Socket Programming

CS 360 Internet Programming

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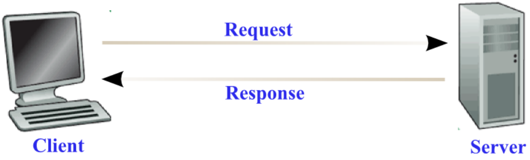
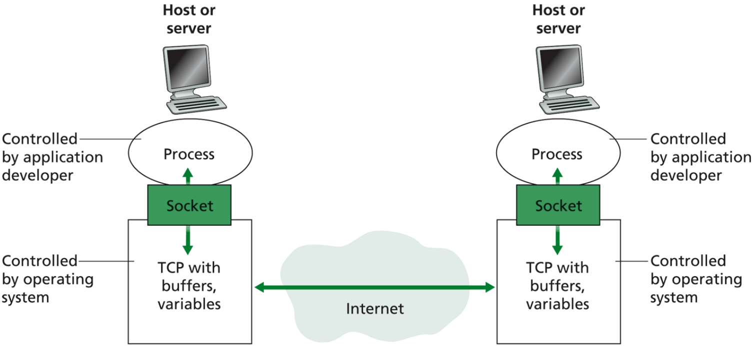
Sockets, Addresses, Ports

Clients and Servers



- clients request a service from a server using a protocol
- need an API for sending and receiving data
- need an abstraction for the Internet
    - a reliable connection: TCP
    - an unreliable message service: UDP
- these are provided by the BSD socket API

Processes and Sockets



- inter-process communication uses messages sent on sockets
- socket API defines
  - how to open, close, read, and write to socket
  - which transport protocol to use
  - various communication parameters

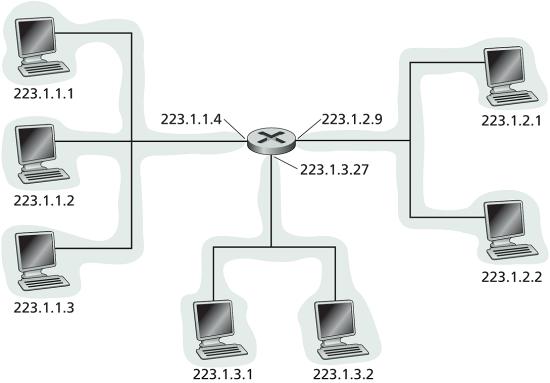
Socket API

- BSD Socket API - the dominant socket API on Linux, BSD, Windows
- Use the man pages!
    - shows C syntax, with include files
    - gives a description of how the system call works
    - lists return values
    - lists errors
    - lists other relevant man pages
- *man man*
- *man socket*
- the socket API is in section 2 of the manual, so you will need to specify the section if the same command exists in an earlier section: *man 2 bind*

Addresses and Ports

- to talk to a process on another machine, you need to identify it
    - IP address: identifies the machine
    - port number: identifies the socket the process is using

IP Addresses



- IPv4 address identifies an interface/link on a host or router
  - 32 bits
  - dotted-decimal notation: each part is 8 bits

Ports

- identifier for a socket on which a process is listening
  - 16 bits
  - a process may listen on more than one socket; each must be on a separate port
- Operating systems (such as Linux) designate some ports as *privileged*, meaning only the superuser can listen on them (typically ports less than 1024)
- To help find common servers, the IANA designates *well-known* ports for many protocols
  - HTTP: 80
  - SMTP: 25
  - SSH: 22
  - NTP: 123

ClientAPI

Client API

1. socket(): create a socket endpoint
2. connect(): connect to a server
3. send(): send data
4. recv(): receive data
5. close(): close the socket

Creating a Socket

```
int socket(int domain, int type, int protocol);

domain = PF_INET
type = SOCK_STREAM for TCP, SOCK_DGRAM for UDP
protocol = 0
```

- on success returns a socket descriptor

Connecting to a Server

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

sockfd = socket you created
serv_addr = pointer to socket address structure
socklen_t = length of socket address
```

- connects to a server
- uses the socket address structure to pass an IP address and port
- on success returns zero
- on error returns -1 and sets errno

Sending and Receiving Data

- usually the client sends a request to the server and the server sends a reply
- socket operations are similar to reading from and writing to a file
    - a socket descriptor acts like a file handle
    - sending $\sim$ writing
    - receiving $\sim$ reading

Send and Receive Syntax

```
ssize_t send(int s, const void *buf, size_t len, int flags);
ssize_t recv(int s, void *buf, size_t len, int flags);
```

- s = socket
- buf = pointer to buffer
- len = size of buffer in bytes
- on success returns the number of bytes actually sent or received
  - if it is less than what you expected, then you must repeat the system call until all data is sent or received
- `recv()` will return 0 if the socket has been closed
- on error returns -1 and sets errno
- see man pages for more advanced options

Closing a Socket

```c
#include <unistd.h>

int close(int fd);
```

- fd = socket
- on success returns zero
- on error returns -1 and sets errno
- releases the socket file descriptor so it can be re-used!

Example

- *See client-a socket code on class web site.*

Socket Addresses

Socket Addresses

- to connect a socket, you must supply a socket address structure that includes the IP address and port of the server you are connecting to
  1. use DNS to convert host name to IP address
  2. initialize a socket address structure

Generic Socket Address Structure

```
struct sockaddr {
  sa_family_t   sa_family;    // address family
  char          sa_data[14];  // address
}
```

- used to represent a generic connection between processes
- potentially provides access to many different addressing standards
- address family can be
  - `AF_UNIX` : local UNIX socket
  - `AF_INET` : Internet socket

IPv4 Socket Address Structure

```c
struct sockaddr_in {
  sa_family_t       sin_family;     // address family
  u_int16_t         sin_port;       // port
  struct in_addr    sin_addr;       // Internet address
  char              sin_zero[8];    // unused
}
```

- can cast IPv4 socket into a generic socket
- port is 2 bytes, address is 4 bytes, zero is 8 bytes = 14 bytes
- IPv4 address structure:

```c
struct in_addr {
  u_int32_t         s_addr;   // address
};
```

Network Byte Order

- you must store the port and address in network byte order (most significant byte sent first)
- provides interoperability among Internet hosts
- use `htons()` for the port and `inet_aton`, `inet_addr()` or `inet_makeaddr()` for the address

```c
struct sockaddr_in server;
server.sin_port = htons(80);
if (!inet_aton(ipaddress,&server.sin_addr))
    printf("inet_addr() conversion error\n");
```

Example

- *See client-a socket code on class web site.*

Server API

Server API

1. create a socket
2. bind: associate the socket with an address and port
3. listen: convert socket to listen for incoming connections
4. accept: accept an incoming client connection
5. send: send data
6. recv: receive data

Binding the Socket

```
int bind(int sockfd, const struct sockaddr *my_addr,
         socklen_t addrlen);

sockfd = socket you created
my_addr = pointer to socket address structure
addrlen = length of socket address
```

- associates an address with a socket
- uses the socket address structure to pass an IP address and port
- on success returns zero, -1 and errno otherwise

Listening on the Socket

```
int listen(int sockfd, int backlog);

sockfd = socket you created and bound
backlog = maximum waiting connections
```

- converts a socket to a passive socket (one that accepts connections rather than connecting)
- backlog is the maximum number of waiting connections the kernel should hold in a queue
- maximum value in Linux is 128
- on success returns zero, -1 and errno otherwise

Accepting a Connection

```
int accept(int sockfd, struct sockaddr *addr,
           socklen_t *addrlen);

sockfd = socket you created and bound
addr = pointer to empty socket address structure
addrlen = length of empty socket address structure
```

- accept a connection from a client; gets the next connection waiting in the queue
- if there are no pending connections, the process sleeps assuming this is a blocking socket (this is the default)
- on success returns a new socket descriptor
- on success, accept() fills in the address of the client

Example

- *See server-a socket code on class web site.*

Parsing Messages

Parsing Messages

- an application protocol reads and write *messages*, but TCP and the socket API use a *byte stream*
  - **when a client calls recv() there is no guarantee that it will get an entire message**
  - the application has to designate where a message starts and ends and then parse the byte stream looking for messages
- two options for reading a message
  1. variable length: read until a sentinel (end-of-message marker)
  2. known length: read a length field and then read the listed number of bytes
- **you will need to write a read-until-sentinel() and read-fixed-length() methods for your socket programming labs**

Try client-a with server-b in the socket example code. Now try client-b with server-b in the socket example code.

Sending and Receiving Properly

- results of send() or recv() call
  1. less than zero bytes, errno == EINTR
     - the system call was interrupted – try again
  2. less than zero bytes, any other error
     - fatal error – try to recover gracefully
  3. zero bytes
     - the socket is closed – try to recover gracefully
  4. positive bytes
     - the return value is the number of bytes sent or received
- **use a send() or recv() loop!**

Example

- *See client-c and server-c socket code on class web site.*