Homework 1

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1 R4

DSL: Home access
Cable: Home access
Ethernet: Enterprise access
Wifi: Enterprise access(also some home access, wide area wireless access)
3G: Wide area wireless access
LTE: Wide area wireless access

2 R10

3G, 4G, LTE and Wifi:

Description:
3G: User get connected within tens of kilometers. Operated by the cellular network provider. It provides packet-switched wide-area wireless Internet access at speeds in excess of 1 Mbps by Telecommunications companies.(Refer to Page 18 of textbook)
4G: higher-speed wide-area access compared to 3G.
LTE: even higher-speed wide-area access compared to 3G in excess of 10 Mbps.
Above are all examples of Wide area wireless accesses.
Wifi(An example of wireless LAN): User get connected within tens of meters. The enterprise's network that user is connected to connects to the wired Internet. It's a widely used wireless access.

Compare and contrast:
Similarities: They are all wireless accesses.
Differences: Using 3G, 4G, LTE, a user need only be within a few tens of kilometers (as opposed to a few tens of meters) of the base station. (Refer to Page 18 of textbook).
3G provides packet-switched wide-area wireless Internet access at speeds in excess of 1 Mbps, whereas 4G provides even higher speed Internet access and LTE's speed is in excess of 10 Mbps. But Wifi provides a shared transmission rate of up to 54 Mbps, which is the fastest(Refer to Page 17 of textbook).

Wireless LAN is used more widely for home, universities etc compared to wide area wireless accesses.

3 R12

Advantage a circuit-switched network has over a packet-switched network: the resources(transmission links and bandwidth) needed along a path to provide for communication between the end systems are reserved for the duration of the communication session between the end system(Refer to Page 27 of textbook). The sender transfers data to the receiver at the "guaranteed" constant rate in this way, reducing a lot of potential waiting time caused by packet-switched network. It is also better for real time connections.

Advantages TDM has over FDM in a circuit-switched network:
In TDM, time is divided into frames of fixed duration, and each frame is divided into a fixed number of time slots, so they share same frequency.
TDM needs simple circuitry.

4 R13

(a) $\frac{2Mbps}{1Mbps} = 2$ Users

(b) If less than two users transmit data at the same time, the data will get successfully passed without burden. This is because the users are sharing 2 Mbps link and each user needs 1 Mbps. But if three users transmit data at the same time, a router cannot transmit three people's file at the same time – If an arriving packet needs to be transmitted onto a link but finds the link busy with the transmission of another packet, the arriving packet must wait in the output buffer(Refer to Page 25 of textbook). The link(2 Mbps) cannot handle three users' transfer requirements(3*1 = 3Mbps) at the same time.

(c) 20 Percent

(d) $3!/3!*0.2*0.2*0.2*0.8^0 = 0.008$ (Probability for Binomial Random Variables)
The fraction of time that the queue grows is equal to the probability that all three users transfer at the same time. So it is also 0.008.

5 R19

(a) throughput is Min(500 kbps, 2 Mbps, 1 Mbps) = 500 kbps

(b) $\frac{4millionBytes}{500kb/s} = \frac{4000000*8}{500000/s} = 64$ seconds

(c) Then throughput is Min(200 kbps, 2 Mbps, 1 Mbps) = 100 kbps
Transfering time = $\frac{4millionBytes}{100kb/s} = \frac{4000000*8}{100000/s} = 320$ seconds

6 R20

It first divides the large file into chunks and add them with headers(which includes the destination IP address). Those are packets.
When a packet arrives at a router in the network, the router examines a portion of the packet's destination address and forwards the packet to an adjacent router. More specifically, each router has a forwarding table that maps destination addresses (or portions of the destination addresses) to that router's outbound links. The router then directs the packet to this outbound link.(Refer to textbook page 26)
This is analogous to driving from one city to another and asking directions along the way because people being asked are analogous to routers who directs which way the driver should take by examining my destination address.

7 R23

They are application, transport, network, link, physical.

Principal responsibilities:
Application: It includes many protocols, such as such as the HTTP protocol (which provides for Web document request and transfer), SMTP (which provides for the transfer of e-mail messages), and FTP (which provides for the transfer of files between two end systems). An application-layer protocol is distributed over multiple end systems, with the application in one end system using the protocol to exchange packets of information with the application in another end system. We'll refer to this packet of information at the application layer as a message. (Refer to textbook page 51)

Transport: It transports application-layer messages between application endpoints. Two transport protocols: TCP and UDP. TCP provides a connection-oriented service to its applications(including guaranteed delivery of application-layer messages to the destination and flow control). UDP protocol provides a connectionless service to its applications(which is a no-frills service that provides no reliability, no flow control, and no congestion control). (Refer to textbook page 51)

Network: It is responsible for moving network-layer packets known as datagrams from one host to another. the network layer contains both the IP protocol(which defines the fields in the datagram as well as how the end systems and routers act on these fields) and numerous routing protocols that determine the routes that datagrams take between sources and destinations. (Refer to textbook page 51)

Link: It moves a packet from one node (host or router) to the next node in the route. The network layer passes the datagram down to the link layer, and at this next node, the link layer passes the datagram up to the network layer. Examples of link- layer protocols include Ethernet, WiFi, and the cable access network's DOCSIS pro- tocol. A datagram may be handled by different link-layer protocols at different links along its route. (Refer to textbook page 51)

Physical: It moves the individual bits within the frame from one node to the next. The protocols in this layer are again link dependent and further depend on the actual transmission medium of the link. So a bit may be moved across the link in a different way. (Refer to textbook page 51)

8 P1

Protocol specification(Assuming no message get lost if connected):

Protocol1: Connection request
Sender: automatic teller machine
Receiver: centralized computer
Message: connection request
Action taken by Receiver: reply connection success message upon reception of request
Action taken by Sender: After sending the request, starts waiting. If no reply for a certain amount of time, report to user of failure in connection. If success message received, display and ask user to input card number or insert card(read card number) and password

Protocol2: Verification request
Sender: automatic teller machine
Receiver: centralized computer
Message: verification request, user's card number and password pair Action taken by Receiver: check if card number and password is a valid pair, if valid, reply with verification success message, if not valid, reply with verification failure message
Action taken by Sender: After sending the request, starts waiting. (Then if verification success message received, ask user which action to take, if verification failure message received, ask user to input card and password again)

Protocol3: CheckBalance request
Sender: automatic teller machine
Receiver: centralized computer
Message: CheckBalance request
Action taken by Receiver: check the user's account balance in the database and send back CheckBalance success message and the corresponding balance
Action taken by Sender: After sending the request, starts waiting. (Then when success message received, display the balance and ask user which action to take)

Protocol4: Withdrawal request
Sender: automatic teller machine
Receiver: centralized computer
Message: withdrawal request, amount Action taken by Receiver: check if account balance is sufficient, if sufficient, decrease the balance and send back the withdrawal success message, if not sufficient, reply with withdrawal failure message
Action taken by Sender: After sending the request, starts waiting. (Then if success message received, give user the money and display thank you message, if withdrawal failure message received, ask user which action to take again)

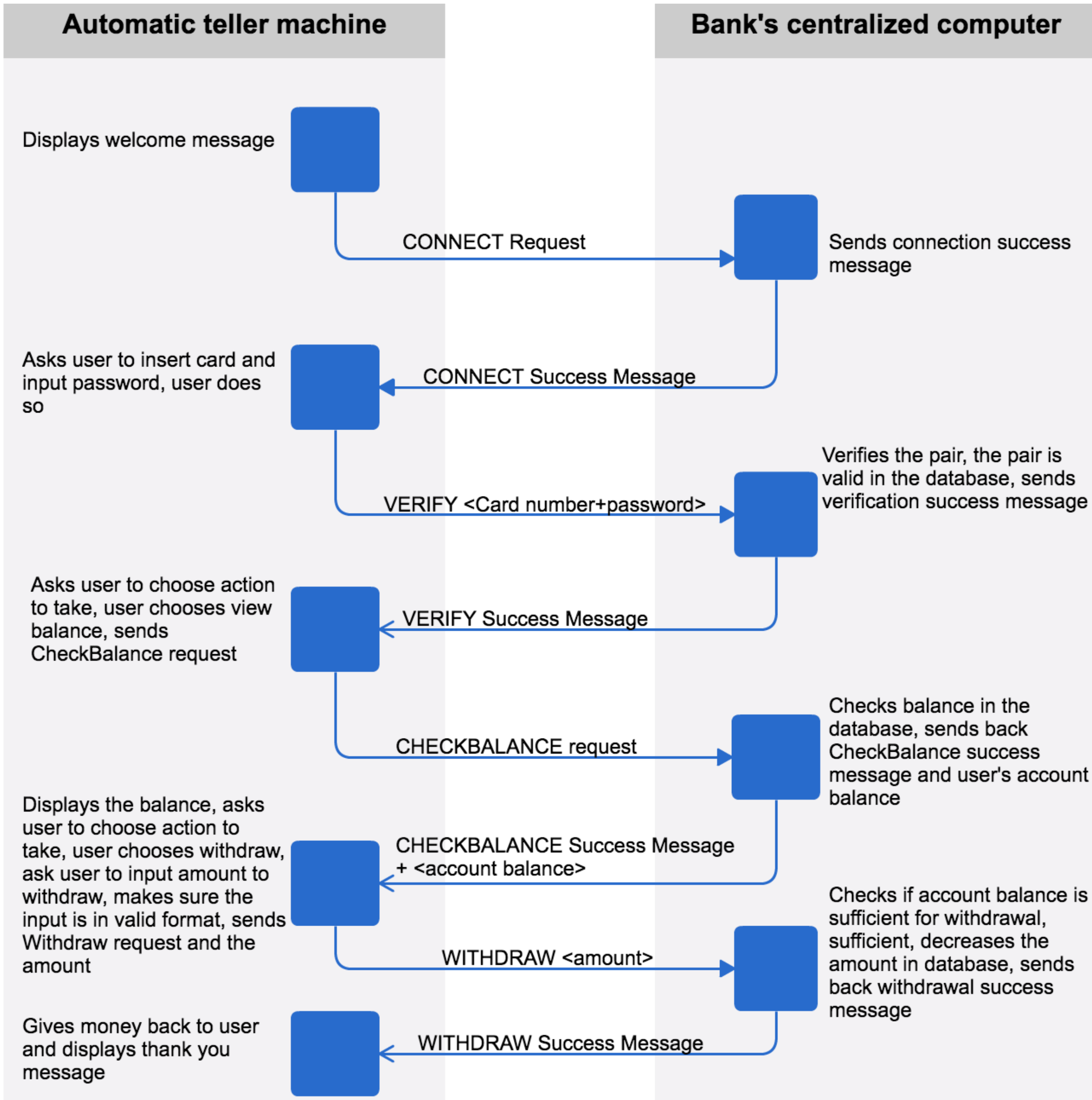
Protocol5: Connection success message
Sender: centralized computer
Receiver: automatic teller machine
Message: connection success
Action taken by Receiver: If verification message received, display account balance and ask user which action to take, if verification failure message received, ask user to input card and password again
Action taken by Sender: /

Protocol6: Verification success message/ failure message
Sender: centralized computer
Receiver: automatic teller machine
Message: Verification success/ Verification failure
Action taken by Receiver: If success verification message received, ask user which action to take, if verification failure message received, ask user to input card and password again
Action taken by Sender: /

Protocol7: CheckBalance success message
Sender: centralized computer
Receiver: automatic teller machine
Message: CheckBalance success and account balance
Action taken by Receiver: When success message received, display the balance and ask user which action to take
Action taken by Sender: /

Protocol8: Withdrawal success message/ failure message
Sender: centralized computer
Receiver: automatic teller machine
Message: withdrawal success/ failure Action taken by Receiver: If success message received, give user the money and display thank you message, if withdrawal failure message received, ask user which action to take again
Action taken by Sender: /

Diagram:



9 P3

circuit-switched network. Because in circuit-switched network, the sender transfers data to the receiver at the ”guaranteed” constant rate in this way, reducing a lot of potential waiting time caused by packet-switched network, which better fits the requirement. It also will continue running in a long time, so it is better to reserve resources.

There is no form of congestion control needed. Because the packets are sent through links, and the sum of the application data rates is less than the capacities of each and every link, so the links are capable of handling the packets.

10 P12

Total length of packets waiting $= (4 * 1500 + 1500/2) * 8 = 54000bits$
Queueing delay: $54000bits/2Mbps = 54000bits/200000bps = 0.027$ seconds
General formula of queuing delay: $\frac{(n+1)L-x}{R} = \frac{nL+L-x}{R}$

11 P18

Visiting from www.net.princeton.edu to www.yahoo.com(98.139.180.149) for intra-continent experiments.
Visiting from www.net.princeton.edu to www.baidu.com(103.235.46.39) for inter-continent experiments.

(a)
Average:
1PM: $(14.841 + 14.948 + 16.126)/3 = 15.185$ms
2PM: $(15.022 + 15.009 + 14.767)/3 = 14.933$ms
3PM: $(14.946 + 24.701 + 15.094)/3 = 18.247$ms

Standard deviation:
1PM: $\sqrt{((14.841 - 15.185)^2 + (14.948 - 15.185)^2 + (16.126 - 15.185)^2)/3} = 0.713$ms
2PM: $\sqrt{((15.022 - 14.933)^2 + (15.009 - 14.933)^2 + (14.767 - 14.933)^2)/3} = 0.144$ms
3PM: $\sqrt{((14.946 - 18.247)^2 + (24.701 - 18.247)^2 + (15.094 - 18.247)^2)/3} = 5.589$ms

Average on three averages: $(15.185 + 14.933 + 18.247)/3 = 16.122$ms
Standard deviation on three averages:
$\sqrt{((15.185 - 16.122)^2 + (14.933 - 16.122)^2 + (18.247 - 16.122)^2)/3} = 1.845$ms

(b)
1PM: 13 routers
2PM: 13 routers
3PM: 13 routers
The paths didn't change during the hours.

(c)
1PM: 10 ISP networks
2PM: 10 ISP networks
3PM: 10 ISP networks
The largest delay occur between adjacent ISPs.

(d)
round-trip delays:

1PM: $(249.561 + 252.106 + 250.910)/3 = 250.859$ms
2PM: $(252.256 + 248.414 + 252.876)/3 = 251.182$ms
3PM: $(253.937 + 254.431 + 256.305)/3 = 254.891$ms

Standard deviation:
1PM: $\sqrt{((249.561 - 250.859)^2 + (252.106 - 250.859)^2 + (250.910 - 250.859)^2)/3}$
$= 1.273$ms
2PM: $\sqrt{((252.256 - 251.182)^2 + (248.414 - 251.182)^2 + (252.876 - 251.182)^2)/3}$
$= 2.417$ms
3PM: $\sqrt{((253.937 - 254.891)^2 + (254.431 - 254.891)^2 + (256.305 - 254.891)^2)/3}$
$= 1.249$ms

Average on three averages: $(250.859 + 251.182 + 254.891)/3 = 252.311$ms
Standard deviation on three averages:
$\sqrt{((250.859 - 252.311)^2 + (251.182 - 252.311)^2 + (254.891 - 252.311)^2)/3} = 2.240$ms

number of routers:

1PM: 16 routers
2PM: 16 routers
3PM: 16 routers
The paths changed route between 2PM and 1PM, specifically, in hop 4 at 1PM, the router's address is 66.28.4.233, but in hop 4 at 2PM, the router's address is 154.54.1.253.

number of ISP networks:

1PM: 7 ISP networks
2PM: 6 ISP networks
3PM: 6 ISP networks

Also, the largest delay occur between adjacent ISPs.

Compare the results: The inter-continent travel takes much longer delay time compared to intra-continent travel. Inter-continent travel bypasses less routers than intra-continent travel does in this case. But the number of ISPs show the opposite result where intra-continent travel has less ISPs in this case. This means that longer distance travel doesn't mean more ISPs involved. It may change route at different hours. Both travels are showing between adjacent ISPs occurs larger delay.