Chapter 2 Review Questions

1. The Web: HTTP; file transfer: FTP; remote login: Telnet; e-mail: SMTP; BitTorrent file sharing: BitTorrent protocol

2. Network architecture refers to the organization of the communication process into layers (e.g., the five-layer Internet architecture). Application architecture, on the other hand, is designed by an application developer and dictates the broad structure of the application (e.g., client-server or P2P).

3. The process which initiates the communication is the client; the process that waits to be contacted is the server.

4. No. In a P2P file-sharing application, the peer that is receiving a file is typically the client and the peer that is sending the file is typically the server.

5. The IP address of the destination host and the port number of the socket in the destination process.

6. You would use UDP. With UDP, the transaction can be completed in one roundtrip time (RTT) - the client sends the transaction request into a UDP socket, and the server sends the reply back to the client's UDP socket. With TCP, a minimum of two RTTs are needed - one to set-up the TCP connection, and another for the client to send the request, and for the server to send back the reply.

7. One such example is remote word processing, for example, with Google docs. However, because Google docs runs over the Internet (using TCP), timing guarantees are not provided.

8. a) Reliable data transfer
   TCP provides a reliable byte-stream between client and server but UDP does not.

   b) A guarantee that a certain value for throughput will be maintained
   Neither

   c) A guarantee that data will be delivered within a specified amount of time
   Neither

   d) Confidentiality (via encryption)
   Neither

9. SSL operates at the application layer. The SSL socket takes unencrypted data from the application layer, encrypts it and then passes it to the TCP socket. If the application developer wants TCP to be enhanced with SSL, she has to include the SSL code in the application.

10. A protocol uses handshaking if the two communicating entities first exchange control packets before sending data to each other. SMTP uses handshaking at the application layer whereas HTTP does not.

11. The applications associated with those protocols require that all application data be received in the correct order and without gaps. TCP provides this service whereas UDP does not.

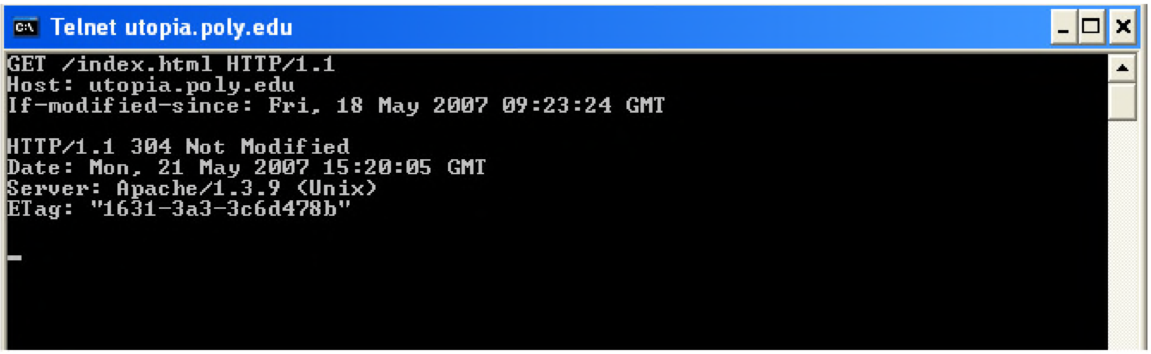
12. When the user first visits the site, the server creates a unique identification number, creates an entry in its back-end database, and returns this identification number as a cookie number. This cookie number is stored on the user's host and is managed by the browser. During each subsequent visit (and purchase), the browser sends the cookie number back to the site. Thus the site knows when this user (more precisely, this browser) is visiting the site.

13. Web caching can bring the desired content "closer" to the user, possibly to the same LAN to which the user's host is connected. Web caching can reduce the delay for all objects, even objects that are not cached, since caching reduces the traffic on links.

14. Telnet is not available in Windows 7 by default. to make it available, go to Control Panel, Programs and Features, Turn Windows Features On or Off, Check Telnet client. To start Telnet, in Windows command prompt, issue the following command

    ```
    > telnet webserverver 80
    ```

    where "webserver" is some webserver. After issuing the command, you have established a TCP connection between your client telnet program and the web server. Then type in an HTTP GET message. An example is given below:

    ```
    GET /index.html HTTP/1.1
    Host: utopia.poly.edu
    If-modified-since: Fri, 18 May 2007 09:23:24 GMT

    HTTP/1.1 304 Not Modified
    Date: Mon, 21 May 2007 15:20:05 GMT
    Server: Apache/1.3.9 (Unix)
    ETag: "1631-3a3-3c6d478b"
    ```

    Since the index.html page in this web server was not modified since Fri, 18 May 2007 09:23:34 GMT, and the above commands were issued on Sat, 19 May 2007, the server returned "304 Not Modified". Note that the first 4 lines are the GET message and header lines inputed by the user, and the next 4 lines (starting from HTTP/1.1 304 Not Modified) is the response from the web server.

15. A list of several popular messaging apps: WhatsApp, Facebook Messenger, WeChat, and Snapchat. These apps use the different protocols than SMS.

16. The message is first sent from Alice's host to her mail server over HTTP. Alice's mail server then sends the message to Bob's mail server over SMTP. Bob then transfers the message from his mail server to his host over POP3.

17.

Received:	from 65.54.246.203 (EHLO bay0-omc3-s3.bay0.hotmail.com) (65.54.246.203) by mta419.mail.mud.yahoo.com with SMTP; Sat, 19 May 2007 16:53:51 -0700
Received:	from hotmail.com ([65.55.135.106]) by bay0-omc3-s3.bay0.hotmail.com with Microsoft SMTPSVC(6.0.3790.2668); Sat, 19 May 2007 16:52:42 -0700
Received:	from mail pickup service by hotmail.com with Microsoft SMTPSVC; Sat, 19 May 2007 16:52:41 -0700
Message-ID:	<BAY130-F26D9E35BF59E0D18A819AFB9310@phx.gbl>
Received:	from 65.55.135.123 by by130fd.bay130.hotmail.msn.com with HTTP; Sat, 19 May 2007 23:52:36 GMT
From:	"prithula dhungel" <prithuladhungel@hotmail.com>
To:	prithula@yahoo.com
Bcc:	
Subject:	Test mail
Date:	Sat, 19 May 2007 23:52:36 +0000
Mime-Version:	1.0
Content-Type:	Text/html; format=flowed
Return-Path:	prithuladhungel@hotmail.com

Figure: A sample mail message header

Received: This header field indicates the sequence in which the SMTP servers send and receive the mail message including the respective timestamps.

In this example there are 4 "Received:" header lines. This means the mail message passed through 5 different SMTP servers before being delivered to the receiver's mail box. The last (forth) "Received:" header indicates the mail message flow from the SMTP server of the sender to the second SMTP server in the chain of servers. The sender's SMTP server is at address 65.55.135.123 and the second SMTP server in the chain is by130fd.bay130.hotmail.msn.com.

The third "Received:" header indicates the mail message flow from the second SMTP server in the chain to the third server, and so on.

Finally, the first "Received:" header indicates the flow of the mail messages from the forth SMTP server to the last SMTP server (i.e. the receiver's mail server) in the chain.

Message-id: The message has been given this number BAY130-F26D9E35BF59E0D18A819AFB9310@phx.gbl (by bay0-omc3-s3.bay0.hotmail.com. Message-id is a unique string assigned by the mail system when the message is first created.

From: This indicates the email address of the sender of the mail. In the given example, the sender is “prithuladhungel@hotmail.com”

To: This field indicates the email address of the receiver of the mail. In the example, the receiver is “prithula@yahoo.com”

Subject: This gives the subject of the mail (if any specified by the sender). In the example, the subject specified by the sender is “Test mail”

Date: The date and time when the mail was sent by the sender. In the example, the sender sent the mail on 19th May 2007, at time 23:52:36 GMT.

Mime-version: MIME version used for the mail. In the example, it is 1.0.

Content-type: The type of content in the body of the mail message. In the example, it is “text/html”.

Return-Path: This specifies the email address to which the mail will be sent if the receiver of this mail wants to reply to the sender. This is also used by the sender’s mail server for bouncing back undeliverable mail messages of mailer-daemon error messages. In the example, the return path is “prithuladhungel@hotmail.com”.

18. With download and delete, after a user retrieves its messages from a POP server, the messages are deleted. This poses a problem for the nomadic user, who may want to access the messages from many different machines (office PC, home PC, etc.). In the download and keep configuration, messages are not deleted after the user retrieves the messages. This can also be inconvenient, as each time the user retrieves the stored messages from a new machine, all of non-deleted messages will be transferred to the new machine (including very old messages).

19. Yes an organization’s mail server and Web server can have the same alias for a host name. The MX record is used to map the mail server’s host name to its IP address.

20. You should be able to see the sender's IP address for a user with an .edu email address. But you will not be able to see the sender's IP address if the user uses a gmail account.

21. It is not necessary that Bob will also provide chunks to Alice. Alice has to be in the top 4 neighbors of Bob for Bob to send out chunks to her; this might not occur even if Alice provides chunks to Bob throughout a 30-second interval.

22. Recall that in BitTorrent, a peer picks a random peer and optimistically unchokes the peer for a short period of time. Therefore, Alice will eventually be optimistically unchoked by one of her neighbors, during which time she will receive chunks from that neighbor.

23. The overlay network in a P2P file sharing system consists of the nodes participating in the file sharing system and the logical links between the nodes. There is a logical link (an "edge" in graph theory terms) from node A to node B if there is a semi-permanent TCP connection between A and B. An overlay network does not include routers.

24. One server placement philosophy is called Enter Deep, which enter deep into the access networks of Internet Service Providers, by deploying server clusters in access ISPs all over the world. The goal is to reduce delays and increase throughput between end users and the CDN servers. Another philosophy is Bring Home, which bring the ISPs home by building large CDN server clusters at a smaller number of sites and typically placing these server clusters in IXPs (Internet Exchange Points). This Bring Home design typically results in lower maintenance and management cost, compared with the enter-deep design philosophy.

25. Other than network-related factors, there are some important factors to consider, such as load-balancing (clients should not be directed to overload clusters), diurnal effects, variations across DNS servers within a network, limited availability of rarely accessed video, and the need to alleviate hot-spots that may arise due to popular video content.
    Reference paper:
    Torres, Ruben, et al. "Dissecting video server selection strategies in the YouTube CDN." The 31st IEEE International Conference on. Distributed Computing Systems (ICDCS), 2011.

    Another factor to consider is ISP delivery cost – the clusters may be chosen so that specific ISPs are used to carry CDN-to-client traffic, taking into account the different cost structures in the contractual relationships between ISPs and cluster operators.

26. With the UDP server, there is no welcoming socket, and all data from different clients enters the server through this one socket. With the TCP server, there is a welcoming socket, and each time a client initiates a connection to the server, a new socket is created. Thus, to support n simultaneous connections, the server would need *n+1* sockets.

27. For the TCP application, as soon as the client is executed, it attempts to initiate a TCP connection with the server. If the TCP server is not running, then the client will fail to make a connection. For the UDP application, the client does not initiate connections (or attempt to communicate with the UDP server) immediately upon execution

Chapter 2 Problems

Problem 1

a) F
b) T
c) F
d) F
e) F

Problem 2

SMS (Short Message Service) is a technology that allows the sending and receiving of text messages between mobile phones over cellular networks. One SMS message can contain data of 140 bytes and it supports languages internationally. The maximum size of a message can be 160 7-bit characters, 140 8-bit characters, or 70 16-bit characters. SMS is realized through the Mobile Application Part (MAP) of the SS#7 protocol, and the Short Message protocol is defined by 3GPP TS 23.040 and 3GPP TS 23.041. In addition, MMS (Multimedia Messaging Service) extends the capability of original text messages, and support sending photos, longer text messages, and other content.

iMessage is an instant messenger service developed by Apple. iMessage supports texts, photos, audios or videos that we send to iOS devices and Macs over cellular data network or WiFi. Apple's iMessage is based on a proprietary, binary protocol APNs (Apple Push Notification Service).

WhatsApp Messenger is an instant messenger service that supports many mobile platforms such as iOS, Android, Mobile Phone, and Blackberry. WhatsApp users can send each other unlimited images, texts, audios, or videos over cellular data network or WiFi. WhatsApp uses the XMPP protocol (Extensible Messaging and Presence Protocol).

iMessage and WhatsApp are different than SMS because they use data plan to send messages and they work on TCP/IP networks, but SMS use the text messaging plan we purchase from our wireless carrier. Moreover, iMessage and WhatsApp support sending photos, videos, files, etc., while the original SMS can only send text message. Finally, iMessage and WhatsApp can work via WiFi, but SMS cannot.

Problem 3

Application layer protocols: DNS and HTTP
Transport layer protocols: UDP for DNS; TCP for HTTP

Problem 4

a) The document request was http://gaia.cs.umass.edu/cs453/index.html. The Host : field indicates the server's name and /cs453/index.html indicates the file name.

b) The browser is running HTTP version 1.1, as indicated just before the first <cr><lf> pair.

c) The browser is requesting a persistent connection, as indicated by the Connection: keep-alive.

d) This is a trick question. This information is not contained in an HTTP message anywhere. So there is no way to tell this from looking at the exchange of HTTP messages alone. One would need information from the IP datagrams (that carried the TCP segment that carried the HTTP GET request) to answer this question.

e) Mozilla/5.0. The browser type information is needed by the server to send different versions of the same object to different types of browsers.

Problem 5

a) The status code of 200 and the phrase OK indicate that the server was able to locate the document successfully. The reply was provided on Tuesday, 07 Mar 2008 12:39:45 Greenwich Mean Time.

b) The document index.html was last modified on Saturday 10 Dec 2005 18:27:46 GMT.

c) There are 3874 bytes in the document being returned.

d) The first five bytes of the returned document are : <!doc. The server agreed to a persistent connection, as indicated by the Connection: Keep-Alive field

Problem 6

a) Persistent connections are discussed in section 8 of RFC 2616 (the real goal of this question was to get you to retrieve and read an RFC). Sections 8.1.2 and 8.1.2.1 of the RFC indicate that either the client or the server can indicate to the other that it is going to close the persistent connection. It does so by including the connection-token "close" in the Connection-header field of the http request/reply.
b) HTTP does not provide any encryption services.
c) (From RFC 2616) “Clients that use persistent connections should limit the number of simultaneous connections that they maintain to a given server. A single-user client SHOULD NOT maintain more than 2 connections with any server or proxy.”

d) Yes. (From RFC 2616) “A client might have started to send a new request at the same time that the server has decided to close the "idle" connection. From the server's point of view, the connection is being closed while it was idle, but from the client's point of view, a request is in progress.”

Problem 7

The total amount of time to get the IP address is
$RTT_1 + RTT_2 + \cdots + RTT_n$.
Once the IP address is known, RTT_O elapses to set up the TCP connection and another RTT_O elapses to request and receive the small object. The total response time is
$2RTT_o + RTT_1 + RTT_2 + \cdots + RTT_n$

Problem 8

a)
$$RTT_1 + \cdots + RTT_n + 2RTT_o + 8 \cdot 2RTT_o$$
$$= 18RTT_o + RTT_1 + \cdots + RTT_n.$$
b)
$$RTT_1 + \cdots + RTT_n + 2RTT_o + 2 \cdot 2RTT_o$$
$$= 6RTT_o + RTT_1 + \cdots + RTT_n$$

c) Persistent connection with pipelining. This is the default mode of HTTP.
$$RTT_1 + \cdots + RTT_n + 2RTT_o + RTT_o$$
$$= 3RTT_o + RTT_1 + \cdots + RTT_n.$$
Persistent connection without pipelining, without parallel connections.
$$RTT_1 + \cdots + RTT_n + 2RTT_o + 8RTT_o$$
$$= 10RTT_o + RTT_1 + \cdots + RTT_n.$$

Problem 9

a) The time to transmit an object of size *L* over a link or rate *R* is *L/R*. The average time is the average size of the object divided by *R*:

Δ = (850,000 bits)/(15,000,000 bits/sec) = .0567 sec

The traffic intensity on the link is given by $\beta\Delta$=(16 requests/sec)(.0567 sec/request) = 0.907. Thus, the average access delay is (.0567 sec)/(1 - .907) ≈ .6 seconds. The total average response time is therefore .6 sec + 3 sec = 3.6 sec.

b) The traffic intensity on the access link is reduced by 60% since the 60% of the requests are satisfied within the institutional network. Thus the average access delay is (.0567 sec)/[1 – (.4)(.907)] = .089 seconds. The response time is approximately zero if the request is satisfied by the cache (which happens with probability .6); the average response time is .089 sec + 3 sec = 3.089 sec for cache misses (which happens 40% of the time). So the average response time is (.6)(0 sec) + (.4)(3.089 sec) = 1.24 seconds. Thus the average response time is reduced from 3.6 sec to 1.24 sec.

Problem 10

Note that each downloaded object can be completely put into one data packet. Let Tp denote the one-way propagation delay between the client and the server.

First consider parallel downloads using non-persistent connections. Parallel downloads would allow 10 connections to share the 150 bits/sec bandwidth, giving each just 15 bits/sec. Thus, the total time needed to receive all objects is given by:

$$\begin{aligned}
&(200/150+T\text{p} + 200/150 +T\text{p} + 200/150+T\text{p} + 100{,}000/150+ T\text{p})\\
&+ (200/(150/10)+T\text{p} + 200/(150/10) +T\text{p} + 200/(150/10)+T\text{p} + 100{,}000/(150/10)+ T\text{p})\\
&= 7377 + 8*T\text{p} \text{ (seconds)}
\end{aligned}$$

Now consider a persistent HTTP connection. The total time needed is given by:

$$\begin{aligned}
&(200/150+T\text{p} + 200/150 +T\text{p} + 200/150+T\text{p} + 100{,}000/150+ T\text{p})\\
&+ 10*(200/150+T\text{p} + 100{,}000/150+ T\text{p})\\
&=7351 + 24*T\text{p} \text{ (seconds)}
\end{aligned}$$

Assuming the speed of light is $300*10^6$ m/sec, then $\text{Tp}=10/(300*10^6)=0.03$ microsec. Tp is therefore negligible compared with transmission delay.

Thus, we see that persistent HTTP is not significantly faster (less than 1 percent) than the non-persistent case with parallel download.

Problem 11

a) Yes, because Bob has more connections, he can get a larger share of the link bandwidth.
b) Yes, Bob still needs to perform parallel downloads; otherwise he will get less bandwidth than the other four users.

Problem 12

Server.py

```
from socket import *
serverPort=12000
serverSocket=socket(AF_INET,SOCK_STREAM)
serverSocket.bind(('',serverPort))
serverSocket.listen(1)
connectionSocket, addr = serverSocket.accept()
while 1:
    sentence = connectionSocket.recv(1024)
    print      'From      Server:',      sentence,      '\n'
serverSocket.close()
```

Problem 13

The MAIL FROM: in SMTP is a message from the SMTP client that identifies the sender of the mail message to the SMTP server. The From: on the mail message itself is NOT an SMTP message, but rather is just a line in the body of the mail message.

Problem 14

SMTP uses a line containing only a period to mark the end of a message body.
HTTP uses “Content-Length header field” to indicate the length of a message body.
No, HTTP cannot use the method used by SMTP, because HTTP message could be binary data, whereas in SMTP, the message body must be in 7-bit ASCII format.

Problem 15

MTA stands for Mail Transfer Agent. A host sends the message to an MTA. The message then follows a sequence of MTAs to reach the receiver’s mail reader. We see that this spam message follows a chain of MTAs. An honest MTA should report where it receives the message. Notice that in this message, “asusus-4b96 ([58.88.21.177])” does not report from where it received the email. Since we assume only the originator is dishonest, so “asusus-4b96 ([58.88.21.177])” must be the originator.

Problem 16

UIDL abbreviates “unique-ID listing”. When a POP3 client issues the UIDL command, the server responds with the unique message ID for all of the messages present in the user's mailbox. This command is useful for “download and keep”. By maintaining a file that lists the messages retrieved during earlier sessions, the client can use the UIDL command to determine which messages on the server have already been seen.

Problem 17

a) **C:** dele 1
C: retr 2
S: (blah blah …
S: ………..blah)
S: .
C: dele 2
C: quit
S: +OK POP3 server signing off

b) **C:** retr 2
S: blah blah …
S: ………..blah
S: .
C: quit
S: +OK POP3 server signing off

c) **C:** list
S: 1 498
S: 2 912
S: .
C: retr 1
S: blah …..
S: ….blah
S: .
C: retr 2
S: blah blah …
S: ………..blah
S: .
C: quit
S: +OK POP3 server signing off

Problem 18

a) For a given input of domain name (such as ccn.com), IP address or network administrator name, the *whois* database can be used to locate the corresponding registrar, whois server, DNS server, and so on.

b) NS4.YAHOO.COM from www.register.com; NS1.MSFT.NET from ww.register.com

c) *Local Domain: www.mindspring.com*
Web servers : www.mindspring.com

207.69.189.21, 207.69.189.22,
207.69.189.23, 207.69.189.24,
207.69.189.25, 207.69.189.26, 207.69.189.27,
207.69.189.28
Mail Servers : mx1.mindspring.com (207.69.189.217)
mx2.mindspring.com (207.69.189.218)
mx3.mindspring.com (207.69.189.219)
mx4.mindspring.com (207.69.189.220)
Name Servers: itchy.earthlink.net (207.69.188.196)
scratchy.earthlink.net (207.69.188.197)

www.yahoo.com
Web Servers: www.yahoo.com (216.109.112.135, 66.94.234.13)
Mail Servers: a.mx.mail.yahoo.com (209.191.118.103)
b.mx.mail.yahoo.com (66.196.97.250)
c.mx.mail.yahoo.com (68.142.237.182, 216.39.53.3)
d.mx.mail.yahoo.com (216.39.53.2)
e.mx.mail.yahoo.com (216.39.53.1)
f.mx.mail.yahoo.com (209.191.88.247, 68.142.202.247)
g.mx.mail.yahoo.com (209.191.88.239, 206.190.53.191)
Name Servers: ns1.yahoo.com (66.218.71.63)
ns2.yahoo.com (68.142.255.16)
ns3.yahoo.com (217.12.4.104)
ns4.yahoo.com (68.142.196.63)
ns5.yahoo.com (216.109.116.17)
ns8.yahoo.com (202.165.104.22)
ns9.yahoo.com (202.160.176.146)

www.hotmail.com
Web Servers: www.hotmail.com (64.4.33.7, 64.4.32.7)

Mail Servers: mx1.hotmail.com (65.54.245.8, 65.54.244.8, 65.54.244.136)
mx2.hotmail.com (65.54.244.40, 65.54.244.168, 65.54.245.40)
mx3.hotmail.com (65.54.244.72, 65.54.244.200, 65.54.245.72)
mx4.hotmail.com (65.54.244.232, 65.54.245.104, 65.54.244.104)

Name Servers: ns1.msft.net (207.68.160.190)
ns2.msft.net (65.54.240.126)
ns3.msft.net (213.199.161.77)
ns4.msft.net (207.46.66.126)
ns5.msft.net (65.55.238.126)

d) The yahoo web server has multiple IP addresses
www.yahoo.com (216.109.112.135, 66.94.234.13)

e) The address range for Polytechnic University: 128.238.0.0 – 128.238.255.255

f) An attacker can use the *whois* database and nslookup tool to determine the IP address ranges, DNS server addresses, etc., for the target institution.

g) By analyzing the source address of attack packets, the victim can use whois to obtain information about domain from which the attack is coming and possibly inform the administrators of the origin domain.

Problem 19

a) The following delegation chain is used for gaia.cs.umass.edu
a.root-servers.net
E.GTLD-SERVERS.NET
ns1.umass.edu(authoritative)

First command:

```
dig +norecurse @a.root-servers.net any gaia.cs.umass.edu
```

```
;; AUTHORITY SECTION:
edu.            172800  IN    NS    E.GTLD-SERVERS.NET.
edu.            172800  IN    NS    A.GTLD-SERVERS.NET.
edu.            172800  IN    NS    G3.NSTLD.COM.
edu.            172800  IN    NS    D.GTLD-SERVERS.NET.
edu.            172800  IN    NS    H3.NSTLD.COM.
edu.            172800  IN    NS    L3.NSTLD.COM.
edu.            172800  IN    NS    M3.NSTLD.COM.
edu.            172800  IN    NS    C.GTLD-SERVERS.NET.
```

Among all returned edu DNS servers, we send a query to the first one.

```
dig +norecurse @E.GTLD-SERVERS.NET any gaia.cs.umass.edu
```

```
umass.edu.          172800  IN    NS    ns1.umass.edu.
umass.edu.          172800  IN    NS    ns2.umass.edu.
umass.edu.          172800  IN    NS    ns3.umass.edu.
```

Among all three returned authoritative DNS servers, we send a query to the first one.

```
dig +norecurse @ns1.umass.edu any gaia.cs.umass.edu
```

```
gaia.cs.umass.edu.     21600   IN     A      128.119.245.12
```

b) The answer for google.com could be:
a.root-servers.net
E.GTLD-SERVERS.NET
ns1.google.com(authoritative)

Problem 20

We can periodically take a snapshot of the DNS caches in the local DNS servers. The Web server that appears most frequently in the DNS caches is the most popular server. This is because if more users are interested in a Web server, then DNS requests for that server are more frequently sent by users. Thus, that Web server will appear in the DNS caches more frequently.

For a complete measurement study, see:
Craig E. Wills, Mikhail Mikhailov, Hao Shang
"Inferring Relative Popularity of Internet Applications by Actively Querying DNS Caches", in IMC'03, October 27-29, 2003, Miami Beach, Florida, USA

Problem 21

Yes, we can use dig to query that Web site in the local DNS server.
For example, "dig cnn.com" will return the query time for finding cnn.com. If cnn.com was just accessed a couple of seconds ago, an entry for cnn.com is cached in the local DNS cache, so the query time is 0 msec. Otherwise, the query time is large.

Problem 22

For calculating the minimum distribution time for client-server distribution, we use the following formula:

$$D_{cs} = max\ \{NF/u_s,\ F/d_{min}\}$$

Similarly, for calculating the minimum distribution time for P2P distribution, we use the following formula:

$$D_{P2P} = max\{F/u_s,\ F/d_{min},\ NF/(u_s + \sum_{i=1}^{N} u_i)\}$$

Where, F = 15 Gbits = 15 * 1024 Mbits
u_s = 30 Mbps
$d_{min} = d_i$ = 2 Mbps

Note, 300Kbps = 300/1024 Mbps.

Client Server

		N		
		10	**100**	**1000**
	300 Kbps	7680	51200	512000
u	**700 Kbps**	7680	51200	512000
	2 Mbps	7680	51200	512000

Peer to Peer

		N		
		10	**100**	**1000**
	300 Kbps	7680	25904	47559
u	**700 Kbps**	7680	15616	21525
	2 Mbps	7680	7680	7680

Problem 23

a) Consider a distribution scheme in which the server sends the file to each client, in parallel, at a rate of a rate of u_s/N. Note that this rate is less than each of the client's download rate, since by assumption $u_s/N \leq d_{\min}$. Thus each client can also receive at rate u_s/N. Since each client receives at rate u_s/N, the time for each client to receive the entire file is F/(u_s/N) = NF/ u_s. Since all the clients receive the file in NF/ u_s, the overall distribution time is also NF/ u_s.

b) Consider a distribution scheme in which the server sends the file to each client, in parallel, at a rate of $d_{\min}$. Note that the aggregate rate, $N\, d_{\min}$, is less than the server's link rate u_s, since by assumption $u_s/N \geq d_{\min}$. Since each client receives at rate $d_{\min}$, the time for each client to receive the entire file is F/ $d_{\min}$. Since all the clients receive the file in this time, the overall distribution time is also F/ $d_{\min}$.

c) From Section 2.6 we know that

$D_{CS} \geq \max \{NF/u_s, F/d_{\min}\}$ (Equation 1)

Suppose that $u_s/N \leq d_{\min}$. Then from Equation 1 we have $D_{CS} \geq NF/u_s$. But from (a) we have $D_{CS} \leq NF/u_s$. Combining these two gives:

$D_{CS} = NF/u_s$ when $u_s/N \leq d_{\min}$. (Equation 2)

We can similarly show that:

$D_{CS} = F/d_{\min}$ when $u_s/N \geq d_{\min}$ (Equation 3).

Combining Equation 2 and Equation 3 gives the desired result.

Problem 24

a) Define u = u1 + u2 + ….. + uN. By assumption

$u_s <= (u_s + u)/N$ Equation 1

Divide the file into N parts, with the ith part having size $(u_i/u)F$. The server transmits the ith part to peer i at rate $r_i = (u_i/u)u_s$. Note that $r_1 + r_2 + \ldots.. + r_N = u_s$, so that the aggregate server rate does not exceed the link rate of the server. Also have each peer i forward the bits it receives to each of the *N-1* peers at rate r_i. The aggregate forwarding rate by peer i is $(N-1)r_i$. We have

$$(N\text{-}1)r_i = (N\text{-}1)(u_s u_i)/u <= u_i,$$

where the last inequality follows from Equation 1. Thus the aggregate forwarding rate of peer i is less than its link rate u_i.

In this distribution scheme, peer i receives bits at an aggregate rate of

$$r_i + \sum_{j<>i} r_j = u_s$$

Thus each peer receives the file in F/u_s.

b) Again define $u = u_1 + u_2 + \ldots.. + u_N$. By assumption

$u_s >= (u_s + u)/N$ Equation 2

Let $r_i = u_i/(N\text{-}1)$ and
$r_{N+1} = (u_s - u/(N\text{-}1))/N$

In this distribution scheme, the file is broken into *N+1* parts. The server sends bits from the ith part to the ith peer ($i = 1, \ldots., N$) at rate r_i. Each peer i forwards the bits arriving at rate r_i to each of the other N-1 peers. Additionally, the server sends bits from the $(N+1)^{st}$ part at rate r_{N+1} to each of the *N* peers. The peers do not forward the bits from the $(N+1)^{st}$ part.

The aggregate send rate of the server is

$$r_1 + \ldots. + r_N + N\, r_{N+1} = u/(N\text{-}1) + u_s - u/(N\text{-}1) = u_s$$

Thus, the server's send rate does not exceed its link rate. The aggregate send rate of peer i is

$$(N\text{-}1)r_i = u_i$$

Thus, each peer's send rate does not exceed its link rate.
In this distribution scheme, peer i receives bits at an aggregate rate of

$$r_i + r_{N+1} + \sum_{j<>i} r j = u/(N-1) + (u_s - u/(N-1))/N = (u_s + u)/N$$

Thus each peer receives the file in $NF/(u_s+u)$.
(For simplicity, we neglected to specify the size of the file part for i = 1, …., N+1. We now provide that here. Let $\Delta = (u_s+u)/N$ be the distribution time. For i = 1, …, N, the i^{th} file part is $F_i = r_i \Delta$ bits. The $(N+1)^{st}$ file part is $F_{N+1} = r_{N+1} \Delta$ bits. It is straightforward to show that $F_1+ ….. + F_{N+1} = F$.)

c) The solution to this part is similar to that of 17 (c). We know from section 2.6 that

$$D_{P2P} >= max\{F/u_s, NF/(u_s+u)\}$$

Combining this with a) and b) gives the desired result.

Problem 25

There are *N* nodes in the overlay network. There are *N(N-1)/2* edges.

Problem 26

Yes. His first claim is possible, as long as there are enough peers staying in the swarm for a long enough time. Bob can always receive data through optimistic unchoking by other peers.

His second claim is also true. He can run a client on each host, let each client "free-ride," and combine the collected chunks from the different hosts into a single file. He can even write a small scheduling program to make the different hosts ask for different chunks of the file. This is actually a kind of Sybil attack in P2P networks.

Problem 27

a. N files, under the assumption that we do a one-to-one matching by pairing video versions with audio versions in a decreasing order of quality and rate.

b. 2N files.

Problem 28

a) If you run TCPClient first, then the client will attempt to make a TCP connection with a non-existent server process. A TCP connection will not be made.

b) UDPClient doesn't establish a TCP connection with the server. Thus, everything should work fine if you first run UDPClient, then run UDPServer, and then type some input into the keyboard.

c) If you use different port numbers, then the client will attempt to establish a TCP connection with the wrong process or a non-existent process. Errors will occur.

Problem 29

In the original program, UDPClient does not specify a port number when it creates the socket. In this case, the code lets the underlying operating system choose a port number. With the additional line, when UDPClient is executed, a UDP socket is created with port number 5432 .

UDPServer needs to know the client port number so that it can send packets back to the correct client socket. Glancing at UDPServer, we see that the client port number is not "hard-wired" into the server code; instead, UDPServer determines the client port number by unraveling the datagram it receives from the client. Thus UDP server will work with any client port number, including 5432. UDPServer therefore does not need to be modified.

Before:

Client socket = x (chosen by OS)
Server socket = 9876

After:

Client socket = 5432

Problem 30

Yes, you can configure many browsers to open multiple simultaneous connections to a Web site. The advantage is that you will you potentially download the file faster. The disadvantage is that you may be hogging the bandwidth, thereby significantly slowing down the downloads of other users who are sharing the same physical links.

Problem 31

For an application such as remote login (telnet and ssh), a byte-stream oriented protocol is very natural since there is no notion of message boundaries in the application. When a user types a character, we simply drop the character into the TCP connection.
In other applications, we may be sending a series of messages that have inherent boundaries between them. For example, when one SMTP mail server sends another SMTP mail server several email messages back to back. Since TCP does not have a mechanism to indicate the boundaries, the application must add the indications itself, so that receiving side of the application can distinguish one message from the next. If each message were instead put into a distinct UDP segment, the receiving end would be able to

distinguish the various messages without any indications added by the sending side of the application.

Problem 32

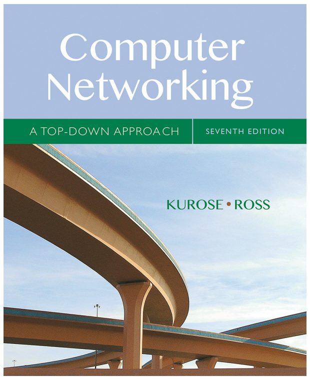
To create a web server, we need to run web server software on a host. Many vendors sell web server software. However, the most popular web server software today is Apache, which is open source and free. Over the years it has been highly optimized by the open-source community.

Wireshark Lab: SSL v7.0

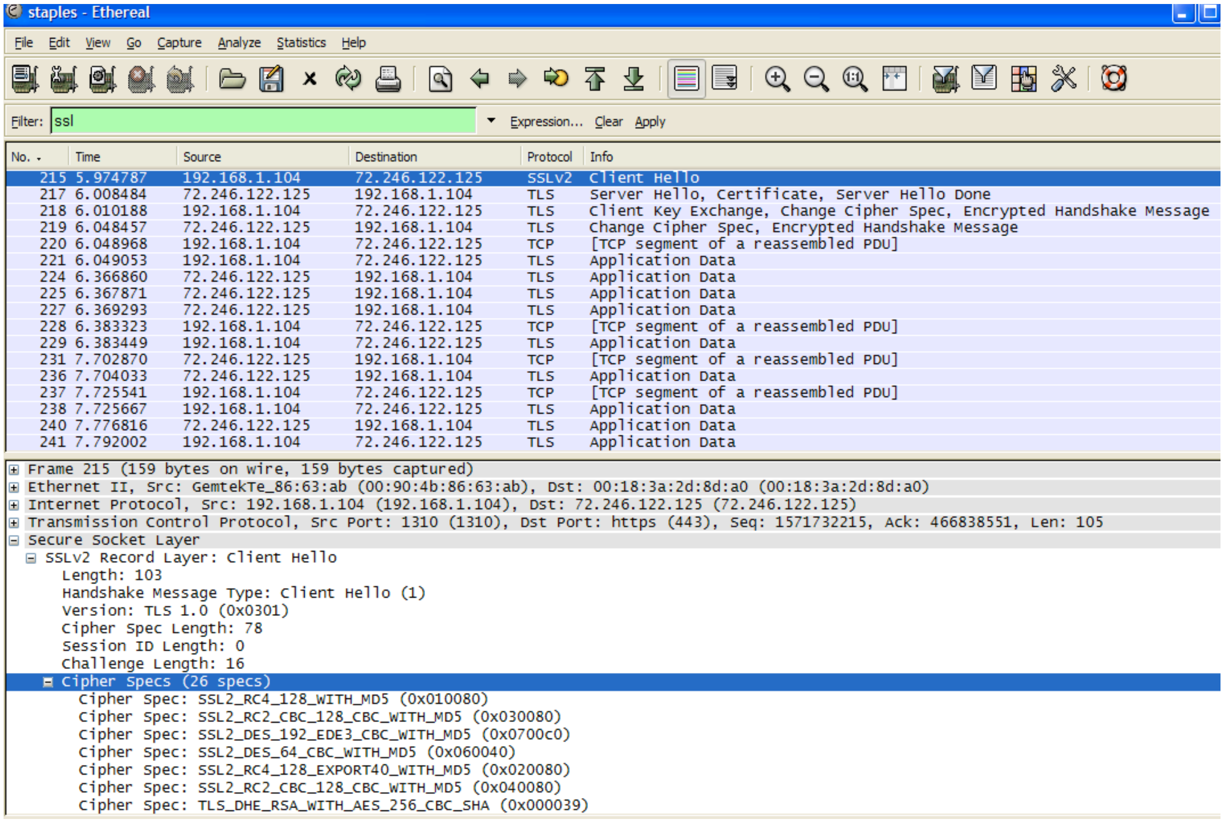
SOLUTION

Supplement to *Computer Networking: A Top-Down Approach, 7th ed.,* J.F. Kurose and K.W. Ross

"Tell me and I forget. Show me and I remember. Involve me and I understand." Chinese proverb



A Look at the Captured Trace:


staples - Ethereal
File Edit View Go Capture Analyze Statistics Help
Expression... Clear Apply

Filter: ssl

```
No. -  Time      Source          Destination     Protocol Info
  215 5.974787  192.168.1.104   72.246.122.125  SSLv2  Client Hello
  217 6.008484  72.246.122.125  192.168.1.104   TLS    Server Hello, Certificate, Server Hello Done
  218 6.010188  192.168.1.104   72.246.122.125  TLS    Client Key Exchange, Change Cipher Spec, Encrypted Handshake Message
  219 6.048457  72.246.122.125  192.168.1.104   TLS    Change Cipher Spec, Encrypted Handshake Message
  220 6.048968  192.168.1.104   72.246.122.125  TCP    [TCP segment of a reassembled PDU]
  221 6.049053  192.168.1.104   72.246.122.125  TLS    Application Data
  224 6.366860  72.246.122.125  192.168.1.104   TLS    Application Data
  225 6.367871  72.246.122.125  192.168.1.104   TLS    Application Data
  227 6.369293  72.246.122.125  192.168.1.104   TLS    Application Data
  228 6.383323  192.168.1.104   72.246.122.125  TCP    [TCP segment of a reassembled PDU]
  229 6.383449  192.168.1.104   72.246.122.125  TLS    Application Data
  231 7.702870  72.246.122.125  192.168.1.104   TCP    [TCP segment of a reassembled PDU]
  236 7.704033  72.246.122.125  192.168.1.104   TLS    Application Data
  237 7.725541  192.168.1.104   72.246.122.125  TCP    [TCP segment of a reassembled PDU]
  238 7.725667  192.168.1.104   72.246.122.125  TLS    Application Data
  240 7.776816  72.246.122.125  192.168.1.104   TLS    Application Data
  241 7.792002  192.168.1.104   72.246.122.125  TLS    Application Data
```

```
⊞ Frame 215 (159 bytes on wire, 159 bytes captured)
⊞ Ethernet II, Src: GemtekTe_86:63:ab (00:90:4b:86:63:ab), Dst: 00:18:3a:2d:8d:a0 (00:18:3a:2d:8d:a0)
⊞ Internet Protocol, Src: 192.168.1.104 (192.168.1.104), Dst: 72.246.122.125 (72.246.122.125)
⊞ Transmission Control Protocol, Src Port: 1310 (1310), Dst Port: https (443), Seq: 1571732215, Ack: 466838551, Len: 105
⊟ Secure Socket Layer
  ⊟ SSLv2 Record Layer: Client Hello
      Length: 103
      Handshake Message Type: Client Hello (1)
      Version: TLS 1.0 (0x0301)
      Cipher Spec Length: 78
      Session ID Length: 0
      Challenge Length: 16
    ⊟ Cipher Specs (26 specs)
        Cipher Spec: SSL2_RC4_128_WITH_MD5 (0x010080)
        Cipher Spec: SSL2_RC2_CBC_128_CBC_WITH_MD5 (0x030080)
        Cipher Spec: SSL2_DES_192_EDE3_CBC_WITH_MD5 (0x0700c0)
        Cipher Spec: SSL2_DES_64_CBC_WITH_MD5 (0x060040)
        Cipher Spec: SSL2_RC4_128_EXPORT40_WITH_MD5 (0x020080)
        Cipher Spec: SSL2_RC2_CBC_128_CBC_WITH_MD5 (0x040080)
        Cipher Spec: TLS_DHE_RSA_WITH_AES_256_CBC_SHA (0x000039)
```

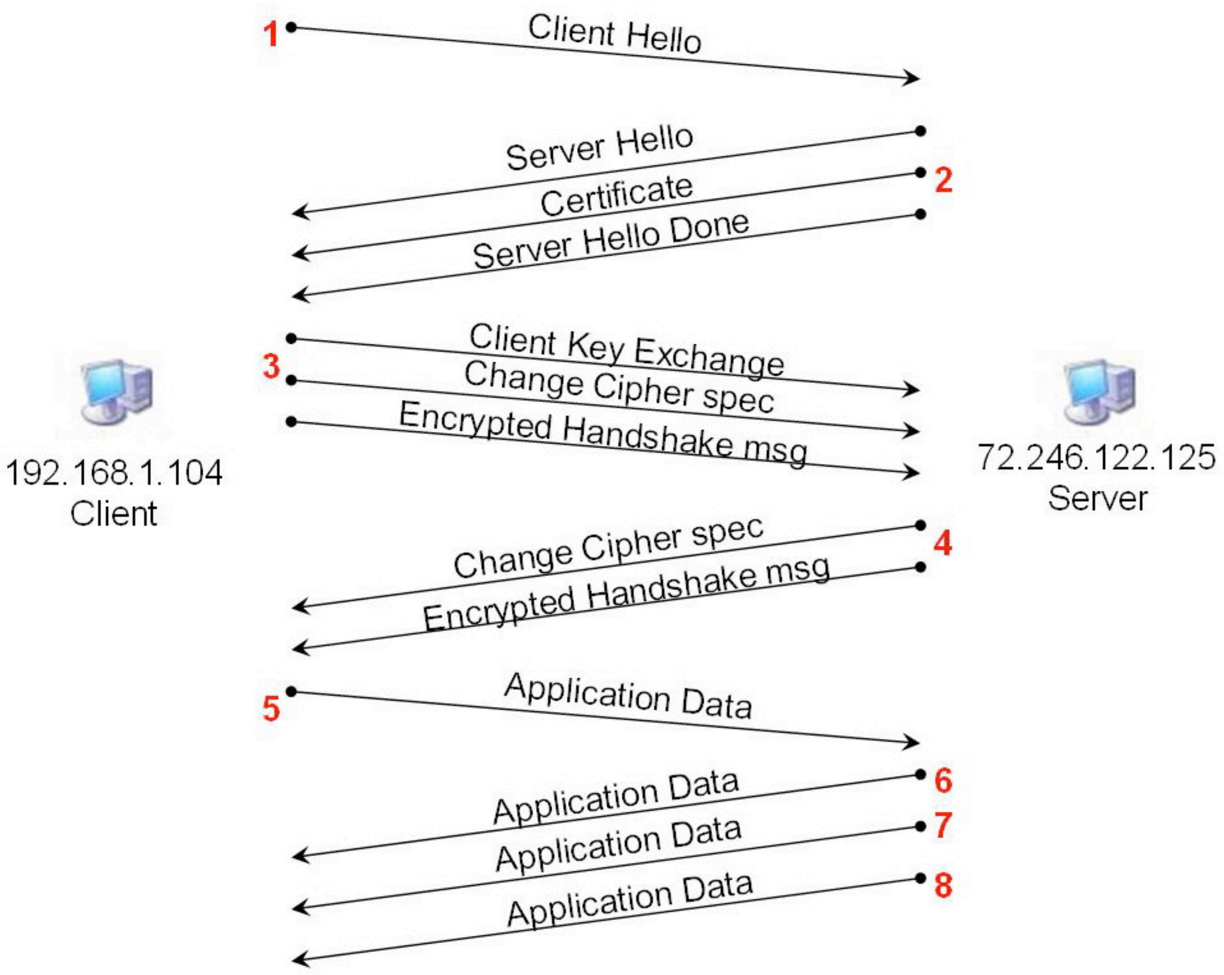
Captured SSL Packets

1. Details of the first 8 captured Ethernet frames (SSL) are listed in the following table:

Frame # in Ethereal	Frame #	Source	Destination	# of SSL Records	List of SSL Records

215	1	192.168.1.104	72.246.122.125	1	Client Hello
217	2	72.246.122.125	192.168.1.104	3	Server Hello Certificate Server Hello Done
218	3	192.168.1.104	72.246.122.125	3	Client Key Exchange Change Cipher spec Encrypted Handshake msg
219	4	72.246.122.125	192.168.1.104	2	Change Cipher spec Encrypted Handshake msg
221	5	192.168.1.104	72.246.122.125	1	Application Data
224	6	72.246.122.125	192.168.1.104	1	Application Data
225	7	72.246.122.125	192.168.1.104	1	Application Data
227	8	72.246.122.125	192.168.1.104	1	Application Data

Details of the first 8 Ethernet Frames for SSL

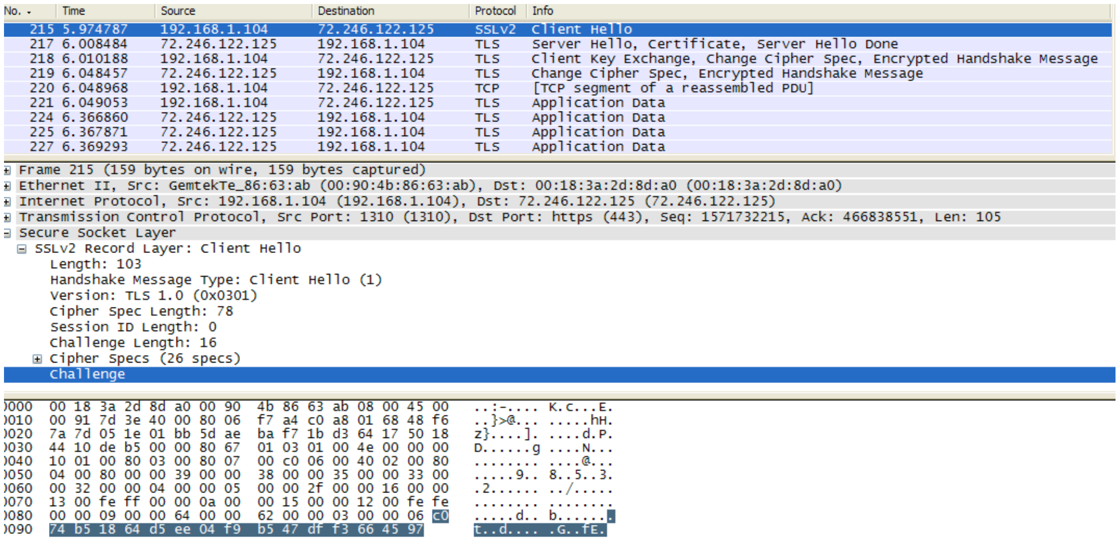


Timing Diagram of the SSL Session

2. Each SSL record begins with the same three fields (content type, version, and length). The values for each SSL record type are listed as follow:

Frame #	SSL Record Types	Content Type	Version	Length
1	Client Hello	Handshake (22)	TLS 1.0 (0x0301)	103
2	Server Hello Certificate Server Hello Done	Handshake (22) Handshake (22) Handshake (22)	TLS 1.0 (0x0301) TLS 1.0 (0x0301) TLS 1.0 (0x0301)	74 989 4
3	Client Key Exchange Change Cipher spec Encrypted Handshake msg	Handshake (22) ChangeCipherSpec(20) Handshake (22)	TLS 1.0 (0x0301) TLS 1.0 (0x0301) TLS 1.0 (0x0301)	134 1 48
4	Change Cipher spec Encrypted Handshake msg	ChangeCipherSpec(20) Handshake (22)	TLS 1.0 (0x0301) TLS 1.0 (0x0301)	1 48
5	Application Data	Application Data (23)	TLS 1.0 (0x0301)	1552
6	Application Data	Application Data (23)	TLS 1.0 (0x0301)	912
7	Application Data	Application Data (23)	TLS 1.0 (0x0301)	32
8	Application Data	Application Data (23)	TLS 1.0 (0x0301)	32

Client Hello Record



```
No. -  Time      Source          Destination     Protocol Info
  215 5.974787  192.168.1.104   72.246.122.125  SSLv2    Client Hello
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  220 6.048968  192.168.1.104   72.246.122.125  TCP      [TCP segment of a reassembled PDU]
  221 6.049053  192.168.1.104   72.246.122.125  TLS      Application Data
  224 6.366860  72.246.122.125  192.168.1.104   TLS      Application Data
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  227 6.369293  72.246.122.125  192.168.1.104   TLS      Application Data

⊞ Frame 215 (159 bytes on wire, 159 bytes captured)
⊞ Ethernet II, Src: GemtekTe_86:63:ab (00:90:4b:86:63:ab), Dst: 00:18:3a:2d:8d:a0 (00:18:3a:2d:8d:a0)
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⊟ Secure Socket Layer
  ⊟ SSLv2 Record Layer: Client Hello
      Length: 103
      Handshake Message Type: Client Hello (1)
      Version: TLS 1.0 (0x0301)
      Cipher Spec Length: 78
      Session ID Length: 0
      Challenge Length: 16
    ⊞ Cipher Specs (26 specs)
      Challenge

)000  00 18 3a 2d 8d a0 00 90  4b 86 63 ab 08 00 45 00   ..:-.... K.c...E.
)010  00 91 7d 3e 40 00 80 06  f7 a4 c0 a8 01 68 48 f6   ..}>@... .....hH.
)020  7a 7d 05 1e 01 bb 5d ae  ba f7 1b d3 64 17 50 18   z}....]. ....d.P.
)030  44 10 de b5 00 00 80 67  01 03 01 00 4e 00 00 00   D......g ....N...
)040  10 01 00 80 03 00 80 07  00 c0 06 00 40 02 00 80   ........ ....@...
)050  04 00 80 00 00 39 00 00  38 00 00 35 00 00 33 00   .....9.. 8..5..3.
)060  00 32 00 00 04 00 00 05  00 00 2f 00 00 16 00 00   .2...... ../.....
)070  13 00 fe ff 00 00 0a 00  00 15 00 00 12 00 fe fe   ........ ........
)080  00 00 09 00 00 64 00 00  62 00 00 03 00 00 06 c0   .....d.. b.......
)090  74 b5 18 64 d5 ee 04 f9  b5 47 df f3 66 45 97      t..d.... .G..fE.
```
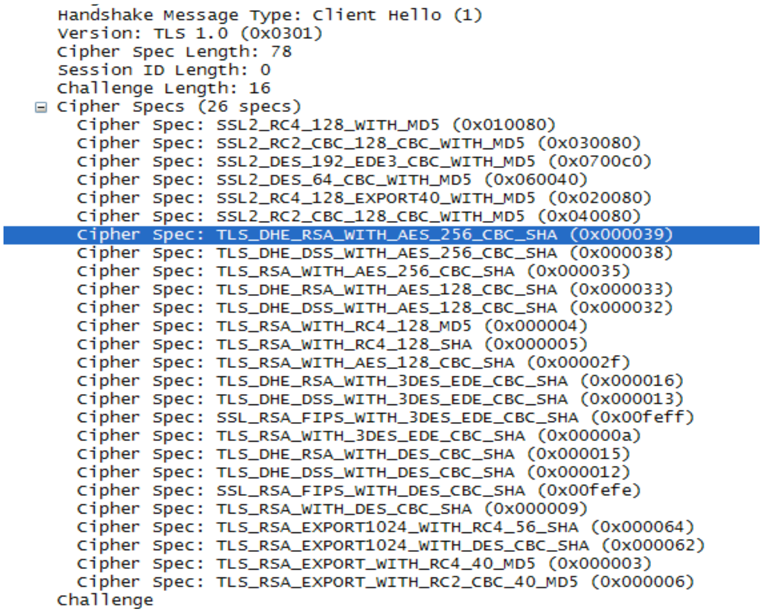

Expanded Client Hello Record

3. The value of the content type is Handshake (22) because this is handshake message type (as shown above).

4. Yes, the Client Hello record contains a challenge and its value in HEX is 0xC074B51864D5EE04F9B547DFF3664597

5. Yes, Client Hello record advertises the cipher suite it supports, as shown below.

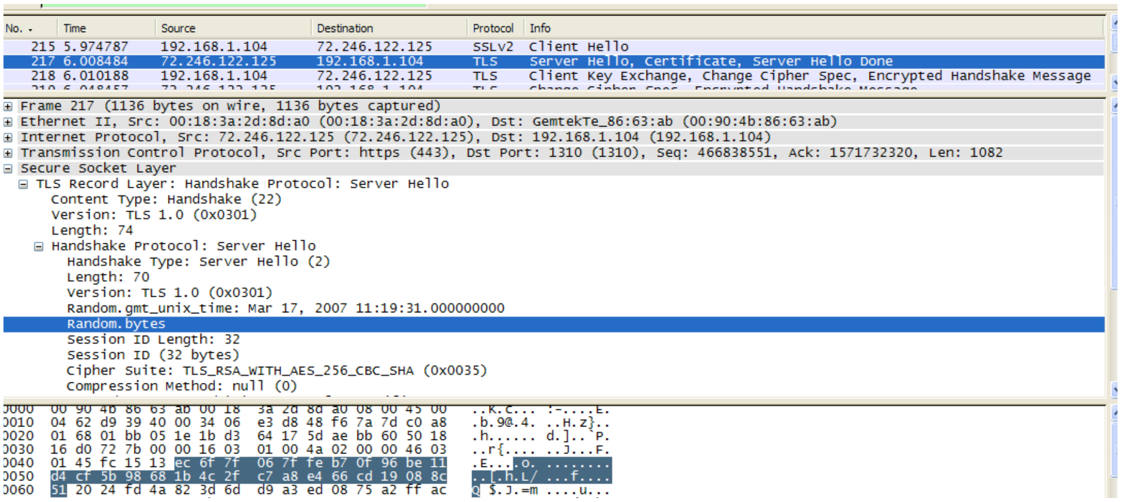


```
Handshake Message Type: Client Hello (1)
Version: TLS 1.0 (0x0301)
Cipher Spec Length: 78
Session ID Length: 0
Challenge Length: 16
⊟ Cipher Specs (26 specs)
    Cipher Spec: SSL2_RC4_128_WITH_MD5 (0x010080)
    Cipher Spec: SSL2_RC2_CBC_128_CBC_WITH_MD5 (0x030080)
    Cipher Spec: SSL2_DES_192_EDE3_CBC_WITH_MD5 (0x0700c0)
    Cipher Spec: SSL2_DES_64_CBC_WITH_MD5 (0x060040)
    Cipher Spec: SSL2_RC4_128_EXPORT40_WITH_MD5 (0x020080)
    Cipher Spec: SSL2_RC2_CBC_128_CBC_WITH_MD5 (0x040080)
    Cipher Spec: TLS_DHE_RSA_WITH_AES_256_CBC_SHA (0x000039)
    Cipher Spec: TLS_DHE_DSS_WITH_AES_256_CBC_SHA (0x000038)
    Cipher Spec: TLS_RSA_WITH_AES_256_CBC_SHA (0x000035)
    Cipher Spec: TLS_DHE_RSA_WITH_AES_128_CBC_SHA (0x000033)
    Cipher Spec: TLS_DHE_DSS_WITH_AES_128_CBC_SHA (0x000032)
    Cipher Spec: TLS_RSA_WITH_RC4_128_MD5 (0x000004)
    Cipher Spec: TLS_RSA_WITH_RC4_128_SHA (0x000005)
    Cipher Spec: TLS_RSA_WITH_AES_128_CBC_SHA (0x00002f)
    Cipher Spec: TLS_DHE_RSA_WITH_3DES_EDE_CBC_SHA (0x000016)
    Cipher Spec: TLS_DHE_DSS_WITH_3DES_EDE_CBC_SHA (0x000013)
    Cipher Spec: SSL_RSA_FIPS_WITH_3DES_EDE_CBC_SHA (0x00feff)
    Cipher Spec: TLS_RSA_WITH_3DES_EDE_CBC_SHA (0x00000a)
    Cipher Spec: TLS_DHE_RSA_WITH_DES_CBC_SHA (0x000015)
    Cipher Spec: TLS_DHE_DSS_WITH_DES_CBC_SHA (0x000012)
    Cipher Spec: SSL_RSA_FIPS_WITH_DES_CBC_SHA (0x00fefe)
    Cipher Spec: TLS_RSA_WITH_DES_CBC_SHA (0x000009)
    Cipher Spec: TLS_RSA_EXPORT1024_WITH_RC4_56_SHA (0x000064)
    Cipher Spec: TLS_RSA_EXPORT1024_WITH_DES_CBC_SHA (0x000062)
    Cipher Spec: TLS_RSA_EXPORT_WITH_RC4_40_MD5 (0x000003)
    Cipher Spec: TLS_RSA_EXPORT_WITH_RC2_CBC_40_MD5 (0x000006)
Challenge
```

Client Hello Record's Cipher specs

The first listed TLS (SSLv3) cipher spec (highlighted above) is: DHE and RSA (public-key algorithms) with 256-bit CBC AES (symmetric-key) with SHA (hash algorithm).

Server Hello Record



```
No. -  Time      Source          Destination     Protocol Info
   215 5.974787  192.168.1.104   72.246.122.125  SSLv2    Client Hello
   217 6.008484  72.246.122.125  192.168.1.104   TLS      Server Hello, Certificate, Server Hello Done
   218 6.010188  192.168.1.104   72.246.122.125  TLS      Client Key Exchange, Change Cipher Spec, Encrypted Handshake Message
   219 6.048457  72.246.122.125  192.168.1.104   TLS      Change Cipher Spec, Encrypted Handshake Message

⊞ Frame 217 (1136 bytes on wire, 1136 bytes captured)
⊞ Ethernet II, Src: 00:18:3a:2d:8d:a0 (00:18:3a:2d:8d:a0), Dst: GemtekTe_86:63:ab (00:90:4b:86:63:ab)
⊞ Internet Protocol, Src: 72.246.122.125 (72.246.122.125), Dst: 192.168.1.104 (192.168.1.104)
⊞ Transmission Control Protocol, Src Port: https (443), Dst Port: 1310 (1310), Seq: 466838551, Ack: 1571732320, Len: 1082
⊟ Secure Socket Layer
  ⊟ TLS Record Layer: Handshake Protocol: Server Hello
      Content Type: Handshake (22)
      Version: TLS 1.0 (0x0301)
      Length: 74
    ⊟ Handshake Protocol: Server Hello
        Handshake Type: Server Hello (2)
        Length: 70
        Version: TLS 1.0 (0x0301)
        Random.gmt_unix_time: Mar 17, 2007 11:19:31.000000000
        Random.bytes
        Session ID Length: 32
        Session ID (32 bytes)
        Cipher Suite: TLS_RSA_WITH_AES_256_CBC_SHA (0x0035)
        Compression Method: null (0)

0000  00 90 4b 86 63 ab 00 18  3a 2d 8d a0 08 00 45 00   ..K.c... :-....E.
0010  04 62 d9 39 40 00 34 06  e3 d8 48 f6 7a 7d c0 a8   .b.9@.4. ..H.z}..
0020  01 68 01 bb 05 1e 1b d3  64 17 5d ae bb 60 50 18   .h...... d.]..`P.
0030  16 d0 72 7b 00 00 16 03  01 00 4a 02 00 00 46 03   ..r{.... ..J...F.
0040  01 45 fc 15 13 ec 6f 7f  06 7f fe b7 0f 96 be 11   .E....o. ........
0050  d4 cf 5b 98 68 1b 4c 2f  c7 a8 e4 66 cd 19 08 8c   ..[.h.L/ ...f....
0060  51 20 24 fd 4a 82 3d 6d  d9 a3 ed 08 75 a2 ff ac   Q $.J.=m ....u...
```

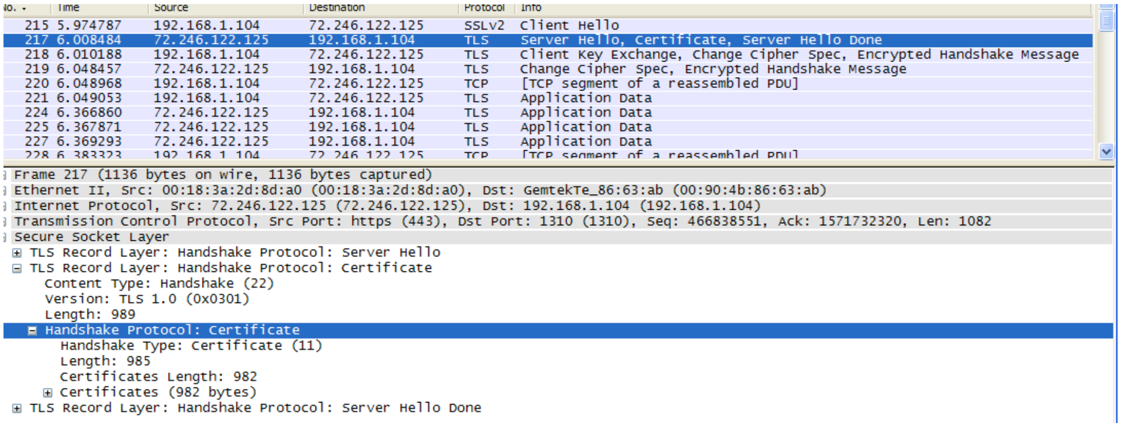
Expanded Server Hello Record

6. Yes, this record specifies a cipher suite. The chosen suite is TLS_RSA_WITH_AES_256_CBC_SHA (0x0035). In other words, RSA (public-key) 256-bit CBC AES (symmetric) and SHA (hash algorithm) are chosen.

7. Yes, this record includes a nonce, as known as Random.bytes, and it is 28 bytes long (as highlighted above). The purpose of the client and server nonces in SSL is to prevent attacker from replaying or reordering records.

8. Yes, this record includes a Session ID which is 32-bytes long. Its purpose is to allow session resumption, which can significantly reduce the number of time-consuming server handshake to crease a new session ID. In the Client Hello record, a nonzero session ID means that the client to resume its previously established session; and a zero session ID means that the client wishes to establish a new session with the server.

9. Yes, this record contains a certificate. The certificate is 982 bytes long, thus it can fit into a single Ethernet frame.



```
No. -   Time       Source           Destination      Protocol  Info
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  218 6.010188   192.168.1.104    72.246.122.125   TLS     Client Key Exchange, Change Cipher Spec, Encrypted Handshake Message
  219 6.048457   72.246.122.125   192.168.1.104    TLS     Change Cipher Spec, Encrypted Handshake Message
  220 6.048968   192.168.1.104    72.246.122.125   TCP     [TCP segment of a reassembled PDU]
  221 6.049053   192.168.1.104    72.246.122.125   TLS     Application Data
  224 6.366860   72.246.122.125   192.168.1.104    TLS     Application Data
  225 6.367871   72.246.122.125   192.168.1.104    TLS     Application Data
  227 6.369293   72.246.122.125   192.168.1.104    TLS     Application Data
  228 6.383323   192.168.1.104    72.246.122.125   TCP     [TCP segment of a reassembled PDU]

⊞ Frame 217 (1136 bytes on wire, 1136 bytes captured)
⊞ Ethernet II, Src: 00:18:3a:2d:8d:a0 (00:18:3a:2d:8d:a0), Dst: GemtekTe_86:63:ab (00:90:4b:86:63:ab)
⊞ Internet Protocol, Src: 72.246.122.125 (72.246.122.125), Dst: 192.168.1.104 (192.168.1.104)
⊞ Transmission Control Protocol, Src Port: https (443), Dst Port: 1310 (1310), Seq: 466838551, Ack: 1571732320, Len: 1082
⊟ Secure Socket Layer
  ⊞ TLS Record Layer: Handshake Protocol: Server Hello
  ⊟ TLS Record Layer: Handshake Protocol: Certificate
      Content Type: Handshake (22)
      Version: TLS 1.0 (0x0301)
      Length: 989
    ⊟ Handshake Protocol: Certificate
        Handshake Type: Certificate (11)
        Length: 985
        Certificates Length: 982
      ⊞ Certificates (982 bytes)
  ⊞ TLS Record Layer: Handshake Protocol: Server Hello Done
```
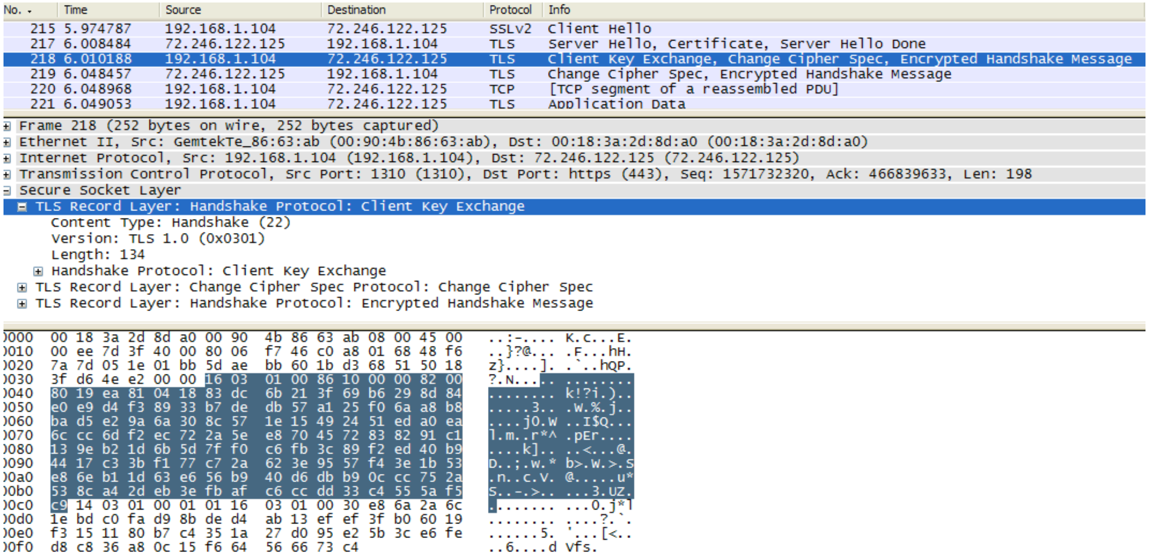

Expanded Server Hello Record (2)

Client Key Exchange Record



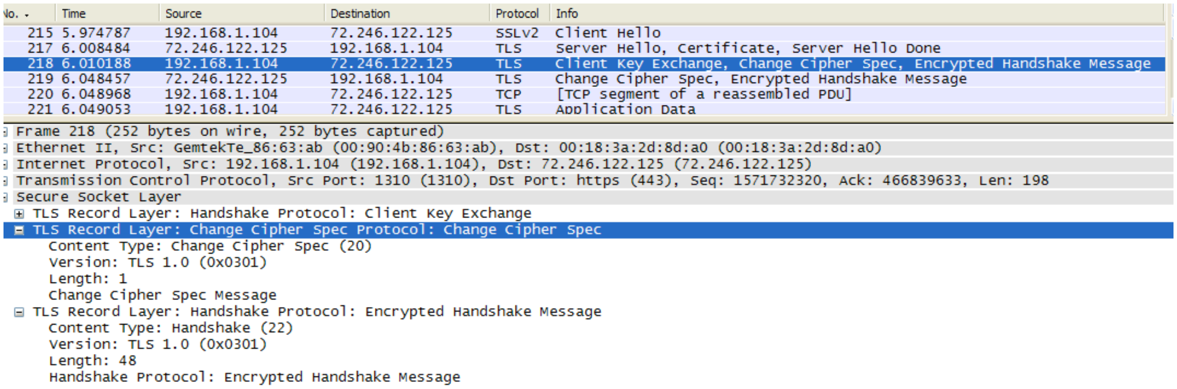
```
No. -   Time       Source           Destination      Protocol  Info
  215 5.974787   192.168.1.104    72.246.122.125   SSLv2   Client Hello
  217 6.008484   72.246.122.125   192.168.1.104    TLS     Server Hello, Certificate, Server Hello Done
  218 6.010188   192.168.1.104    72.246.122.125   TLS     Client Key Exchange, Change Cipher Spec, Encrypted Handshake Message
  219 6.048457   72.246.122.125   192.168.1.104    TLS     Change Cipher Spec, Encrypted Handshake Message
  220 6.048968   192.168.1.104    72.246.122.125   TCP     [TCP segment of a reassembled PDU]
  221 6.049053   192.168.1.104    72.246.122.125   TLS     Application Data

⊞ Frame 218 (252 bytes on wire, 252 bytes captured)
⊞ Ethernet II, Src: GemtekTe_86:63:ab (00:90:4b:86:63:ab), Dst: 00:18:3a:2d:8d:a0 (00:18:3a:2d:8d:a0)
⊞ Internet Protocol, Src: 192.168.1.104 (192.168.1.104), Dst: 72.246.122.125 (72.246.122.125)
⊞ Transmission Control Protocol, Src Port: 1310 (1310), Dst Port: https (443), Seq: 1571732320, Ack: 466839633, Len: 198
⊟ Secure Socket Layer
  ⊟ TLS Record Layer: Handshake Protocol: Client Key Exchange
      Content Type: Handshake (22)
      Version: TLS 1.0 (0x0301)
      Length: 134
    ⊞ Handshake Protocol: Client Key Exchange
  ⊞ TLS Record Layer: Change Cipher Spec Protocol: Change Cipher Spec
  ⊞ TLS Record Layer: Handshake Protocol: Encrypted Handshake Message

0000  00 18 3a 2d 8d a0 00 90  4b 86 63 ab 08 00 45 00   ..:-.... K.c...E.
0010  00 ee 7d 3f 40 00 80 06  f7 46 c0 a8 01 68 48 f6   ..}?@... .F...hH.
0020  7a 7d 05 1e 01 bb 5d ae  bb 60 1b d3 68 51 50 18   z}....]. .`..hQP.
0030  3f d6 4e e2 00 00 16 03  01 00 86 10 00 00 82 00   ?.N..... ........
0040  80 19 ea 81 04 18 83 dc  6b 21 3f 69 b6 29 8d 84   ........ k!?i.)..
0050  e0 e9 d4 f3 89 33 b7 de  db 57 a1 25 f0 6a a8 b8   .....3.. .W.%.j..
0060  ba d5 e2 9a 6a 30 8c 57  1e 15 49 24 51 ed a0 ea   ....j0.W ..I$Q...
0070  6c cc 6d f2 ec 72 2a 5e  e8 70 45 72 83 82 91 c1   l.m..r*^ .pEr....
0080  13 9e b2 1d 6b 5d 7f f0  c6 fb 3c 89 f2 ed 40 b9   ....k].. ..<...@.
0090  44 17 c3 3b f1 77 c7 2a  62 3e 95 57 f4 3e 1b 53   D..;.w.* b>.W.>.S
00a0  e8 6e b1 1d 63 e6 56 b9  40 d6 db b9 0c cc 75 2a   .n..c.V. @.....u*
00b0  53 8c a4 2d eb 3e fb af  c6 cc dd 33 c4 55 5a f5   S..-.>.. ...3.UZ.
00c0  c9 14 03 01 00 01 01 16  03 01 00 30 e8 6a 2a 6c   ........ ...0.j*l
00d0  1e bd c0 fa d9 8b de d4  ab 13 ef ef 3f b0 60 19   ........ ....?.`.
00e0  f3 15 11 80 b7 c4 35 1a  27 d0 95 e2 5b 3c e6 fe   ......5. '...[<..
00f0  d8 c8 36 a8 0c 15 f6 64  56 66 73 c4              ..6....d Vfs.
```

Expanded Client Key Exchange Record

10. Yes, this record contains a pre-master secret (highlighted above). This encrypted pre-master secret is decrypted at the server side and is used to produce a master secret. Then this master secret is used to produces "key block", which is then sliced and diced into client MAC key, server MAC key, client encryption key, server encryption key, client IV

and serve IV. The secret is encrypted using server's public key. The encrypted secret is 130-byte long.

Change Cipher Spec and Encrypted Handshake Records



```
No.   Time       Source           Destination      Protocol  Info
  215 5.974787   192.168.1.104    72.246.122.125   SSLv2     Client Hello
  217 6.008484   72.246.122.125   192.168.1.104    TLS       Server Hello, Certificate, Server Hello Done
  218 6.010188   192.168.1.104    72.246.122.125   TLS       Client Key Exchange, Change Cipher Spec, Encrypted Handshake Message
  219 6.048457   72.246.122.125   192.168.1.104    TLS       Change Cipher Spec, Encrypted Handshake Message
  220 6.048968   192.168.1.104    72.246.122.125   TCP       [TCP segment of a reassembled PDU]
  221 6.049053   192.168.1.104    72.246.122.125   TLS       Application Data
Frame 218 (252 bytes on wire, 252 bytes captured)
Ethernet II, Src: GemtekTe_86:63:ab (00:90:4b:86:63:ab), Dst: 00:18:3a:2d:8d:a0 (00:18:3a:2d:8d:a0)
Internet Protocol, Src: 192.168.1.104 (192.168.1.104), Dst: 72.246.122.125 (72.246.122.125)
Transmission Control Protocol, Src Port: 1310 (1310), Dst Port: https (443), Seq: 1571732320, Ack: 466839633, Len: 198
Secure Socket Layer
  ⊞ TLS Record Layer: Handshake Protocol: Client Key Exchange
  ⊟ TLS Record Layer: Change Cipher Spec Protocol: Change Cipher Spec
      Content Type: Change Cipher Spec (20)
      Version: TLS 1.0 (0x0301)
      Length: 1
      Change Cipher Spec Message
  ⊟ TLS Record Layer: Handshake Protocol: Encrypted Handshake Message
      Content Type: Handshake (22)
      Version: TLS 1.0 (0x0301)
      Length: 48
      Handshake Protocol: Encrypted Handshake Message
```

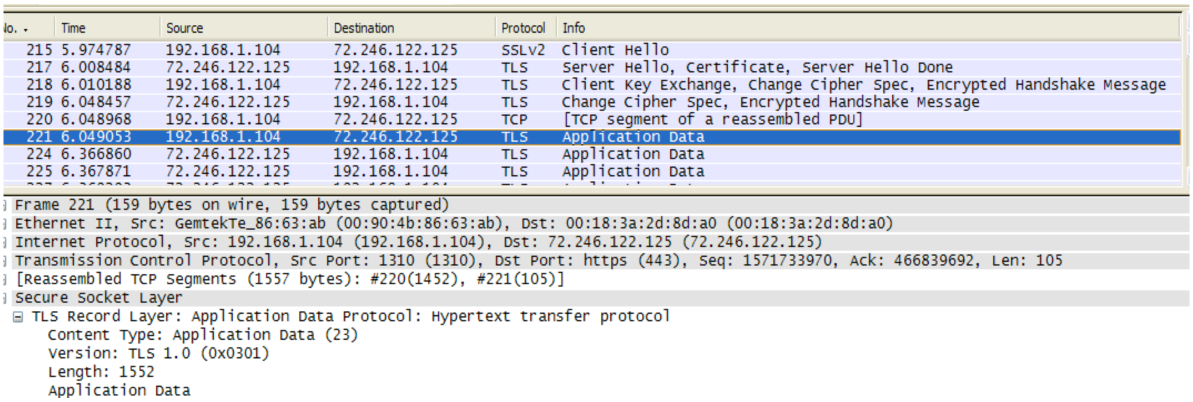
Expanded Change Cipher Spec and Encrypted Handshake Records

11. The purpose of Change Cipher Spec is to indicate change in encryption and authentication algorithms and to update the cipher suite to be used on this connection. This record is only 1 byte long in my trace.

12. The sender of this Encrypted Handshake Records and all handshake messages up to but not including this message are encrypted in record. This information is concatenated and hashed using two hash algorithms, MD5 and SHA. The content of this record is the concatenation of these two hash values. The Encrypted Handshake Record is used to verify that key exchange and authentication processes were successful.

13. Yes, the server also sends its own Change Cipher Spec and Encrypted Handshake records. The only difference is the sender of this record; the sender is now the server while the sender was the client in previous message.

Application Data Records



```
No.   Time      Source          Destination     Protocol Info
  215 5.974787  192.168.1.104   72.246.122.125  SSLv2    Client Hello
  217 6.008484  72.246.122.125  192.168.1.104   TLS      Server Hello, Certificate, Server Hello Done
  218 6.010188  192.168.1.104   72.246.122.125  TLS      Client Key Exchange, Change Cipher Spec, Encrypted Handshake Message
  219 6.048457  72.246.122.125  192.168.1.104   TLS      Change Cipher Spec, Encrypted Handshake Message
  220 6.048968  192.168.1.104   72.246.122.125  TCP      [TCP segment of a reassembled PDU]
  221 6.049053  192.168.1.104   72.246.122.125  TLS      Application Data
  224 6.366860  72.246.122.125  192.168.1.104   TLS      Application Data
  225 6.367871  72.246.122.125  192.168.1.104   TLS      Application Data
```

```
Frame 221 (159 bytes on wire, 159 bytes captured)
Ethernet II, Src: GemtekTe_86:63:ab (00:90:4b:86:63:ab), Dst: 00:18:3a:2d:8d:a0 (00:18:3a:2d:8d:a0)
Internet Protocol, Src: 192.168.1.104 (192.168.1.104), Dst: 72.246.122.125 (72.246.122.125)
Transmission Control Protocol, Src Port: 1310 (1310), Dst Port: https (443), Seq: 1571733970, Ack: 466839692, Len: 105
[Reassembled TCP Segments (1557 bytes): #220(1452), #221(105)]
Secure Socket Layer
  TLS Record Layer: Application Data Protocol: Hypertext transfer protocol
    Content Type: Application Data (23)
    Version: TLS 1.0 (0x0301)
    Length: 1552
    Application Data
```

Expanded Application Data Record

14. The application data is encrypted using the specified algorithms in the chosen cipher suite; in my case, RSA (public-key), 256-bit CBC AES (symmetric), and SHA (hash algorithm). Yes, the records containing application data include a MAC; however, Ethereal does not distinguish between the encrypted application data and the MAC.