

Application Layer

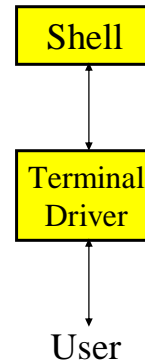
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Telnet and Rlogin

- ❑ Login to and execute commands on remote machines.
- ❑ Telnet works between hosts with different OS
 - dates back to 1969 on the ARPANET
 - its name stands for “telecommunications network protocol”
- ❑ Rlogin works between Unix systems only.

Local Shell Execution

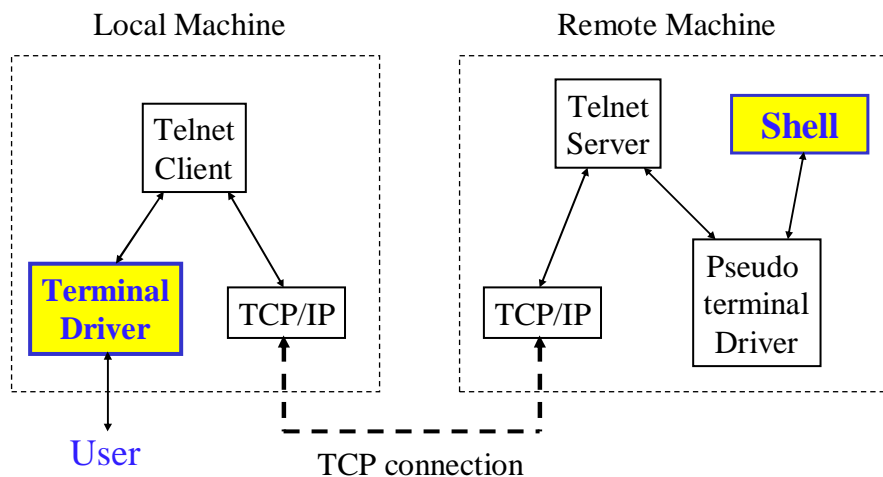
- A “shell” is an application that reads and understands user commands and invokes corresponding programs on behalf of users.
 - Command.com in Windows
 - Tcsh, bash, sh, etc. in Unix



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3

Remote Shell Execution



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During a Session

- ❑ The client sends 1 byte at a time to the server.
- ❑ Echoing is done by the server.
- ❑ Force the TCP to send 1-byte segment ?
 - optimizes responsiveness
 - high-speed LANs can sustain the workload anyway
- ❑ TCP decides the sizes of segments ?
 - enables TCP to send large segments and reduce network workload, at the expenses of slow responses

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5

Nagle's Algorithm

- ❑ Many TCP *implementations* support this algorithm in order to strike a balance between the response time of interactive applications and network workload.
- ❑ The rules:

1. A TCP connection can have one, and only one, outstanding small segment.
2. No additional small segments can be sent until that ack is received.

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6

- ❑ Consider a telnet/rlogin session in which the user is typing fast.
 - the first character the user typed is sent immediately as a one-byte segment
 - over a fast LAN, the ACK of the segment returns shortly, allowing the second character to be transmitted as a one-byte segment too
 - over a slow WAN, many more characters have been collected in the second segment when the ACK arrives

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7

FTP: File Transfer Protocol

- ❑ one **control connection** for each FTP session
- ❑ one **data connection** for each file transfer
- ❑ Common commands:
 - ABOR: abort data transfer
 - LIST *filelist*: list files or directories
 - QUIT: logoff
 - RETR *filename*: retrieve (get) a file
 - STOR *filename*: store (put) a file
 - TYPE *transfertype*: A, ASCII; I, binary
 - USER *username*: username on server

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8

- PASS *password*: password on server
- PORT *a,b,c,d,e,f*: client endpoint
(*a.b.c.d, e*256 + f*)
- ❑ Common Replies:
 - 125: data connection open; transferring
 - 331: username OK, password required
 - 425: cannot open data connection
 - 452: error writing file
 - 500: unrecognized command
- ❑ Note that the user interface (graphic or text-based) is determined by the implementation, not the protocol.

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9

Control Connection

- ❑ The server waits for connection requests on port 21
- ❑ The client sends connection requests to port 21 of the server
 - A group of well-known ports has been reserved for important applications
 - ports 20 and 21 are reserved for FTP
 - client port # is up to client OS

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10

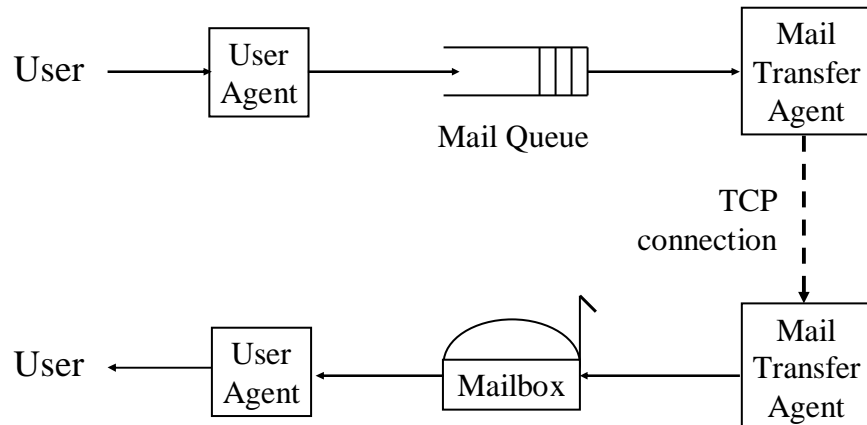
Data Connection

- ❑ To establish a data connection, the client chooses an unused port number and sends this number to the server via the control connection, using the PORT command
- ❑ The server receives the client's port number and establishes a TCP connection to the client; the server's port number is always 20.

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SMTP: Simple Mail Transfer Protocol



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12

- ❑ **Mail transfer agent:** the program that performs the SMTP protocol to actually deliver e-mails.
 - Unix implementation: `sendmail`
- ❑ **User agent:** the program that interacts with the end user and manipulates mail storages (mail queue and mailbox).

Remote User Agents

- ❑ If a user agent runs on a machine different from the one in which mail storages reside, then a mail-access protocol is needed to access remote mail storages.
 - protocols: POP, IMAP
 - user agents: Netscape Communicator, Euroda, MS Outlook, ...

SMTP Commands

- ❑ SMTP commands and replies are ASCII ended with <CRLF> (carriage return and line feed).
- ❑ After a TCP connection is established between two SMTP servers, the HELLO command is used to confirm the identities of the two servers.
- ❑ Subsequently, they use MAIL, RCPT, and DATA commands to deliver message.
- ❑ The above step may be repeated to deliver multiple messages.
- ❑ Finally, the QUIT command is used to close the connection.

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15

An SMTP Session

S: HELLO alpha.gmu.edu
R: 250 beta.gmu.edu
S: MAIL FROM: mulder@alpha.gmu.edu
R: 250 OK
S: RCPT TO: scully@beta.gmu.edu
R: 250 OK
S: DATA
R: 354 Start mail input
S: *message headers and body*

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16

S: <CRLF>.<CRLF>

R: 250OK

S: QUIT

R: 221 beta.gmu.edu service closing

Note: If the message body contain a line that starts with a period, two periods are transmitted.

Discussions

- Notice the lack of sender ID verifications
 - The origin of SPAM problems.

- Multimedia is supported thru format conventions in the email body (MIME) and independent of SMTP (email delivery).

World Wide Web

□ History:

- WWW began in 1989 at CERN, the European center for nuclear research.
- Initial proposal by Tim Berners-Lee, a physicist.
- Today he is the director of the World Wide Web Consortium, which defines Web related standards.
- First graphical interface, Mosaic, available in early 1993.
- Later, the author of Mosaic, Marc Andreesson, launched Netscape Communications Corp.

□ Operation:

- Server provides access to web pages, which are typically prepared off-line.
- Browsers request web pages from server using Hypertext Transfer Protocol (HTTP).
- Objects on the web are identified by Uniform Resource Locators (URL).

HTTP

- ❑ A simple client-server transaction protocol.
- ❑ Four steps to each transaction:
 - client establishes a TCP connection to server at port 80
 - client issues a request to retrieve a particular object
 - server sends a reply that contains a status code and the requested object
 - either client or server closes the TCP connection

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21

HTTP Commands

- ❑ Clients send HTTP commands, called methods, to send requests to the server.
 - GET: download a page
 - HEAD: read a page's header
 - PUT: upload a page
 - POST: append to a page
 - DELETE: remove the named page
- ❑ Server responds with a status line and possibly additional information (the requested page).

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22

HTML: Hypertext Markup Language

An Example Web Page:

CS455 Homework #1, Due 3:00pm Oct 4

1. **(7pt)** Give a one or two sentence description of each of the seven layers of the OSI reference model.
2. **(6pt)** Given a bit stream
0, 1, 1, 1, 0, 1, 0, 0, 0, 1
show the results of manchester and bipolar encoding.

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23

HTML Code

```
<H3>CS656 Homework #1, Due 3:00pm  
Oct 4</H3>  
<OL>  
<LI> <B>(7pt)</B> Give a one or two  
sentence description of each of the  
seven layers of the OSI reference model.  
<LI> <B>(6pt)</B> Given a bit stream<BR>  
<TT>0, 1, 1, 1, 0, 1, 0, 0, 0, 1</TT>  
show the results of manchester and  
bipolar encoding.  
</OL>
```

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24

Discussion

- ❑ HTML is *not* WYSIWYG.
- ❑ Tags usually describe the “nature” of their tagged parts, rather than specifying precisely how the document is rendered.
 - <H3> and </H3> specify a level-3 header, without saying explicitly about the font, boldface or not, etc.
 - the rendering of the document is up to the browser

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25

Modern Applications

- ❑ Multimedia streaming
- ❑ Instant messages
- ❑ Peer to peer networks
- ❑ Internet Telephony

- ❑ Many many more to come, maybe from **YOU!**

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26

A Bird's View of the Internet

- ❑ Users use PCs (hosts) to connect to routers using modem or LANs.
- ❑ Routers interconnect with other routers through optical fibers and some satellite links.
- ❑ Routers exchange routing information (such as distance vectors) to build routing tables.
 - The routing table of a router maps a destination network ID to a port number leading to that network.

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27

- ❑ When you send a message to X:
 - If X is on the same network, just send it using local DLL.
 - Otherwise, send the message to your gateway router, which consults the routing table and relays the message one step closer to X.
- ❑ ARP is used wherever IP addresses must be mapped to DLL addresses.
- ❑ Congestion is handled by hosts, not the network

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28

Discussions

- ❑ The basic ideas of the Internet are amazingly simple perhaps to the point of being naïve.
 - No way to stop abusers
 - No verifications of user identities (no checking of sender IP addresses by routers)
- ❑ This fundamental simplicity contributes to the success of the Internet.
- ❑ It is also the origin of many security problems we witness and suffer from today.