1. A single host can run multiple network application programs, e.g., a Web browser, an e-mail client, etc. How can different application programs running on the same host be uniquely identified?

By using "ports", with each port assigned to a specific application.

2. Given your answer for (1), explain how multiplexing and de-multiplexing at the transport layer works.

All packets arrive at the host specified by the IP address in the packet's header. The transport layer looks at the destination port number in the transport-layer header, and delivers data to the appropriate application process (the one listening on that port).

3. For each of the Web requests below, list the sequence of steps to resolve the Web server's name. Assume names are not initially cached and name resolution is done iteratively.

i. Web client at att.com is requesting an object from www.ucsc.edu.

- DNS client sends DNS query to att.com's local DNS server.
- Local DNS NS looks up its cache. If the information is in the cache, it will reply to the client immediately.
- If not, it will query the DNS root NS, which will reply with the .edu DNS NS
- It will then query the .edu DNS NS, and receive the records for ucsc.edu's DNS NS.

ii. Web client at att.com is requesting an object from www.comcast.com.

- DNS client sends DNS query to att.com's local DNS server.
- Local DNS NS looks up its cache. If the information is in the cache, it will reply to the client immediately.
- If not, it will query the DNS root NS, which will reply with the .com DNS NS
- It will then query the .com DNS NS, and receive the records for comcast.com's DNS NS.

4. HTTP uses TCP as its underlying transport protocol.

i. Why do you thing the designers of HTTP picked TCP as its transport protocol?

One of HTTP's design goals was to be a simple protocol. HTTP can use TCP to handle reliability and in-order delivery at a lower level.

ii. What is the consequence of using TCP when considering delay?

Using TCP results in an additional RTT in order to set up the TCP connection ahead of sending data; therefore it does incur higher delay but achieves reliable data transfer.

5. We saw in class that both HTTP and DNS use caching to improve performance.

i. Explain how caching improves the performance of HTTP.

HTTP caching improves performance by trying to serve objects from caches that are located closer to the client requesting the object. That way, response times are reduced as well as the load on the network and origin servers. Think about nodal and end-to-end delay and the corresponding components.

ii. Explain how caching improves the performance of DNS.

In DNS, a DNS server may store DNS records that it recently received, in which case it can answer requests for these DNS records without needing to contact the authoritative name server.

iii. What is the main problem with caching? Explain.

Ensuring the content in the cache is up to date. Additionally, if cache miss ratios are too high, response times may end up increasing since the cache is consulted first before the request is forwarded to the origin.

6. A Web page has 7 embedded objects. Assume that the time to transmit the page and each of its embedded objects is 20ms while the propagation delay and service time within the network combined amount to approximately 150ms.

What is the total time perceived by the user between clicking on a link and having the entire object rendered if the user's browser employs:

i. Non-persistent HTTP.

1 object per request
2.56s

ii. Persistent HTTP.

Multiple object per request
1.51s

7. The Obama administration is committed to interconnect 15,000 K-12 schools to the Internet this year. Due to budget constraints, the schools can only afford connecting to the Internet through a 15Mbps link while the schools' local area networks use 100Mbps links. You were hired by the Department of Education to help design the solution to mitigate the mismatch between the access link and the local area network.

Assume that the delay to retrieve an object from the Internet is on average 3 seconds, while the delay to get an object of similar size residing in the LAN is 20ms. In order to improve access time, you then decide to install a Web cache in the village's network whose hit rate is 50%. What's the average delay to access an object? Compare it to the initial "cache-less" configuration.

With cache: .5(20) + .5(3000) = 1510ms
Without cache: 3000ms

1.99x speedup