Network Programming

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IP Address vs. Machine Name

People: multiple identifiers
- SSN – good for machine bookkeeping, indexing
- name – human friendly, easy to remember

Internet hosts:
- IP address – used for addressing, routing on the Internet
- “name”, e.g., cycle1.csug.rochester.edu – human friendly

Q: map between IP addresses and names?
- DNS query: find the IP address for a given name
- not a fundamental part of the Internet as a network
- ease of use for Internet applications
  - “ssh cycle1.csug.rochester.edu” vs. “ssh 128.151.69.85”

Domain Name System (DNS)
- Distributed database
  - implemented with collaboration of many name servers distributed all over the Internet in a hierarchical manner:
    - local name server manages the mappings for local hosts
    - a handful of global root name servers connect local name servers
    - extensive caching (local name server as well as local host)
- Try “nslookup www.google.com”
  - You see multiple answers. Why is that?

Hardware and Software Organization of an Internet Application

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Multiplexing/demultiplexing

*Port Number Specifics*

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

How multiplexing/demultiplexing works?

- Using port numbers
  - each IP packet contains source IP address, destination IP address
  - each IP packet (often) carries a TCP/UDP segment which contains 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

Machine A: Port 1234

Machine B: Port 5678

Machine C: Port 1234
**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.

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**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 name to IP translation.

- **Note**
  - "gdb tells me *gethostbyname* fails with segmentation fault"!!
  - Not reentrant. Why?
  - Only provide one IP address.

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 telnet

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

Testing Servers With telnet

- 1linux> telnet www.google.com 80
  Trying 173.194.73.99...
  Connected to www.google.com.
  Escape character is '^]'.
  GET / HTTP/1.0
  HTTP/1.0 200 OK
  Date: Thu, 12 Apr 2012 17:28:59 GMT
  ...

- 1linux> telnet <gmail mail server> 25
  220 gmail.com
  HELO cs.rochester.edu
  250 Hello cs.rochester.edu, pleased to meet you
  MAIL FROM: <bob@cs.rochester.edu>
  250 bob@cs.rochester.edu... Sender ok
  RCPT TO: <alice@gmail.com>
  250 alice@gmail.com... Recipient ok
  ...

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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

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