Network Programming

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Hardware and Software Organization of an Internet Application

Multiplexing/demultiplexing

How multiplexing/demultiplexing works?

- Using port numbers
  - each IP packet has source IP address, destination IP address
  - each IP packet carries a transport-layer segment
  - each segment has source, destination port number
- Dest. IP address for routing to the host; IP addresses and port numbers for going to appropriate socket in the dest. host.
UDP Demultiplexing: An Example

UDP socket identified by dest. IP address and port number

TCP Demultiplexing (Connection-oriented)

- Multiple TCP connections may simultaneously share a single port:
  - Example: web server (on default port 80) has multiple connections, one for each client
- TCP socket identified by 4-tuple:
  - (source IP address, source port number, dest IP address, dest port number)
  - recv host uses all four values to direct segment to appropriate socket

TCP Demultiplexing: An Example

Port Number Specifics

- A port is a 16-bit integer (0-65535) that helps identify a socket:
  - Ephemeral port: Assigned automatically when client makes a connection request (applications don’t need to know)
  - Server port: Associated with some service provided by a server that clients need to know when connecting

- Port numbers ranging from 0 to 1023 are restricted for system-level services, e.g.,
  - Port 22: Secure shell server
  - Port 25: Mail server
  - Port 80: Web server
- Your server (without root privilege) can use ports at or above 1024.
- Ports are shared across the whole machine
  - If your buddy takes your favorite port number, just change your favorite.
TCP/UDP Sockets

Connection-oriented byte streams (TCP):
- Client/server need to establish connection before communications
- Communications flow in streams of ordered bytes
- But no clear sense of messages

Connectionless datagram (UDP):
- No connection is needed before communications;
- Clear boundaries between groups of bytes (messages)
- But no ordering between messages.

Socket Programming Notes

- `gethostbyname()`
  - Query name server for IP to name translation.
- Note
  - "`gdb` tells me `gethostbyname` fails with segmentation fault"!!!

Socket Programming Notes

- `connfd = accept(listenfd, ...)`
  - Server waiting for a connection request.
- Notes
  - Returns when the connection with a new client is established and ready for data transfers
  - Data communications are done through the connection socket, not the listening socket
  - One listening socket for the whole server, one connection socket per active connection with a client
**Socket Programming Notes**

- **read/recv, write/send**
  - Data transfer calls.

- **Note**
  - TCP communications are stream-oriented, with no clear sense of message boundaries.
  - When one sends 2000 bytes, the other side may receive twice (with 1460 bytes the first time, and 540 bytes the next time).

- How do you know when you are done with receiving?
  - Your protocol semantics should tell, three typical ways:
    - Fixed-size messages defined by protocol
    - Fixed-size header which contains a field that indicates the size of body
    - Always ends with a special pattern (e.g., an empty line "\n\n")

**Socket Programming Notes**

- How to write your receiver code?
  - Fixed-size messages defined by protocol
    - `read/recv` for a certain size?
      - Must retry in case you don’t get all the first time.
      - Likely fine with one try if the size is small.
    - Fixed-size header which contains a field that indicates the size of body
      - Similar to above.
    - Always ends with a special pattern (e.g., an empty line "\n\n")
      - Be careful that the ending pattern may straddle over two messages.

**Socket Programming Notes**

- Why I can’t bind while restarting my server?
  - Your server port is kept by the OS for a certain amount of time in case some lingering packets belonging to the previous socket connection suddenly appears.
  - Can be disabled by setting certain socket option.

**Important!**

- Check the return code of every socket call (in fact, every system call).
- Do error processing, warning messages for all cases.
- See UNIX manual pages for error codes and possible meaning.
Testing Servers Using \texttt{telnet}

- The \texttt{telnet} program is invaluable for testing servers that transmit ASCII strings over Internet connections
- Your simple FOOBAR server
- Web servers
- Mail servers
- Usage:
  - \texttt{unix> telnet <host> <portnumber>}
  - Creates a connection with a server running on \texttt{<host>} and listening on port \texttt{<portnumber>}

Testing the Echo Server With \texttt{telnet}

\begin{verbatim}
11inux> telnet www.google.com 80
Trying 173.194.73.99...
Connected to www.google.com.
\texttt{Escape character is '['.}
GET / HTTP/1.0
HTTP/1.0 200 OK
Date: Thu, 12 Apr 2012 17:28:59 GMT
... ...
11inux> telnet <gmail mail server> 25
250 gmail.com
HELO cs.rochester.edu
MAIL FROM: <bob@cs.rochester.edu>
RCPT TO: <alice@gmail.com>
250 alice@gmail.com... Recipient ok
... ...
\end{verbatim}

Learn Network Programming

- Learn to use UNIX manual pages
- Complete versions of an echo client and server in the text
- Updated versions linked to course website
- Find information on the web
- Reference book
- C versus Java

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