Introduction to Computer Networks

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Unix Network Programming

The socket
struct and data handling
System calls

Based on **Beej's Guide to Network Programming**

Quiz Time!

The Unix Socket

- A file descriptor really
- The Unix fact
  - When Unix programs do any sort of I/O, they do it by reading or writing to a file descriptor
  - A file descriptor is simply an integer associated with an open file

A File Descriptor

- A file in Unix can be
  - A network connection
  - A FIFO queue
  - A pipe
  - A terminal
  - A real on-the-disk file
  - Or just about anything else

Jeez, *everything* in Unix is a file!

Well, we know how to handle files!

- In theory
  - The read() and write() calls allows to communicate through a socket
- In practice
  - The send() and recv() offer much greater control over your data transmission

The structs

- int
  - For the file descriptor
- struct sockaddr
  - Space holder for “types” of addresses
- struct sockaddr_in
  - Specific for the “Internet” type
  - _in for Internet
- struct in_addr
  - 4 byte IP address

struct sockaddr

```
struct sockaddr {
    unsigned short sa_family;
        // address family, AF_xxx
    char sa_data[14];
        // 14 bytes of protocol address
};
```

struct sockaddr_in

```
struct sockaddr_in {
    short int sin_family;
        // Address family unsigned, AF_INET
    short int sin_port;
        // Port number, in network byte order
    struct in_addr sin_addr;
        // Internet address, in network byte order
    unsigned char sin_zero[8];
        // Same size as struct sockaddr
};
```

Struct in_addr

```
struct in_addr {
        // Internet address (a structure for historical reasons)
    unsigned long s_addr;
        // that's a 32-bit long, or 4 bytes
};
```

Reference

- Let *ina* be of type struct sockaddr_in
- *ina.sin_addr.s_addr* references the 4-byte IP address in network byte order

Types of Byte Ordering

- Network Byte Order
  - Most significant byte first
  - Need conversion from the app program to the network
- Host Byte Order
  - Least significant byte first
  - Usually no need in app program
  - But need conversion if data coming from the network

Functions to Convert

- htons()
  - Host to Network Short
- htonl()
  - Host to Network Long
- ntohs()
  - Network to Host Short
- ntohl()
  - Network to Host Long

Storing the IP address

```
ina.sin_addr.s_addr = inet_addr("10.12.110.57”);
```

- Returns “–1” on error
- For unsigned short it’s 255.255.255.255
- A broadcast address

A Cleaner Interface

- #include <sys/socket.h>
- #include <netinet/in.h>
- #include <arpa/inet.h>

- int inet_aton(const char *cp, struct in_addr *inp);

An Example

```
struct sockaddr_in my_addr;
my_addr.sin_family = AF_INET;
        // host byte order
my_addr.sin_port = htons(MYPORT);
        // short, network byte order
inet_aton("10.12.110.57", &(my_addr.sin_addr));
memset(&(my_addr.sin_zero), '\0', 8);
        // zero the rest of the struct
```

Things to Note

- inet_addr() and inet_aton() both convert IP addresses into the network byte order
- Not all platforms implement inet_aton()

Get the IP Address Back

- printf("%s", inet_ntoa(ina.sin_addr));
- inet_ntoa() returns a pointer to a char*
- And…

Use strcpy()

```
char *a1, *a2; . .
a1 = inet_ntoa(ina1.sin_addr);
        // this is 192.168.4.14
a2 = inet_ntoa(ina2.sin_addr);
        // this is 10.12.110.57
printf("address 1: %s\n",a1);
printf("address 2: %s\n",a2);
```

This program will print:

address 1: 10.12.110.57

address 2: 10.12.110.57

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System Calls

socket()
Creating the File Descriptor

```
#include <sys/types.h>
#include <sys/socket.h>

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

domain: AF_INET

type: SOCK_STREAM or SOCK_DGRAM

protocol: 0 or getprotobyname()

bind()
Associating Port with the FD

- #include <sys/types.h>
- #include <sys/socket.h>

- int bind(int sockfd, struct sockaddr *my_addr, int addrlen);

Example (Typical Server)

```
#include <string.h>
#include <sys/types.h>
#include <sys/socket.h>
#include <netinet/in.h>

#define MYPORT 3490
main() {
        int sockfd;
        struct sockaddr_in my_addr;
        sockfd = socket(AF_INET, SOCK_STREAM, 0); // do some error checking!
        my_addr.sin_family = AF_INET; // host byte order
        my_addr.sin_port = htons(MYPORT); // short, network byte order
        my_addr.sin_addr.s_addr = inet_addr("10.12.110.57");
        memset(&(my_addr.sin_zero), '\0', 8); // zero the rest of the struct

        // don't forget your error checking for bind():
        bind(sockfd, (struct sockaddr *)&my_addr, sizeof(struct sockaddr));
         . . .
```

connect()
Making a Connection

- #include <sys/types.h>
- #include <sys/socket.h>

- int connect(int sockfd, struct sockaddr *serv_addr, int addrlen);

Example (Typical Client)

```
#include <string.h>
#include <sys/types.h>
#include <sys/socket.h>
#include <netinet/in.h>

#define DEST_IP "10.12.110.57"
#define DEST_PORT 23
main() {
    int sockfd;
    struct sockaddr_in dest_addr; // will hold the destination addr
    sockfd = socket(AF_INET, SOCK_STREAM, 0); // do some error checking!
    dest_addr.sin_family = AF_INET; // host byte order
    dest_addr.sin_port = htons(DEST_PORT); // short, network byte order
    dest_addr.sin_addr.s_addr = inet_addr(DEST_IP);
    memset(&(dest_addr.sin_zero), '\0', 8); // zero the rest of the struct

    // don't forget to error check the connect()!
    connect(sockfd, (struct sockaddr *)&dest_addr, sizeof(struct sockaddr));
    . . .
```

listen()
Waiting for Connection

```
#include <sys/socket.h>
int listen(int sockfd, int backlog);
```

On the server side, you see typically this:

```
socket();
bind();
listen();
/* accept() goes here */
```

accept()
Getting a Connection

```
#include <sys/socket.h>
int accept(int sockfd, void *addr, int *addrlen);
```

The Server Example

```
#include <string.h>
#include <sys/types.h>
#include <sys/socket.h>
#include <netinet/in.h>

#define MYPORT 3490 // the port users will be connecting to
#define BACKLOG 10 // how many pending connections queue will hold
main() {
        int sockfd, new_fd; // listen on sock_fd, new connection on new_fd
        struct sockaddr_in my_addr; // my address information
        struct sockaddr_in their_addr; // connector's address information
        int sin_size;
        sockfd = socket(AF_INET, SOCK_STREAM, 0); // do some error checking!
        my_addr.sin_family = AF_INET; // host byte order
        my_addr.sin_port = htons(MYPORT); // short, network byte order
        my_addr.sin_addr.s_addr = INADDR_ANY; // auto-fill with my IP
        memset(&(my_addr.sin_zero), '\0', 8); // zero the rest of the struct

         // don't forget your error checking for these calls:
        bind(sockfd, (struct sockaddr *)&my_addr, sizeof(struct sockaddr));
        listen(sockfd, BACKLOG);
        sin_size = sizeof(struct sockaddr_in);
        new_fd = accept(sockfd, (struct sockaddr *)&their_addr, &sin_size);
```

send() and recv() Data Transmission

```
int send(int sockfd, const void *msg, int len, int flags);
int recv(int sockfd, void *buf, int len, unsigned int flags);
```

Example

```
char *msg = “Hello World!";
int len, bytes_sent;
. .
len = strlen(msg);
bytes_sent = send(sockfd, msg, len, 0);
. . .
```

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sendto() and recvfrom()
Transmission the Datagram Style

int sendto(int sockfd, const void *msg, int len, unsigned int flags, const struct sockaddr *to, int tolen);

int recvfrom(int sockfd, void *buf, int len, unsigned int flags, struct sockaddr *from, int *fromlen);

Or if transmitting over **TCP socket**,

one can simply use send() and recv().

close() and shutdown()
Closing the Communication

close(sockfd);

int shutdown(int sockfd, int how);

- 0 -- Further receives are disallowed
- 1 -- Further sends are disallowed
- 2 -- Further sends and receives are disallowed (like close())

Reference

- **Beej's Guide to Network Programming**
  - https://beej.us/guide/bgnet/
- Additional system calls
- TCP stream client, server example
- UDP datagram example