from the time a bit is created (from the original analog signal at Host A) until the bit is decoded (as part of the analog signal at Host B)?

Given data:
Host A converts analog voice to a digital 64 kbps bit stream on the fly. Host A then groups the bits into 56- byte packets. There is one link between Hosts A and B; its transmission rate is 2 Mbps and its propagation delay is 10 msec.

<u>Answer:</u>

$$= \frac{\text{Total number of packets}}{\text{Conversion of analog signal to digital bit stream}}$$

$$= \frac{56\times 8}{64\times 10^3}\text{sec} \quad [\because 1\text{byte}=8\text{bits}]$$

$$=0.007\text{sec}$$

$$\text{Transer packet time} = \frac{56\times 8}{2\times 10^6}\text{sec}$$

$$= 0.000224 \text{ sec}$$

$$\text{Elapsed time} = 0.007 + 0.000224 + 0.01\,\text{sec}$$
$$= 0.017224\,\text{sec}$$

8. Suppose users share a 3 Mbps link. Also suppose each user requires 150 kbps when transmitting, but each user transmits only 10 percent of the time.
a. When circuit switching is used, how many users can be supported?
b. For the remainder of this problem, suppose packet switching is used. Find the probability that a given user is transmitting.
c. Suppose there are 120 users. Find the probability that at any given time, exactly *n* users are transmitting simultaneously. (*Hint*: Use the binomial distribution.)
d. Find the probability that there are 21 or more users transmitting simultaneously.

Answer:

a)

$$\text{The number of users} = \frac{\text{Transmission rate of the link used by the user}}{\text{Transmission rate required by each user}}$$
$$= \frac{3\text{Mbps}}{150\text{Kbps}}$$

We know that 1Mbps=10^6 bps

$$= \frac{3000\text{Kbps}}{150\text{Kbps}}$$
$$= 20\ \text{users}$$

So, the total number of users=20.

b)

Transmission rate=10%

probability=1/10=0.1

c)

$$P(n) = {}^{N}C_{n}\,(P)^{n}\,(1\text{-}P)^{N\text{-}n}$$
$$P(n) = {}^{120}C_{n}\left(\frac{1}{10}\right)^{n}\left(\frac{9}{10}\right)^{120-n}$$
$$= {}^{120}C_{n}\left(\frac{1}{10}\right)^{n}\left(\frac{9}{10}\right)^{120-n}$$

d)

$$P\,(21 \text{ or more users}) = 1 - P\left(\sum_{j=1}^{120} X_j \le 10\right)$$

$$P\left(\sum_{j=1}^{120} X_j \le 10\right) = P\left(\frac{\sum_{j=1}^{120} X_j - 4}{\sqrt{120\times 0.1\times 0.9}} \le \frac{6}{\sqrt{120\times 0.1\times 0.9}}\right)$$

$$= P\left(Z \le \frac{6}{\sqrt{10.8}}\right)$$

$$= P(Z \le 1.83)$$

$$= 0.999$$

So, P (21 or more users) =1-0.999 = 0.001(approx.)

9. Consider the discussion in Section 1.3 of packet switching versus circuit switching in which an example is provided with a 1 Mbps link. Users are generating data at a rate of 100 kbps when busy, but are busy generating data only with probability *p* = 0.1. Suppose that the 1 Mbps link is replaced by a 1 Gbps link.

a) What is *N*, the maximum number of users that can be supported simultaneously under circuit switching?

b) Now consider packet switching and a user population of *M* users. Give a formula (in terms of *p*, *M*, *N*) for the probability that more than *N* users are sending data.

Answer:

a)

Number of users (N)=

$$= \frac{\text{total transmission rate}}{\text{Rate of data generation by the user when busy}}$$

$$= \frac{1\,\text{Gbps}}{100\,\text{kbps}}$$

$$= \frac{1000\times 1000\times 1000\,\text{bps}}{100\times 1000\,\text{bps}}$$

$$=1000\times 10$$

$$=10000\ \text{users}$$

So, the maximum number of users that can be supported simultaneously under circuit switching=1000 users

b)

Consider packet switching and a user population of *M* users.

Formula (in terms of *p*, *M*,*N*) for the probability that more than *N* users are sending data=

$$M\sum n = N + 1\left(Mp^{n}(1-p)^{M-n}\right)$$

10. Consider a packet of length *L* which begins at end system A and travels over three links to a destination end system. These three links are connected by two packet switches. Let *di*, *si*, and *Ri* denote the length, propagation speed, and the transmission rate of link *i*, for *i* = 1, 2, 3. The packet switch delays each packet by d_{proc}. Assuming no queuing delays, in terms of *di*, *si*, *Ri*, (*I* = 1,2,3), and *L*, what is the total end-to-end delay for the packet? Suppose now the packet is 1,500 bytes, the propagation speed on all three links is 2.5 · 108 m/s, the transmission rates of all three links are 2 Mbps, the packet switch processing delay is 3 msec, the length of the first link is 5,000 km, the length of the second link is 4,000 km, and the length of the last link is 1,000 km. For these values, what is the end-to-end delay?

Answer:

First link Transmit packet = L/R_1

$$= \frac{(1500 \times 8)}{2 \times 10^6}$$

$$= 0.006 \sec$$

First propagates of link is d1/s1 = $\frac{5000 \times 10^3}{2.5 \times 10^8}$

$$= 0.02 \text{ sec}$$

Delay time d_{proc} = 3msec,

Second link Transmit packet = L/R2

$$= \frac{(1500 \times 8)}{2 \times 10^6}$$

$$=0.006\text{sec}$$

11. In the above problem, suppose *R*1 = *R*2 = *R*3 = *R* and *d*proc = 0. Further suppose the packet switch does not store-and-forward packets but instead immediately transmits each bit it receives before waiting for the entire packet to arrive. What is the end-to-end delay?

Answer:

Given data:

Transmission rate = R1=R2=R3=R.

Size = 1500 bytes = 1500×8 bits

Propagation speed = $2.5\times 10^8 m/s$

$d_{proc}=0$

The first link transmits time = L/R

$$= \frac{(1500\times 8)}{2\times 10^6}$$

$= 0.006$ ms

The first link propagation time= d1/s1

$$= \frac{5000\times 10^3}{2.5\times 10^8}$$

$= 0.02$ seconds

The second link propagation time =d2/s2

$$= \frac{4000\times 10^3}{2.5\times 10^8}$$

$= 0.016$ seconds

The last link propagation time= d3/s3

$$= \frac{1000\times 10^3}{2.5\times 10^8}$$

$= 0.004$ seconds

The end-to-end delay = L/R +d1/s1 + d2/s2 +d3/s3

$= 0.006 + 0.02 + 0.016 + 0.004$

$= 0.046$ seconds

12. **A packet switch receives a packet and determines the outbound link to which the packet should be forwarded. When the packet arrives, one other packet is halfway done being transmitted on this outbound link and four other packets are waiting to be transmitted. Packets are transmitted in order of arrival.**

Suppose all packets are 1,500 bytes and the link rate is 2 Mbps. What is the queuing delay for the packet? More generally, what is the queuing delay when all packets have length *L*, the transmission rate is *R*, *x* bits of the currently-being-transmitted packet have been transmitted, and *n* packets are already in the queue?

Answer:

Packet length= ***L***
Transmission rate= ***R***
Currently transmitted packet = ***x*** bits
Waiting queue= ***n*** packets

Formula for Queuing delay:

$$\boxed{\text{Queuing delay} = \frac{\left[nL + (L - x)\right]}{R}}$$

Given data:

L=1500 bytes.
$R = 2$ Mbps (or) 2×10^6bps .
$x = \frac{1500}{2} = 750$.
$n = 4$.

Calculation:

$$\begin{aligned}\left[nL + (L - x)\right] &= (4 \times 1500) + (1500 - 750) \\ &= 6000 + 750 \\ &= 6750 \text{bytes}\end{aligned}$$

Packets are transmitted at 2Mbps,
=6750*2*4
=54000

The queuing delay for packet is calculated as follows:

$$\begin{aligned}\text{Queuing delay} &= \frac{54000}{2 \times 10^6} \\ &= 0.027 \text{sec}\end{aligned}$$

Thus, the queuing delay = 0.027 seconds.

13. (a) Suppose *N* packets arrive simultaneously to a link at which no packets are currently being transmitted or queued. Each packet is of length *L* and the link has transmission rate *R*. What is the average queuing delay for the *N* packets?
(b) Now suppose that *N* such packets arrive to the link every *LN/R* seconds. What is the average queuing delay of a packet?

Answer:

a)

The first packet queuing delay =0

The second packet queuing delay $= \frac{L}{R}$

The third packet queuing delay $= 2\frac{L}{R}$ and so on

The Nth packet queuing delay $= (N-1)\frac{L}{R}$

Therefore, the average queuing delay of Nth packet =

$$= \frac{\left(\frac{L}{R} + 2\frac{L}{R} + 3\frac{L}{R} + \ldots + (N-1)\frac{L}{R}\right)}{N}$$

$$= \frac{L}{(RN)}\sum_{i=1}^{N-1} i$$

$$= \left(\frac{L}{(RN)}\right)\frac{N(N-1)}{2}$$

$$= (N-1)\frac{L}{(2R)}$$

b)

To transmit N such batches, it takes LN/R seconds. Therefore, a new batch arrives then the queue is empty each time. Thus, the average delay of a packet across all batches is the average delay within one batch.

Hence, the average queuing delay of a packet $= (N-1)\frac{L}{(2R)}$

14. **Consider the queuing delay in a router buffer. Let *I* denote traffic intensity; that is, *I* = *La/R*. Suppose that the queuing delay takes the form *IL/R* (1 – *I*) for *I* < 1.**

a. Provide a formula for the total delay, that is, the queuing delay plus the transmission delay.

b. Plot the total delay as a function of *L/R*.

Answer:

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

$$\text{Total delay} = d_{queue} + d_{trans}$$

$$= \frac{IL}{R(1-I)} + \frac{L}{R}$$

$$= \frac{L}{R}\left[\frac{I}{1-I} + 1\right]$$

$$= \frac{L}{R}\left[\frac{I+1-I}{1-I}\right]$$

$$= \frac{L}{R}\left[\frac{1}{1-I}\right] \text{sec}$$

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= $\frac{x}{1-xa}$

15. **Let *a* denote the rate of packets arriving at a link in packets/sec, and let μ denote the link's transmission rate in packets/sec. Based on the formula for the total delay (i.e., the queuing delay plus the transmission delay) derived in the previous problem, derive a formula for the total delay in terms of *a* and μ.**

Answer:

Let the rate of the transmission link= μ packets/sec.
Let the rate of packets arriving at a link= a packets/sec.

Formula for Queuing delay= $\frac{IL}{\mu(1-I)}$

Formula for Traffic intensity I= $\frac{La}{\mu}$ .....(1)

Calculation of Total delay in terms of 'a' and 'μ':

Add the Queuing delay and Transmission delay to get the total delay.

Nodal delay (or) Total delay = Queuing delay + Transmission delay

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

Substituting the value of '**I**' from (1) in the above equation:

$$
\frac{L}{\mu}\left[\frac{1}{1-\frac{La}{\mu}}\right] \Rightarrow \frac{L}{\mu}\left[\frac{1}{\frac{\mu - La}{\mu}}\right] \Rightarrow \frac{L}{\mu}\left[\frac{\mu}{\mu - La}\right] \Rightarrow \frac{L}{\mu - La}
$$

Therefore, the formula in terms of 'a' and 'μ' is:

$$
\boxed{\text{Total delay} = \frac{L}{\mu - La} \text{packets/sec}}
$$

16. Consider a router buffer preceding an outbound link. In this problem, you will use Little's formula, a famous formula from queuing theory. Let *N* denote the average number of packets in the buffer plus the packet being transmitted. Let *a* denote the rate of packets arriving at the link. Let *d* denote the average total delay (i.e., the queuing delay plus the transmission delay) experienced by a packet. Little's formula is $N = a \cdot d$. Suppose that on average, the buffer contains 10 packets, and the average packet queuing delay is 10 msec. The link's transmission rate is 100 packets/sec. Using Little's formula, what is the average packet arrival rate, assuming there is no packet loss?

Answer:

Total delay = Transmission delay+ Queuing delay $\rightarrow$(1)

Transmission delay= $\frac{L}{R}$

Assume that only 1 packet is transmitted.

L=1packet

R=100 packets/sec

So Transmission delay= $\frac{1}{100}$ sec

=0.010 sec $\rightarrow$ (2)

Queuing delay= 10 msec

=0.010sec $\rightarrow$ (3)

From (2) and (3) values subtitude in (1)

Therefore,

Total delay(d) = 0.010sec + 0.010sec

= 0.020 sec

$\boxed{\therefore d = 0.020\text{sec}}$

17.a. Generalize Equation 1.2 in Section 1.4.3 for heterogeneous processing rates, transmission rates,
and propagation delays.
b. Repeat (a), but now also suppose that there is an average queuing delay of *q*ueue at each node.

Answer:

a)
Consider Data,
Generalize Equation 1.2 in Section 1.4.3 for heterogeneous processing rates, transmission rates, and propagation delays.
Total end-to-end delay = Transmission delay + Propagation delay

$$\therefore \text{ Total end-to-end delay} = NL\sum_{I=1}^{N}\frac{1}{R_I} + \sum_{I=1}^{N}\frac{D_I}{S_I} \text{ seconds}$$

b)
Consider data,
Suppose that there is an average queuing delay of *d*queue at each node.
Total end-to-end delay = Transmission delay + Propagation delay + Queuing delay

$$\therefore \text{ Total end-to-end delay} = NL\sum_{I=1}^{N}\left(\frac{1}{R_I}\right) + \sum_{I=1}^{N}\left(\frac{D_I}{S_I}\right) + N.d_{queue}\text{seconds}$$

18. **Perform a Traceroute between source and destination on the same continent at three different hours of the day.**

a) **Find the average and standard deviation of the round-trip delays at each of the three hours.**

b) **Find the number of routers in the path at each of the three hours. Did the paths change during any of the hours?**

c) **Try to identify the number of ISP networks that the Traceroute packets pass through from source to destination. Routers with similar names and/or similar IP addresses should be considered as part of the same ISP. In your experiments, do the largest delays occur at the peering interfaces between adjacent ISPs?**

d) **Repeat the above for a source and destination on different continents. Compare the intra-continent and inter-continent results**.

Answer:

a)

Assume the three trials of the round-trip delay between source and the destination is

D_1=1.03msec

D_2=0.48msec

D_3=0.45msec

The average of the three round-trip delays:

$$\overline{D}=\frac{D_1+D_2+D_3}{3}$$

$$\overline{D}=\frac{(1.03+0.48+0.45)}{3}$$

$$\overline{D}=\mathbf{0.65msec}$$

The standard deviation of the three round-trip delays:

$$\begin{aligned}\sigma &= \sqrt{\frac{1}{N}\left[\left(D_1\text{-}\overline{D}\right)^2+\left(D_2\text{-}\overline{D}\right)^2+\left(D_3\text{-}\overline{D}\right)^2\right]}\\ &=\sqrt{\frac{1}{3}\left[(1.03\text{-}0.65)^2+(0.48\text{-}0.65)^2+(0.45\text{-}0.65)^2\right]}\\ &=\sqrt{0.0711}\\ &= \mathbf{0.267msec}\end{aligned}$$

Therefore, the average = 0.65 msec and the standard deviation is =0.267msec.

b)

- The number of routers in the path at each of the three hours is 9.
- The path may be changed due to the hours at some specific period of time.

c)

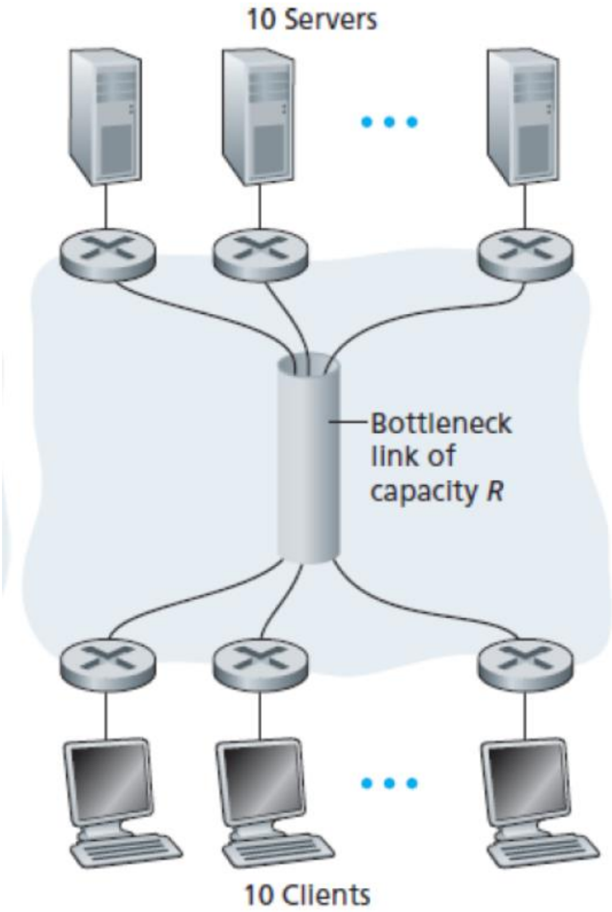
Consider the data and our experiments as follows:

The largest delays occur at the peering interfaces between adjacent ISPs is 7.

d)

- The intra-continent results are used to makes faster to reach to the DNS.
- The inter-continent results are used to the server that is essential for the user.

19. Consider the throughput example corresponding to Figure. Now suppose that there are *M* client-server pairs rather than 10. Denote *Rs*, *Rc*, and *R* for the rates of the server links, client links, and network link. Assume all other links have abundant capacity and that there is no other traffic in the network besides the traffic generated by the *M* client-server pairs. Derive a general expression for throughput in terms of *Rs*, *Rc*, *R*, and *M*.



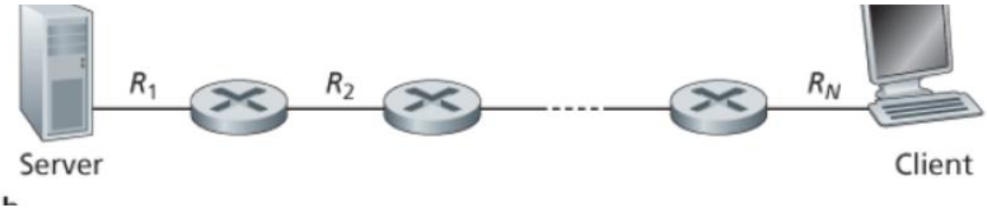
Given data:
Rs = Server link rate
Rc = Client link rate
R = Network link rate
M = Client-server pair

Instantaneous throughput and average throughput are two types of throughput. The server throughput *Rc* faster than *Rs*.

Networks always depends on client-server links(M). The min is a simple two link network links on the network.

***Therefore, general expression for throughput in terms of Rs, Rc, R, and M is* min {*Rs* ,*Rc* , R/M}.**

20. Consider Figure. Now suppose that there are *M* paths between the server and the client. No two paths share any link. Path *k* (*k* = 1, . . ., *M*) consists of *N* links with transmission rates *Rk1*, *Rk2*, . . ., *RkN* . If the server can only use one path to send data to the client, what is the maximum throughput that the server can achieve? If the server can use all *M* paths to send data, what is the maximum throughput that the server can achieve?

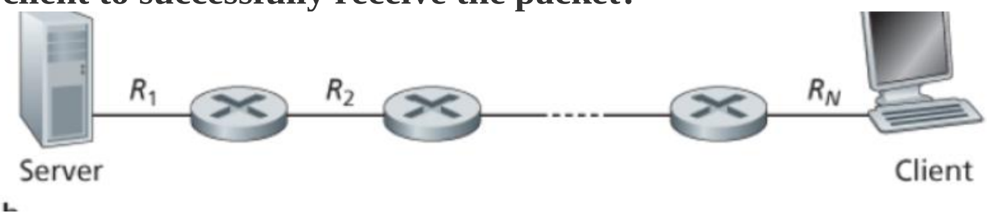


Answer:

Given data:
Number of client and server paths= M
The transmission rate of path k consists of N links = R_1^k, R_2^k, R_3^k ...., R_N^k
Generally two types of throughputs are **Instantaneous throughput and Average throughput**.

- If the server uses single path to send data to the client, the maximum throughput= $\{\mathbf{R_1^k}\}$
- If the server uses all the M paths to send data, the maximum throughput = $\mathbf{min}\ \{\mathbf{R_1^k},\ \mathbf{R_2^k},\ \mathbf{R_3^k}\ ....,\ \mathbf{R_N^k}\}$

21. Consider Figure. Suppose that each link between the server and the client has a packet loss probability *p*, and the packet loss probabilities for these links are independent. What is the probability that a packet (sent by the server) is successfully received by the receiver? If a packet is lost in the path from the server to the client, then the server will re-transmit the packet. On average, how many times will the server re-transmit the packet in order for the client to successfully receive the packet?



Consider the given data:
Loss probability of packet between the server and the client =p
Probability that the packet is successfully received through the receiver p1.

The probability that the packet transmitted by the server is received by the client successfully is 1/p1

The probability of successful transmissions -1 if the packet re-transmitted by the server is received.

So, the probability that the packet re-transmitted by the server is received by the client is 1/p_1-1.

22. Suppose you would like to urgently deliver 40 terabytes data from Boston to Los Angeles. You have available a 100 Mbps dedicated link for data transfer.

Would you prefer to transmit the data via this link or instead use FedEx overnight delivery? Explain.

40 terabytes = 40 * 1012 * 8 bits. So, if using the dedicated link, it will take 40 * 1012 * 8 / (100 *106) =3200000 seconds = 37 days. But with FedEx overnight delivery, you can guarantee the data arrives in one day, and it should cost less than $100.

23. Suppose two hosts, A and B, are separated by 20,000 kilometres and are connected by a direct link of *R* = 2 Mbps. Suppose the propagation speed over the link is 2.5 x 10^8 meters/sec.

a) **Calculate the bandwidth-delay product, *R* _ *d*prop.**
b) **Consider sending a file of 800,000 bits from Host A to Host B. Suppose the file is sent continuously as one large message. What is the maximum number of bits that will be in the link at any given time?**
c) **Provide an interpretation of the bandwidth-delay product.**
d) **What is the width (in meters) of a bit in the link? Is it longer than a football field?**
e) **Derive a general expression for the width of a bit in terms of the propagation speed *s*, the transmission rate *R*, and the length of the link *m*.**

<u>Answer:</u>

The distance (Distance) between two hosts A and B = 20,000 km

a)

The distance (Distance) between two hosts A and B = 20,000 km

$= 2 \times 10^7 meters \left(since 1km = 10^3 m\right)$

Transmission rate(R) of the direct link between A and B =2Mbps

$= 2 \times 10^6 bps \left(1Mbps = 10^6 bps\right)$

Propagation Speed(S) of the link between A and B $= 2.5 \times 10^8 meter s/sec$

Calculate the propagation delay:

$$d_{prog} = \frac{Distance}{Speed} = \frac{2 \times 10^7}{2.5 \times 10^8} = 0.08sec$$

Calculate the band-width delay product:

$$R \times d_{prog} = 2 \times 10^6 \times 0.08 = 16 \times 10^4 bits$$

Therefore, band-with delay product is 160000bits

b)

Size of the file =800000 bits $= 8 \times 10^5 bits$

Transmission rate(R) of the direct link between A and B =2Mbps

$= 2 \times 10^6 bps \left(1Mbps = 10^6 bps\right)$

The band-width delay product:

$$R \times d_{prog} = 2 \times 10^6 \times 0.08 = 16 \times 10^4 bits$$

Therefore, the maximum number of bits at a given time will be 160000bits.

c)

The product of band-width delay is equal to the maximum number of bits on the transmission line.

d)

Transmission rate(R) of the direct link between A and B =2Mbps

$= 2 \times 10^6 bps \left(1Mbps = 10^6 bps\right)$

Propagation Speed(S) of the link between A and B $= 2.5 \times 10^8 meter\, s/sec$

Formula to calculate the length of 1 bit on the transmission line $= \frac{Speed(S)}{Transmissionrate(R)}$

$$Lengthof1bit = \frac{Speed(S)}{Transmissionrate(R)} = \frac{2.5 \times 10^8}{2 \times 10^6} = 125m/bit$$

Therefore, it is longer than a football field.

e)

A general expression for the width = (Transmission rate(R) * Speed(s))/ length of the link (*m)*

24. Referring to problem P25, suppose we can modify *R*. For what value of *R* is the width of a bit as long as the length of the link?

Answer:

Consider the given data:
A and B hostsare connected with a direct link. The distance is '*d*'.

$$d = 20,000\,\text{km}$$
$$= 20000 \times 10^3\,\text{m} \qquad (\text{Since } 1\,\text{km} = 10^3\,\text{m})$$
$$= 2 \times 10^7\,\text{m}$$

R is the transmission rate of A and B hosts.

$$R = 2\,\text{Mbps}$$
$$= 2 \times 10^6\,\text{bps} \qquad (\text{Since } 1\,\text{Mbps} = 10^6\,\text{bps})$$

S is the propagation speed.

$$S = 2.5 \times 10^8 \text{ meters/sec}$$

L is the length of the file.
$L = 800,000\,\text{bits}$.
Consider the length of the link = m meters.
The general expression for the width of bit in terms of propagation speed and transition rate is given below:

$$m = \frac{S}{R} \qquad \cdots\cdots(1)$$

25. **Consider problem P25 but now with a link of *R* = 1 Gbps.**
a. Calculate the bandwidth-delay product, *R* _ *d*prop.
b. Consider sending a file of 800,000 bits from Host A to Host B. Suppose the file is sent continuously as one big message. What is the maximum number of bits that will be in the link at any given time?
c. What is the width (in meters) of a bit in the link?

Answer:

$$\begin{aligned} d &= 20,000\,\text{km} \\ &= 20000 \times 10^3\,\text{m} \qquad \left(\text{Since } 1\,\text{km} = 10^3\,\text{m}\right) \\ &= 2 \times 10^7\,\text{m} \end{aligned}$$

$$\begin{aligned} R &= 1\,\text{Gbps} \\ &= 1 \times 10^9\,\text{bps} \qquad \left(\text{Since } 1\,\text{Gbps} = 10^6\,\text{bps}\right) \\ &= 10^9\,\text{bps} \end{aligned}$$

$$S = 2.5 \times 10^8 \text{ meters/sec}$$

$$\begin{aligned} d_{prop} &= \frac{d}{S} \\ &= \frac{2 \times 10^7}{2.5 \times 10^8} \\ &= 0.08\,\text{sec} \end{aligned}$$

$$\begin{aligned} \text{R} \times d_{Prop} &= 10^9 \times 0.08 \\ &= 80000000\,\text{bits} \end{aligned}$$

26. **Refer again to problem P25.**

a) **How long does it take to send the file, assuming it is sent continuously?**
b) **Suppose now the file is broken up into 20 packets with each packet containing 40,000 bits. Suppose that each packet is acknowledged by the receiver and the transmission time of an acknowledgment packet is negligible. Finally, assume that the sender cannot send a packet until the preceding one is acknowledged. How long does it take to send the file?**
c) **Compare the results from (a) and (b).**

Answer:

As per problem 25, two hosts (A and B) are connected using direct link.
The distance between these two hosts A and B = 20,000km
= 20000x10^3 m
=2x10^7 m

Transmission rate (speed) of the direct link between A and B(R) = 2Mbps
= 2 x 10^6 bps
Propagation speed of the link between A and B(S) = 2.5x10^8 meters/sec
a)
Here, length of the file is transmitted continuously and it is represented as L.
The length of the file (L) = 800,000bits
Calculating the propagation delay = distance/speed
= 2x10^7 / 2.5 x 10^8 = 0.08sec = 80msec
Calculate the transmission delay =

$$= \frac{800000 \text{ bits}}{2 \times 10^6 \text{ bits/sec}} = 0.4 \sec = 400 \text{ msec} \qquad (\text{Since} 1 \sec = 1000 \text{ msec})$$

The time required for transmitting the file continuously =

$$T = d_{\text{prop}} + d_{\text{trans}} = 80 + 400 = 480 \text{ msec}$$

b)
The length of the file (L) = 800,000bits
The file is divided into 20 packets. So, the length of each packet =40,000bits

Calculating the propagation delay = distance/speed
= 2x10^7 / 2.5 x 10^8 = 0.08sec = 80msec
Calculate the transmission delay =

$$= \frac{40000 \text{ bits}}{2 \times 10^6 \text{ bits/sec}} = 0.02 \sec = 20 \text{ msec}$$

Calculate the total time required to transmit *n* packets:

$$= n\left(2d_{\text{prop}} + d_{\text{trans}}\right) = 20\left(2 \times 80 + 20\right) = 20\left(160 + 20\right) = 20\left(180\right) = 3600 \text{ msec}$$

c)
The time taken to transfer the file continuously from the host A to B is **480** msec as per part(a).
The time taken to transfer the file by divided into multiple packets from the host A to B is **3600** msec as per part(b).
Hence, transmitting the file continuously is more efficient than transmitting the file as multiple packets.

27. Suppose there is a 10 Mbps microwave link between a geostationary satellite and its base station on Earth. Every minute the satellite takes a digital photo and sends it to the base station. Assume a propagation speed of 2.4 _ 108 meters/sec.

a) **What is the propagation delay of the link?**
b) **What is the bandwidth-delay product, *R* · *d*prop?**
c) **Let *x* denote the size of the photo. What is the minimum value of *x* for the microwave link to be continuously transmitting?**

Answer:

a)

The Distance between geostationary satellite and earth (d) = $3.6*10^{7}$ meters

The Propagation speed (s) = $2.4*10^{8}$ meters/sec

The Transmission rate(R) = 10Mbps

The propagation delay is calculated by using the below formula

$$d_{prop} = \frac{\text{Distance (d)}}{\text{Propagation speed (s)}} = \frac{d}{s}$$

$$= \frac{3.6 \times 10^{7} \text{ meters}}{2.4 \times 10^{8} \text{ meters/sec}}$$

$$= 0.15 \text{ sec}$$

Hence, the propagation delay of the link = 0.15sec

b)

Transmission rate(R) = 10Mbps $= 10 \times 10^{6} = 10^{7}$ bits

Propagation delay = 0.15 sec

The bandwidth-delay product is calculated by using the formula

$$R.d_{prop} = 10^{7} \times 0.15 \text{bits} = 15 \times 10^{5} \text{bits} = 1,500,000 \text{ bits}$$

Hence, the product of bandwidth and delay is 1500,000 bits.

c)

Transmission rate(R) = 10Mbps $= 10 \times 10^{6} = 10^{7}$ bits

Assume the photo size is x

The frequency of transmitting the digital photo by the satellite is equal to 1per minute or per 60 seconds. So, the interval between each photo is 60 seconds.

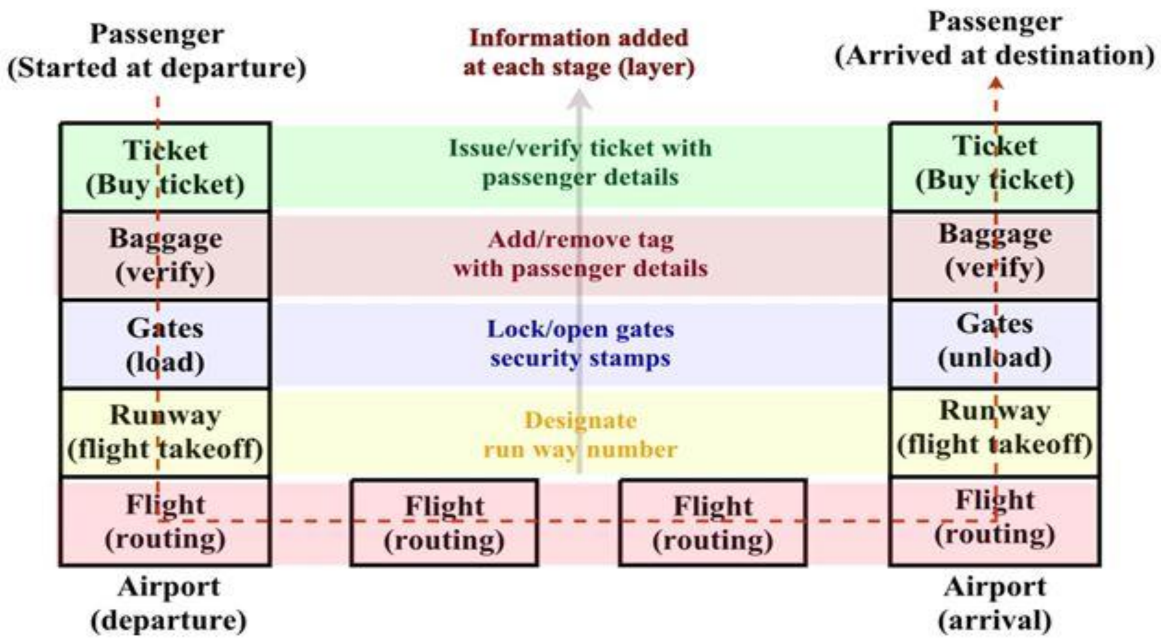
Minimum value of $x = 10^{7}$ bits * 60 seconds

=600,000,000 bits

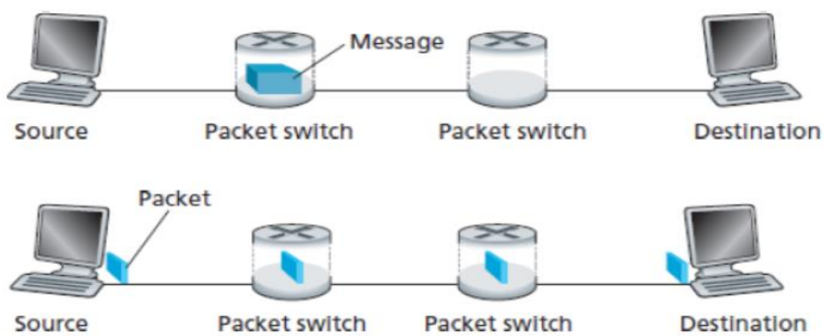
Hence, the minimum value of x for the microwave link can continuously transmitting is 600000000 bits.

28. **Consider the airline travel analogy in layering, and the addition of headers to protocol data units as they flow down the protocol stack. Is there an equivalent notion of header information that is added to passengers and baggage as they move down the airline protocol stack?**

Answer:



29. **In modern packet-switched networks, including the Internet, the source host segments long, application-layer messages (for example, an image or a music file) into smaller packets and sends the packets into the network. The receiver then reassembles the packets back into the original message. We refer to this process as *message segmentation*. Figure illustrates the end-to-end transport of a message with and without message segmentation. Consider a message that is 8 · 106 bits long that is to be sent from source to destination in Figure. Suppose each link in the figure is 2 Mbps. Ignore propagation, queuing, and processing delays.**



Answer:

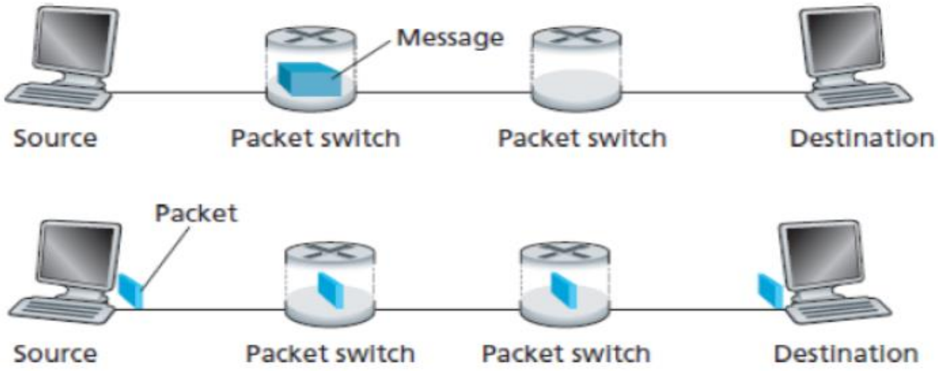
a. Consider sending the message from source to destination *without* message segmentation. How long does it take to move the message from the source host to the first packet switch? Keeping in mind that each switch uses store-and-forward packet switching, what is the total time to move the message from source host to destination host?

b. Now suppose that the message is segmented into 800 packets, with each packet being 10,000 bits long. How long does it take to move the first packet from source host to the first switch? When the first packet is being sent from the first switch to the second switch, the second packet is being sent from the source host to the first switch. At what time will the second packet be fully received at the first switch?

c. How long does it take to move the file from source host to destination host when message segmentation is used? Compare this result with your answer in part (a) and comment.

d. In addition to reducing delay, what are reasons to use message segmentation?

e. Discuss the drawbacks of message segmentation.



a) 1) Time to send message from source host to first packet switch = $\frac{8\times10^6}{2\times10^6}\sec = 4\sec$

2) With store-and-forward switching, the total time to move message from source host to destination host = $4\sec\times 3\ hops = 12\sec$.

b) 1) Time to send 1st packet from source host to first packet switch = $\frac{1\times10^4}{2\times10^6}\sec = 5\ m\sec$.

2) Time at which 2nd packet is received at the first switch = time at which 1st packet is received at the second switch = $2\times 5m\sec = 10\ m\sec$

c) 1) Time at which 1st packet is received at the destination host = $5\ m\sec\times 3\ hops = 15\ m\sec$. After this, every 5msec one packet will be received; thus time at which last (800th) packet is received = $15\ m\sec + 799 * 5m\sec = 4.01\sec$.

2) It can be seen that delay in using message segmentation is significantly less (almost 1/3rd).

30. Experiment with the Message Segmentation applet at the book's Web site. Do the delays in the applet correspond to the delays in the previous problem?

<u>Answer:</u>

How do link propagation delays affect the overall end-to-end delay for packet switching (with message segmentation) and for message switching?

Yes, the delays in the applet correspond to the delays in the Problem 31. The propagation delays affect the overall end-to-end delays both for packet switching and message switching equally.

31. Consider sending a large file of *F* bits from Host Ato Host B. There are three links (and two switches) between A and B, and the links are uncongested (that is, no queuing delays). Host A segments the file into segments of *S* bits each and adds 80 bits of header to each segment, forming packets of *L* = 80 + *S* bits. Each link has a transmission rate of *R* bps. Find the value of *S* that minimizes the delay of moving the file from Host A to Host B. Disregard propagation delay.

<u>Answer:</u>

A large file is transmitted with F bits from host A to host B.
No. of links between the hosts A and B is 3
No. of switches that connects the links is 2
The file size is *F* bits
The each segment size is *S* bits

The number of segments that the file is divided $= \frac{F}{S}$

The header size is 80 bits
The packet size (L) is 80+S bits
The transmission rate (R) is Rbps
The transmission delay is calculated by using the formula.

$$T_{delay} = \frac{L}{R} = \frac{80+S}{R} \text{ seconds}$$

The number of links between the hosts A and B is 3.

The time (T) required for the first packet to be transmitted to destination is calculated as shown below.

$$T = T_{delay} \text{number of links} = \left(\frac{80+S}{R}\right) \times 3 \text{seconds}$$

After the first packet reaches the destination, one packet is received at destination for every $\left(\frac{80+S}{R}\right)$ seconds.

The total delay in transmitting the total file is calculated by using the below formula:

$$T_{total} = \text{delay for first packet} + (\text{number of packets} \times \text{delay for one packet})$$
$$= \left(\frac{80+S}{R}\right) \times 3 + \left(\frac{F}{S} - 1\right) \times \left(\frac{80+S}{R}\right)$$
$$= \left(\frac{80+S}{R}\right)\left(\frac{F}{S} + 2\right)$$

The following equation gives the transmission delay as a function of size of segment.

$$T_{total} = \left(\frac{80+S}{R}\right)\left(\frac{F}{S} + 2\right)$$

Differentiate the above equation with respective to S and equate to 0 to find the minimum value of S.

$$\frac{d(uv)}{dx} = v\frac{du}{dx} + u\frac{dv}{dx}$$
$$\frac{dc}{dx} = 0$$
$$\frac{dx}{dx} = 1$$
$$\frac{d}{dx}\left(\frac{1}{x}\right) = \frac{-1}{x^2}$$

Differentiate the equation $T_{total} = \left(\frac{80+S}{R}\right)\left(\frac{F}{S} + 2\right)$ with respective to S.

$$\frac{dT_{total}}{dS} = 0$$
$$\frac{d}{dS}\left[\left(\frac{80+S}{R}\right)\left(\frac{F}{S} + 2\right)\right] = 0$$
$$\left(\frac{F}{S} + 2\right)\frac{d}{dS}\left(\frac{80+S}{R}\right) + \left(\frac{80+S}{R}\right)\frac{d}{dS}\left(\frac{F}{S} + 2\right) = 0$$
$$\left(\frac{F}{S} + 2\right)\left(\frac{d}{dS}\left(\frac{80}{R}\right) + \frac{d}{dS}\left(\frac{S}{R}\right)\right) + \left(\frac{80+S}{R}\right)\left(\frac{d}{dS}\left(\frac{F}{S}\right) + \frac{d}{dS}(2)\right) = 0$$
$$\left(\frac{F}{S} + 2\right)\left(0 + \frac{1}{R}\right) + \left(\frac{80+S}{R}\right)\left(\frac{-F}{S^2} + 0\right) = 0$$
$$\left(\frac{F+2S}{S}\right)\left(\frac{1}{R}\right) + \left(\frac{80+S}{R}\right)\left(\frac{-F}{S^2}\right) = 0$$
$$\frac{\cancel{SF} + 2S^2 - 80F - \cancel{SF}}{RS^2} = 0$$
$$2S^2 - 80F = 0$$
$$2S^2 = 80F$$
$$S^2 = 40F$$
$$S = \sqrt{40F}$$

Hence, the value of $S = \boxed{\sqrt{40F}}$

References:

1. http://www.sr2jr.com/textbook-solutions/computer-science/10102034/computer-networking-a-top-down-approach-computer-networks-and-the-internet
2. James F. Kurose, Keith W. Ross, Computer Networking, A Top-Down Approach Featuring the Internet, Eighth Edition, Pearson Education, 2021