Network Programming

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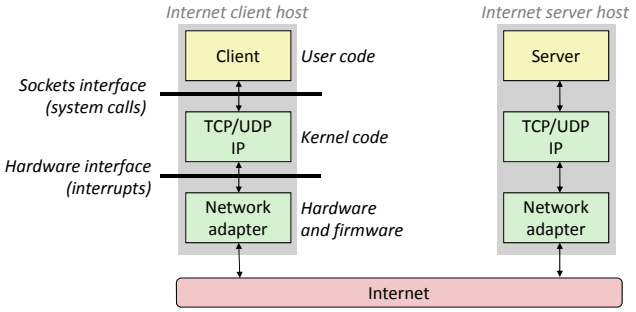
Hardware and Software Organization of an Internet Application



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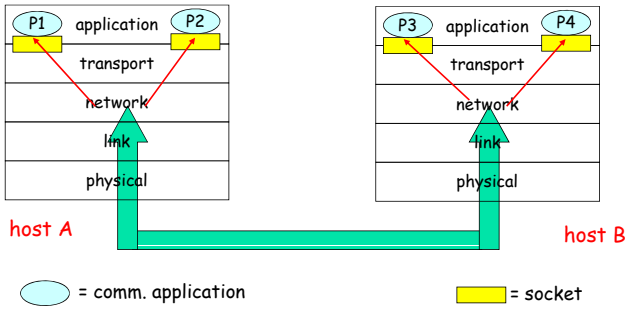
Multiplexing/demultiplexing



P1 on host A is communicating with P3 on host B; while at the same time, P2 on host A is communicating with P4 on host B.

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How multiplexing/demultiplexing works?

IP packet format

- 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.

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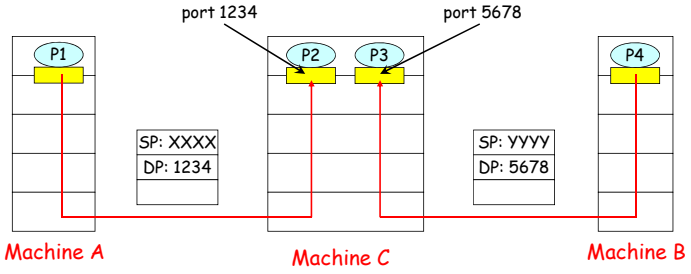
UDP Demultiplexing: An Example

UDP socket identified by dest. IP address and port number



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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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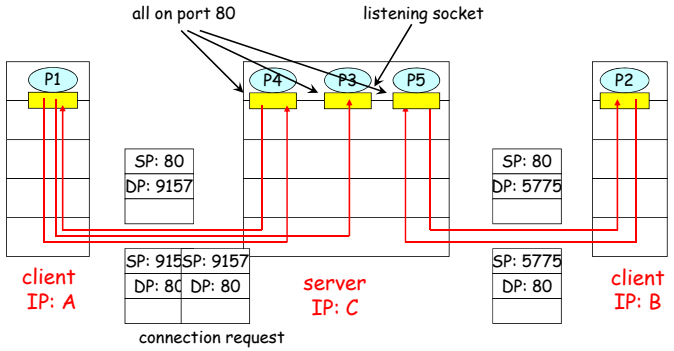
TCP Demultiplexing: An Example



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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.

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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.

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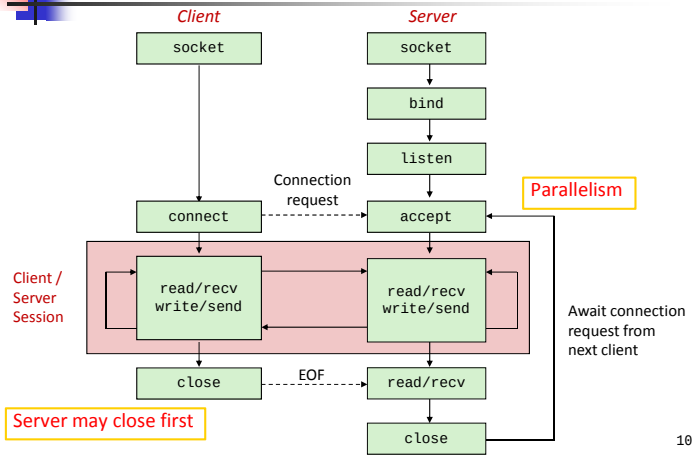
Overview of TCP Sockets



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Socket Programming Notes

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

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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

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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")

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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

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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

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Socket Programming Notes

- 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

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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>`**

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Testing the Echo Server With `telnet`

```
linux> 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
… … … …
```

```
linux> 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
  - Network programming in C: Stevens, "Unix Network Programming, Volume I", 2nd edition, 1998.
- C versus Java

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