Problem 1

In this problem, you will put together much of what you have learned about Internet protocols. Suppose you walk into a room, connect to Ethernet, and want to download a Web page. What are the protocol steps that take place, starting form powering on your PC to getting the Web page? Assume there is nothing in our DNS or browser caches when you power on your PC. Explicitly indicate in your steps how you obtain the IP and MAC addresses of the first-hop router.

From starting with powering on the PC:
The first thing that happens is that your PC needs to get its own IP address, which is usually locally saved. Then, through the Ethernet Connection, your PC sends a broadcast message to the DHCP Server. The DHCP Server will then provide the PC with the IP adresses of both the first-hop router of the local network as well as the local DNS Server. In some cases, the device will also need to get an IP address from this DHCP Server, based on the allocated addresses available.
Next, the ARP protocol is used to get the MAC address of these two devices (first hop router, DNS server) and save these addresses to a switch table.
Next, after the specific web page is requested, a DNS query is made to the local DNS server to try and resolve this host name to an IP address; this is done using either iterative or recursive DNS queries.
Once the IP is found, we generate the IP datagram that is to be sent to the Server hosting the web page (specified by the IP received from DNS). This is done by creating an HTTP request for this web page at the Application Layer to be sent out.
This message is sent in the transport layer using the TCP protocol (the HTTP request data split into the payload of TCP Packets). These TCP Packets sent from the host to the destination will be encapsulated by an IP packet, which is routed using OSPF (if the destination is in the same AS) or iBGP and eBGP to get to the correct AS with the destination server, using OSPF within an AS.
The Initial IP datagrams sent will include the packets from the TCP Handshake. One these packets are sent and finalized and the TCP connection is established, then the PC will send the actual HTTP request message. This message is split into TCP packets that are put into IP datagrams, based on the MTU size of each protocol. All of these packets sent go through the input ports, switching fabrics(which may have different implementations), and output ports of the routers/routing devices on the internet in the process of data forwarding at the Network Layer.
Once this message is received at the destination server that hosts the web page, the server will respond with an HTTP response message containing the data of the web page. This includes the metadata as well as any data on the page or referenced objects/images.
Just like the messages from the PC to the server, the HTTP response is split into various TCP segments that are then forwarded in IP datagrams sent back to the PC. The PC then extracts the HTTP response data from these packets, and formats the HTTP response in our browser so that the downloaded web page displays on the PC.

Problem 2

Suppose four active nodes—nodes A, B, C and D—are competing for access to a channel using slotted ALOHA. Assume each node has an infinite number of packets to send. Each node attempts to transmit in each slot with probability p. The first slot is numbered slot 1, the second slot is numbered slot 2, and so on.

(a) What is the probability that node A succeeds for the first time in slot 5?

(b) What is the probability that any node (either A, B,C or D) succeeds in slot 4?

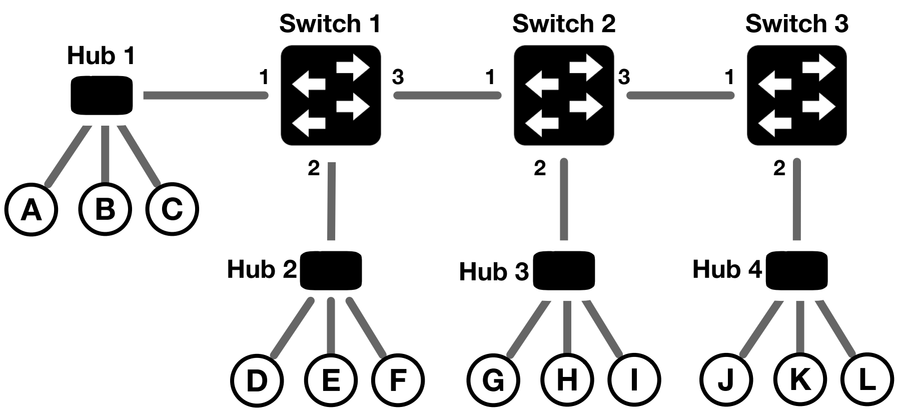
(a) Here, the probability that the first success for A is on its 5th try means the probability of 4 failsures for A (ie on the first 4 tries, one of the other nodes succeeded but not A) times the probability of a success on trial 5. This can be represented by:
Probability of A failing = Probability of B, C or D succeeding = 1-P(A succeeding) = 1-P(A succeeding, BCD all failing) = 1-(p*(1-p)*(1-p)*(1-p) = $1 - p * (1 - p)^3$
Probability of Succeeding on the 5th try = P(A failing 4 times) * P(A succeeding)
$= (1 - p * (1 - p)^3)^4 * p(1 - p)^3$

(b) For this communication to work, only one host is able to talk at a time. This means that all other hosts must not talk/transmit in this time. Thus, the probability of one host succeeding is equal to the probability of the even that one host succeeds AND all other hosts fail. There will be 4 cases of this, each with the same probablility because ANY of the four hosts can succeed.
$= 4 * p * (1 - p)^3$

Problem 3

Consider the following network connected by three switches. The circles in the figure indicate the hosts (From host A to host L). At time=0s, the forwarding tables of all three switches are empty. Assume that all the hosts already know MAC addresses of other hosts, therefore no ARP is required. Also, assume that the TTL values of the forwarding table entries are big enough so that it will not expire in this problem. Suppose, the following seven events happen sequentially:

- Time=1s: Host A sends an IP datagram to Host G
- Time=2s: Host G sends an IP datagram to Host A
- Time=3s: Host D sends an IP datagram to Host L
- Time=4s: Host D sends an IP datagram to Host I
- Time=5s: Host F sends an IP datagram to Host A
- Time=6s: Host K sends an IP datagram to Host G
- Time=7s: Host J sends an IP datagram to Host F



(a) How many times has each switch broadcasted the received frames? (Considering all seven events above.)

Switch 1 has broadcasted its received frames 3 times.
Switch 2 has broadcasted its received frames 4 times.
Switch 3 has broadcasted its received frames 5 times.

(b) List the forwarding table of each switch after the seven events.

Switch 1:

Host	Interface
A	1
G	3
D	2
F	2
J	3

Switch 2:

Host	Interface
A	1
G	2
D	1
K	3
J	3

Switch 3:

Host	Interface
A	1
D	1
K	2
J	2

(c) At time=10s, Host A sends Broadcast IP datagram in the network. How many hosts will receive this broadcast IP datagram excluding the sender?

The broadcast from Host A is received by the hosts: B, C, D, E, F, G, H, J, K, and L.
Thus, 11 hosts receive this broadcasted IP datagram.

Problem 4

Suppose there are two ISPs, providing WiFi access in a particular café, with each ISP operating its own AP and having its own IP address block.

(a) Further suppose that by accident, each ISP has configured its AP to operate over channel 11. Will the 802.11 protocol completely break down in this situation? Discuss what happens when two stations, each associated with a different ISP, attempt to transmit at the same time.

(b) Now suppose that one AP operates over Channel 1 and the other over Channel 11. How do your answers change?

(a) If working at different times, there is theoretically no big problems with this. However, when the two stations on different ISPs attempt to transmit at the same time, there will be a collision if they are on the same channel. Each ISP will run through an individual AP, and each of these will be unique from one other with their own SSIDs and MAC addresses. Two stations can still use these APs to connect to the internet; in the case that one station transmits at a time, then both APs will see this transmission, but only the one with the corresponding SSID and MAC address will actually accept the transmission. Problems arise when they both try to transmit at the same time. This is because since they are using the same channel, they will be competing for the same bandwidth within the channel. This leads to less connectivity/throughput for each, and both transmissions combined are limited to the total throughput of the channel, which differs based on the type of 802.11 protocol being used. Thus, while the 802.11 protocol will not completely break down, there will be an increase in latency for each of these internet connections.

(b) If the APs are operating on different channels, then the two stations that are connecting (one to each AP) will not have any issues with collisions between each other. This is because each of these stations will be able to use the entire bandwidth from its corresponding channel. Thus, there is no issue of collision and each of these transmissions is individually limited by the full throughput available from a channel, rather than both of them competing for bandwidth in the same channel.

Problem 5

In Mobile IP, what effect will mobility have on end-to-end delays of datagrams between the source and destination?

Depending on the implementation of mobility, Mobile IP could increase end-to-end delays of datagrams between source and destination. This is because of the IP addresses (in other words, the device with a certain IP) being mobile and connecting to different agents. In the case of indirect routing, a mobile device will use its IP on a visiting network to connect to a foreign agent, which then establishes a connection to the device's home agent. In this routing, everything sent from and end-system on the internet that is meant for a mobile host is sent first to the home agent on the receiving (mobile) host's home network, and then sent to the foreign agent where the host currently is before final reaching the host. An increase in delay could come due to this propagation of the packets from an end-system through the home agent to the foreign agent then to the receiver (the mobile host), rather than going from the foreign agent directly to the receiver. Another thing is that in this indirect routing, an added delay occurs in the home router because here, the IP datagram received has to be encapsulated in another IP datagram, one with a destination address that can reach the receiveing host through the foreign agent. In the case of direct routing, however, it is theoretically possible for a mobile host to connect to a foreign agent, and create a new TCP connection to an end-system over this internet to pick up where it left off when it was previously at its home network; this could potentially create a shorter path for the datagrams to travel compared to the indirect case. Therefore, mobility can increase end-to-end delays of datagrams on the internet if the routing used is indirect routing.