

## 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 from 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 a gateway router.

(The following description is short, but contains all major key steps and key protocols involved.)

Your computer first uses DHCP to obtain an IP address. Your computer first creates a special IP datagram destined to 255.255.255.255 in the DHCP server discovery step, and puts it in a Ethernet frame and broadcast it in the Ethernet. Then following the steps in the DHCP protocol, your computer is able to get an IP address with a given lease time.

A DHCP server on the Ethernet also gives your computer a list of IP addresses of first-hop routers, the subnet mask of the subnet where your computer resides, and the addresses of local DNS servers (if they exist).

Since your computer's ARP cache is initially empty, your computer will use ARP protocol to get the MAC addresses of the first-hop router and the local DNS server.

Your computer first will get the IP address of the Web page you would like to download. If the local DNS server does not have the IP address, then your computer will use DNS protocol to find the IP address of the Web page.

Once your computer has the IP address of the Web page, then it will send out the HTTP request via the first-hop router if the Web page does not reside in a local Web server. The HTTP request message will be segmented and encapsulated into TCP packets, and then further encapsulated into IP packets, and finally encapsulated into Ethernet frames. Your computer sends the Ethernet frames destined to the first-hop router. Once the router receives the frames, it passes them up into IP layer, checks its routing table, and then sends the packets to the right interface out of all of its interfaces.

Then your IP packets will be routed through the Internet until they reach the Web server.

The server hosting the Web page will send back the Web page to your computer via HTTP response messages. Those messages will be encapsulated into TCP packets and then further into IP packets. Those IP packets follow IP routes and finally reach your first-hop router, and then the router will forward those IP packets to your computer by encapsulating them into Ethernet frames.

## Problem 2

Consider the hierarchical network in Slide 6-84 and suppose that the data center needs to support email and video distribution among other applications. Suppose four racks of servers are reserved for email and four racks are reserved for video. For each of the applications, all four racks must lie below a single tier-2 switch since the tier-2 to tier-1 links do not have sufficient bandwidth to support the intra-application traffic. For the email application, suppose that for 99.99 percent of the time only three racks are used, and that the video application has identical usage patterns.

- (a) For what fraction of time does the email application need to use a fourth rack? How about for the video application?
- (b) Assuming email usage and video usage are independent, for what fraction of time do (equivalently, what is the probability that) both applications need their fourth rack?

- (a) Both email and video application uses the fourth rack for 0.01 percent of the time.
- (b) Probability that both applications need fourth rack is  $0.0001 * 0.0001 = 10^{-8}$ .

## Problem 3

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) The two APs will typically have different SSIDs and MAC addresses. A wireless station arriving to the café will associate with one of the SSIDs (that is, one of the APs). After association, there is a virtual link between the new station and the AP. Label the APs AP1 and AP2. Suppose the new station associates with AP1. When the new station sends a frame, it will be addressed to AP1. Although AP2 will also receive the frame, it will not process the frame because the frame is not addressed to it. Thus, the two ISPs can work in parallel over the same channel. However, the two ISPs will be sharing the same wireless bandwidth. If wireless stations in different ISPs transmit at the same time, there will be a collision. For 802.11b, the maximum aggregate transmission rate for the two ISPs is 11 Mbps.
  - (b) Now if two wireless stations in different ISPs (and hence different channels) transmit at the same time, there will not be a collision. Thus, the maximum aggregate transmission rate for the two ISPs is 22 Mbps for 802.11b.

## Problem 4

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

Because datagrams must be first forward to the home agent, and from there to the mobile, the delays will generally be longer than via direct routing. Note that it is possible, however, that the direct delay from the correspondent to the mobile (i.e., if the datagram is not routed through the home agent) could actually be smaller than the sum of the delay from the correspondent to the home agent and from there to the mobile. It would depend on the delays on these various path segments. Note that indirect routing also adds a home agent processing (e.g., encapsulation) delay.

## Problem 5

Answer the following questions:

- (a) What are three important differences between the 3G and 4G cellular architectures?
- (b) What is the role of the eNodeB, MME, P-GW, and S-GW in 4G architecture?

- (a) In 3G architecture, there are separate network components and paths for voice and data, i.e., voice goes through public telephone network, whereas data goes through public Internet. 4G architecture is a unified, all-IP network architecture, i.e., both voice and data are carried in IP datagrams to/from the wireless device to several gateways and then to the rest of the Internet.

The 4G network architecture clearly separates data and control plane, which is different from the 3G architecture.

The 4G architecture has an enhanced radio access network (E-UTRAN) that is different from 3G's radio access network UTRAN.

- (b) The data plane role of eNodeB is to forward datagram between UE (over the LTE radio access network) and the P-GW. Its control plane role is to handle registration and mobility signaling traffic on behalf of the UE.

The mobility management entity (MME) performs connection and mobility management on behalf of the UEs resident in the cell it controls. It receives UE subscription information from the HHS.

The Packet Data Network Gateway (P-GW) allocates IP addresses to the UEs and performs QoS enforcement. As a tunnel endpoint it also performs datagram encapsulation/decapsulation when forwarding a datagram to/from a UE.

The Serving Gateway (S-GW) is the data-plane mobility anchor point as all UE traffic will pass through the S-GW. The S-GW also performs charging/billing functions and lawful traffic interception.