Operating Systems

Sockets

Outline

- *Socket basics*
- Socket details
- Socket options
- Final notes
- Project 3

Socket Basics

- An *end-point* for a IP network connection
  - what the application layer "plugs into"
  - programmer cares about Application Programming Interface (API)
- End-point determined by two things:
  - *Host address* (IP address) - name of machine
  - *Port number* - location of process
- Two end-points determine a connection: socket pair
  - ex: 206.62.226.35,p21 + 198.69.10.2,p1500
  - ex: 206.62.226.35,p21 + 198.69.10.2,p1499

Ports

- Numbers (vary in BSD, Solaris):
  - 0-1023 "reserved", must be root
  - 1024 - 5000 "ephemeral"
  - however, many systems allow > 5000 ports
    - + (50,000 is correct number)
- /etc/services:

```
ftp 21/tcp
telnet 23/tcp
finger 79/tcp
snmp 161/udp
```

Sockets and the OS

User

Socket

Operating System

(Transport Layer)

- User sees "descriptor", integer index
  - like: `FILE *`, or file index from `open()`
  - returned by `socket()` call (more later)

Network Communication

- *UDP*: User Datagram Protocol
  - no acknowledgements
  - no retransmissions
  - out of order, duplicate possible
  - connectionless
  - Games, Streaming audio/video
- *TCP*: Transmission Control Protocol
  - reliable (in order, all arrive, no duplicates)
  - flow control
  - connection
  - duplex
  - Web traffic, Telnet, FTP
  - (Project 3 uses TCP)

Outline

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- *Socket details*
- Socket options
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Socket Details

Unix Network Programming, W. Richard Stevens, 2nd edition, ©1998, Prentice Hall

- Socket address structure
- TCP client-server
- Misc stuff
  - `setsockopt()`, `getsockopt()`
  - `fcntl()`

Addresses and Sockets

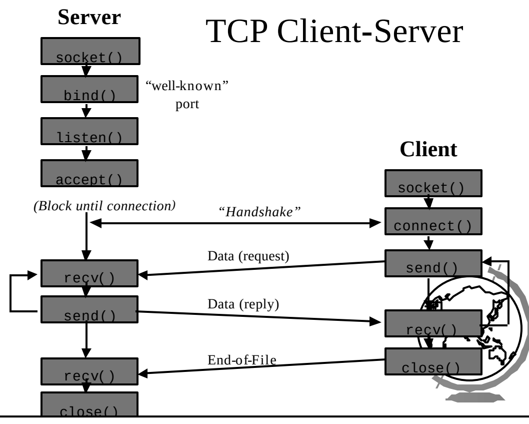
- Structure to hold address information
- Functions pass address from app to OS
  - `bind()`
  - `connect()`
  - `sendto()`
- Functions pass address from OS to app
  - `accept()`
  - `recvfrom()`

Socket Address Structure

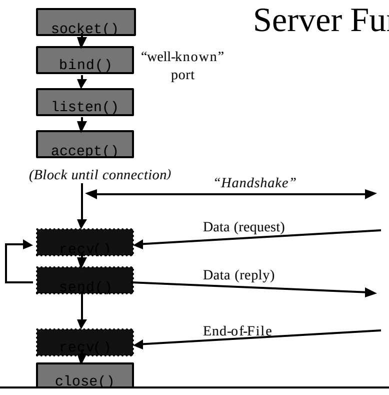
```
struct in_addr {
  in_addr_t s_addr;          /* 32-bit IPv4 addresses */
};
struct sock_addr_in {
  unit8_t      sin_len;      /* length of structure */
  sa_family_t  sin_family;   /* AF_INET */
  in_port_t    sin_port;     /* TCP/UDP Port num */
  struct in_addr sin_addr;   /* IPv4 address */
  char sin_zero[8];          /* unused */
}
```

- Are also "generic" and "IPv6" socket structures

TCP Client-Server



Server Functions



socket()

`int socket(int family, int type, int protocol);`
Create a socket, giving access to transport layer service.

- *family* is one of
  - AF_INET (IPv4), AF_INET6 (IPv6), AF_LOCAL (local Unix),
  - AF_ROUTE (access to routing tables), AF_KEY (new, for encryption)
- *type* is one of
  - SOCK_STREAM (TCP), SOCK_DGRAM (UDP)
  - SOCK_RAW (for special IP packets, PING, etc. Must be root)
    - setuid bit (`-rws--x--x root 1997 /sbin/ping*`)
- *protocol* is 0 (used for some raw socket options)
- upon success returns socket descriptor
  - similar to a file descriptor or semaphore id
  - returns -1 if failure

bind()

```
int bind(int sockfd, const struct sockaddr *myaddr,
      socklen_t addrlen);
```
Assign a local protocol address ("name") to a socket.

- *sockfd* is socket descriptor from `socket()`
- *myaddr* is a pointer to address struct with:
  - *port number* and *IP address*
  - if port is 0, then host will pick ephemeral port
    - not usually for server (exception RPC port-map)
  - IP address != INADDR_ANY (multiple nics)
- *addrlen* is length of structure
- returns 0 if ok, -1 on error
  - EADDRINUSE ("Address already in use")

listen()

`int listen(int sockfd, int backlog);`
Change socket state for TCP server.

- *sockfd* is socket descriptor from `socket()`
- *backlog* is maximum number of *incomplete* connections
  - historically 5
  - rarely above 15 on a even moderate web server!
- Sockets default to active (for client)
  - change to passive to OS will accept connection

accept()

```
int accept(int sockfd, struct sockaddr cliaddr,
      socklen_t *addrlen);
```
Return next completed connection.

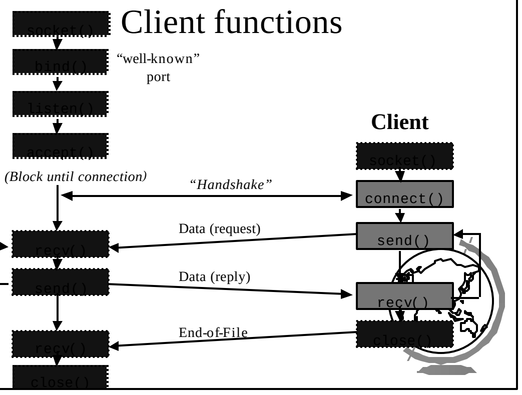
- *sockfd* is socket descriptor from `socket()`
- *cliaddr* and *addrlen* return protocol address from client
- returns brand new descriptor, created by OS
- if used with `fork()`, can create concurrent server (more later)

close()

`int close(int sockfd);`
Close socket for use.

- *sockfd* is socket descriptor from `socket()`
- closes socket for reading/writing
  - returns (doesn't block)
  - attempts to send any unsent data
  - socket option SO_LINGER
    - block until data sent
    - or discard any remaining data
  - Returns -1 if error

Client functions



connect()

```
int connect(int sockfd, const struct sockaddr
*servaddr, socklen_t addrlen);
```

Connect to server.

- *sockfd* is socket descriptor from `socket()`
- *servaddr* is a pointer to a structure with:
  - *port number* and *IP address*
  - must be specified (unlike `bind()`)
- *addrlen* is length of structure
- client doesn't need `bind()`
  - OS will pick ephemeral port
- returns socket descriptor if ok, -1 on error

Sending and Receiving

```
int recv(int sockfd, void *buff,
  size_t mbytes, int flags);
int send(int sockfd, void *buff,
  size_t mbytes, int flags);
```

- Same as `read()` and `write()` but for *flags*
  - MSG_DONTWAIT (this send non-blocking)
  - MSG_OOB (out of band data, 1 byte sent ahead)
  - MSG_PEEK (look, but don't remove)
  - MSG_WAITALL (don't give me less than `max`)
  - MSG_DONTROUTE (bypass routing table)

Socket Options (General)

- `setsockopt`(), `getsockopt`()
- SO_LINGER
  - upon close, discard data or block until sent
- SO_RCVBUF, SO_SNDBUF
  - change buffer sizes
  - for TCP is "pipeline", for UDP is "discard"
- SO_RCVLOWAT, SO_SNDLOWAT
  - how much data before "readable" via `select`()
- SO_RCVTIMEO, SO_SNDTIMEO
  - timeouts

Socket Options (TCP)

- TCP_KEEPALIVE
  - idle time before close (2 hours, default)
- TCP_MAXRT
  - set timeout value
- TCP_NODELAY
  - disable *Nagle Algorithm*

fcntl()

- 'File control' but used for sockets, too
- Signal driven sockets
- Set socket owner
- Get socket owner
- Set socket non-blocking

```
flags = fcntl(sockfd, F_GETFL, 0);
flags |= O_NONBLOCK;
fcntl(sockfd, F_SETFL, flags);
```

- Beware not getting flags before setting!
- (Should not need for project 3)

Concurrent Servers

Text segment

```
sock = socket()
/* setup socket */
while (1) {
     newsock = accept(sock)
     fork()
     if child
          read(newsock)
          until exit

}
```

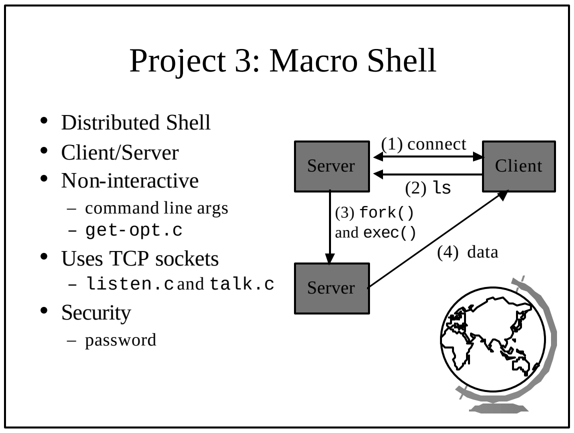
Parent

```
int sock;
int newsock;
```

Child

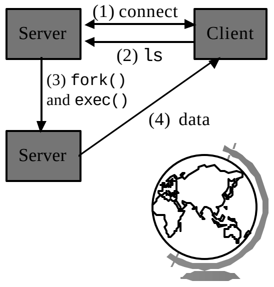
```
int sock;
int newsock;
```

- Close `sock` in child, `newsock` in parent
- Reference count for socket descriptor



Project 3: Macro Shell

- Distributed Shell
- Client/Server
- Non-interactive
  - command line args
  - `get-opt.c`
- Uses TCP sockets
  - `listen.c` and `talk.c`
- Security
  - password


Server
Client
(1) connect
(2) ls
(3) fork() and exec()
Server
(4) data