Application Layer

Classic Internet Applications

These slides are created by Dr. Yih Huang of George Mason University. Students registered in Dr. Huang’s courses at GMU can make a single machine-readable copy and print a single copy of each slide for their own reference, so long as each slide contains the copyright statement, and GMU facilities are not used to produce paper copies. Permission for any other use, either in machine-readable or printed form, must be obtained from the author in writing.
- Telnet and Rlogin enable us to login in to and execute commands on remote machines.
- Telnet works between hosts that use different operating systems.
- `telnet` dates back to 1969 on the ARPANET
- Its name stands for "telecommunications network protocol"
- Rlogin was developed to work between Unix systems only.
- Due to its assumption about the underlying OS, rlogin is much easier to implement and efficient to execute than telnet.

---

### Rlogin Startup

- An rlogin session uses a single TCP connection.
- After connection establishment, the client sends the following information to the server:
  1. local login name
  2. remote login name
  3. type and speed of the terminal
- Next, the server asks the user to enter a password.
During a Session

- The client sends 1 byte at a time to the server.
- All echoing is done by the server.
- However, such operations cause problems.

   ✗ Do we want to force the TCP to send 1-byte segment?
     * doing so optimizes responsiveness
     * some high-speed LANs (or intranets) can sustain the workload anyway

   ✗ Or, do we want the TCP to decide the sizes of segments?
     * doing so enables TCP to send large segments and reduce network workload, at the expenses of slow responses

Nagle Algorithm

- Many TCP implementations support this algorithm in order to strike a balance between the response time of interactive applications and network workload.
- The algorithm:
  1. A TCP connection can have one, and only one, outstanding small segment that has not been acknowledged.
  2. No additional small segments can be sent until the acknowledgment is received.
• 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

---

**Rlogin Signaling**

• Server-to-Client Commands

  - When the server sends a command to the client, it enters urgent mode with the last byte of the urgent data being the command byte.
  - Four command bytes are defined:
    - 0x02: Flush output
    - 0x10: stop performing flow control (CTL-S and CTL-Q)
    - 0x20: resume performing flow control
    - 0x80: respond by sending the current window size

  - Is this **out-of-band signaling** (control commands not part of the normal data stream)?
• Client-to-Server Commands
  
  there is only one such command: window size

  format: two 0xff, followed by two character s, followed by
  the number of characters per row, the number of character
  per column, the number of pixels per row, and the number
  of pixels per column

  this is an example of in-band signaling (control
  commands part of the normal data stream)

  Disadvantage?

• Telnet
  
  defines a minimum-feature virtual terminal, called network
  virtual terminal (NVT)

  uses in-band signaling in both direction

  a command byte is proceeded by 0xff, called IAC for
  “interpret as command”

  many commands are provided for option negotiation, such as
  terminal speed, window size, echoing method, and so forth
**FTP: File Transfer Protocol**

- True out-of-band signaling
  - A **control connection** is established for each FTP session
  - A **data connection** is established for each file transfer

- Common commands:
  1. **ABOR**: abort data transfer
  2. **LIST filelist**: list files or directories
  3. **QUIT**: logoff
  4. **RETR filename**: retrieve (get) a file
  5. **STOR filename**: store (put) a file
  6. **TYPE transfertype**: A for ASCII, I for Image (binary)

- **USER username**: username on server
- **PASS password**: password on server
- **PORT a,b,c,d,e,f**: client endpoint \((a.b.c.d.e \times 256 + f)\)

- Common Replies:
  1. **125**: data connection open; transferring
  2. **331**: username OK, password required
  3. **425**: cannot open data connection
  4. **452**: error writing file
  5. **500**: unrecognized command

- Note that user interface (graphic or text-based) is determined by the implementation, not the protocol.
Reply Code Conventions

- Many Internet application protocols use the convention described here in replies.
- A reply code contains three digits xyz.
- The first digit x denotes whether the response is good, bad, or incomplete.

1yz, positive preliminary reply
   command accepted; client needs to send more commands to finish the task

2yz, positive completion reply
   requested task successfully completed

3yz, positive intermediate reply
   command accepted; requested action held due to missing information; client should send more commands to provide such information

4yz, transient negative completion reply
   command not accepted; error condition is temporary and the action may be performed in the future

5yz, permanent negative completion reply
   command not accepted; error condition is permanent; the task should not be tried again

- Note that the meaning of “transient” and “permanent” are somewhat vague in many applications.
The second digit encodes responses in specific categories.

- x0z, syntax
- x1z, information
  - This reply is the responses for an information request
- x2z, connections
  - The reply refers to the transmission channel
- x3z, unspecified
- x4z, unspecified
- x5z, depends (file system status in FTP)

The third digit gives a finer gradation of the meaning specified by the second digit; its definition is application dependent.

---

Connection Management

- Control connection

1. The server waits for (control) connection request messages on port 21

2. The client sends connection request message to port 21 of the server

   - In the Internet architecture, a group of well-known ports has been reserved for important applications
   - Ports 20 and 21 are reserved for FTP

3. In Unix implementation, the server, called ftpd (FTP daemon), forks a new process to handle the new session. Why?
• Data connection

1. To establish a data connection, the client chooses an unused port number and sends this number to the server, using the PORT command.

2. The server receives the client’s port number and establishes a TCP connection to the client; the server’s port number is always 20.

Email

• Major difference between email and other types of network communication:

  In other forms of communication, a direct connection (say, a TCP connection) is set up to the remote machine. Lost packets are handled by retransmission. Failures of the destination and the network are not usually recovered from.

  Email must be able to overcome such problems, assuming they are transient. In other words, email is asynchronous, allowing for delayed delivery.
- User agent: the program that interacts with the end user and manipulates mail storages (mail queue and mailbox).

  - common Unix user agents: elm, mailx, mailtool

- If a user agent runs on a different machine from the one in which mail storages reside, then a mail-access protocol is needed to access remote mail storages.

  - protocols: POP, IMAP, and DMSP
  - user agents: Netscape Communicator, Internet Explorer, Euroda, MS Outlook.

- Mail transfer agent: the program that performs the SMTP protocol to actually deliver e-mails.

  - Unix implementation: sendmail
Typically, a sendmail process is started up in daemon mode at boot time and periodically checks the queue for undelivered message.

A mail agent, after composing a mail message, may invoke another instance of send mail to immediately deliver the message.

**Message Format**

- An email message starts with several headers, followed by a blank line and message body.

<table>
<thead>
<tr>
<th>Header</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>To:</td>
<td>primary recipient(s)</td>
</tr>
<tr>
<td>Cc:</td>
<td>secondary recipient(s)</td>
</tr>
<tr>
<td>Bcc:</td>
<td>blind secondary recipients</td>
</tr>
<tr>
<td>From:</td>
<td>creator of the message</td>
</tr>
<tr>
<td>Date:</td>
<td>date and time the message was sent</td>
</tr>
<tr>
<td>Subject:</td>
<td>short summary of the message</td>
</tr>
</tbody>
</table>

- The body of the message is simply an unstructured sequence of ASCII codes.
SMTP Commands

- SMTP commands and replies are ASCII strings ended with <CRLF> (carriage return and line feed).
- When 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 command to deliver messages.
- The above step can repeated several times to deliver several messages.
- Finally, the QUIT command is used to close the connection.

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
S: <CRLF><CRLF>
R: 250 OK
S: QUIT
R: 221 beta.gmu.edu service closing

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

---

**Multipurpose Internet Mail Extensions (MINE)**

- Extensions to the basic message format in order to handle
  1. different languages
  2. multimedia contents

<table>
<thead>
<tr>
<th>MINE Header</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIME-Version:</td>
<td>version #</td>
</tr>
<tr>
<td>Content-Transfer-Encoding:</td>
<td>ASCII, base64, ...</td>
</tr>
<tr>
<td>Content-Type</td>
<td>text, image, audio, application, ...</td>
</tr>
</tbody>
</table>

- Each content type has several subtypes.

  - Content-Type: image/jpeg
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.
- Later, the author of Mosaic, Marc Andreessen, 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).

URL Syntax:

- `<scheme><scheme specific part>`
- Schemes: ftp, http, news, gopher, file, mailto, telnet
- HTTP scheme syntax
  - `http://<host>:<port>/<path>?<search>`
HTTP

- A simple client-server transaction protocol.
- Four steps to each transaction:
  1. client establishes a TCP connection to server at port 80
  2. client issues a request to retrieve a particular object
  3. server sends a reply that contains a status code and the requested object
  4. either client or server closes the TCP connection
- HTTP is a stateless protocol and is limited to one transaction per TCP connection.

HTTP Commands

- HTTP commands, called methods, are ASCII strings.
- HTTP methods are issued by clients to send requests to 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 (similar to the ones of FTP) and possibly additional information (for example, the requested page, in MIME format).
<body>
<h3>CS656 Homework #3, due April 8th</h3>
<ul>
<li>Consider the network below (all the nodes are routers). The network uses distance vector routing. Answer the following questions.</li>
<li><center><img src="graph1.gif" /></center></li>
<li>(3pt) Show the initial distance vectors at all routers.</li>
<li>(3pt) Assume that C is the first to send its vector, followed by D. Show the contents of all distance vectors after the two events.</li>
<li>(3pt) Next, E sends its vector. Show the contents of all distance vectors.</li>
<li>(3pt) Next, F sends its vector. Show the contents of all distance vectors.</li>
<li>(3pt) At this moment, a packet P with destination address C arrives at router A. Give the path that P uses to reach C, assuming that no routers send their distance vectors in the process.</li>
</ul>

<ul>
<li>(3pt) In the Internet, each packet contains an 8-bit field that indicates Type of Service. One type of service is the minimum delay service, whereby the packet should be forwarded by routers along a minimum-delay path. A second type is the maximum reliability service, whereby the packet should be forwarded along a most reliable path. Use five or less sentences to discuss how this discrimination in packet routing can be achieved with link state routing.</li>
</ul>

Discussion:
- HTML is not WYSIWYG.
- Tags usually describe the “nature” of their tagged parts, rather than specifying precisely how the document is rendered on screen.
- The final rendering of the document is up to the browser.