IPv4 Socket Address Structure

The Internet socket address structure is named `sockaddr_in` and is defined by including `<netinet/in.h>` header.

```c
struct in_addr {
    in_addr_t s_addr;    /* 32-bit IP address */
};
/* network byte ordered */

struct sockaddr_in {
    uint8_t sin_len;    /* length of structure (16) */
    sa_family_t sin_family;    /* AF_INET */
    in_port_t sin_port;        /* 16-bit TCP or UDP port number */
    /* network byte ordered */
    struct in_addr sin_addr;    /* 32-bit IPv4 address */
    /* network byte ordered */
    char sin_zero[8];    /* unused */
};
```
The Socket Interface

Application 1

Socket

Underlying communication Protocols

Communications network

Application 2

Socket

Underlying communication Protocols

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Figure 2.16
TCP Socket Calls

Server

socket()
bind()
listen()
accept()

blocks until server receives a connect request from client

connect negotiation

read()
write()
close()

Client

socket()
connect()
write()
read()
close()
UDP Socket Calls

Server

socket()

bind()

recvfrom()

blocks until server receives data from client

sendto()

close()

Client

socket()

bind()

Not needed

sendto()

recvfrom()

close()
System Calls for Elementary TCP Sockets

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

socket Function

int socket ( int family, int type, int protocol );

family: specifies the protocol family  {AF_INET for TCP/IP}

type: indicates communications semantics

SOCK_STREAM stream socket TCP
SOCK_DGRAM datagram socket UDP
SOCK_RAW raw socket

protocol: set to 0 except for raw sockets

returns on success: socket descriptor  {a small nonnegative integer}
on error: -1

Example:

if (( sd = socket (AF_INET, SOCK_STREAM, 0)) < 0)
  err_sys ("socket call error");
**connect Function**

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

- `sockfd`: a socket descriptor returned by the socket function
- `*servaddr`: a pointer to a socket address structure
- `addrlen`: the size of the socket address structure

The socket address structure must contain the **IP address** and the **port number** for the connection wanted.

In TCP `connect` initiates a three-way handshake. `connect` returns only when the connection is established or when an error occurs.

**returns on success: 0**

**on error: -1**

Example:

```c
if ( connect (sd, (struct sockaddr *) &servaddr, sizeof (servaddr)) != 0)
    err_sys("connect call error");
```
TCP Socket Calls

Server

- `socket()`
- `bind()`
- `listen()`
- `accept()`
  - blocks until server receives a connect request from client

Client

- `socket()`
- `connect()`
- `read()`
- `write()`
- `close()`

Connect negotiation

Data flow:
- Data from server to client
- Data from client to server

Figure 2.17: Leon-Garcia & Widjaja: Communication Networks
bind Function

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

bind assigns a local protocol address to a socket. Protocol address: a 32 bit IPv4 address and a 16 bit TCP or UDP port number.

sockfd: a socket descriptor returned by the socket function.
*myaddr: a pointer to a protocol-specific address.
addrlen: the size of the socket address structure.

Servers bind their “well-known port” when they start.

returns on success: 0
on error: -1

Example:

if (bind (sd, (struct sockaddr *) &servaddr, sizeof (servaddr)) != 0)
errsys (“bind call error”);
**listen Function**

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

**listen** is called **only** by a TCP server and performs two actions:

1. Converts an unconnected socket *(sockfd)* into a passive socket.
2. Specifies the maximum number of connections *(backlog)* that the kernel should queue for this socket.

**listen** is normally called before the **accept** function.

**returns**
- on success: 0
- on error: -1

**Example:**

```c
if (listen (sd, 2) != 0)
    errsysty (“listen call error”);
```
**accept Function**

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

- **accept** is called by the TCP server to return the next completed connection from the front of the completed connection queue.
- **sockfd**: This is the same socket descriptor as in **listen** call.
- **cliaddr**: used to return the protocol address of the connected peer process (i.e., the client process).
- **addrlen**: {this is a value-result argument}
  - **before the accept call**: We set the integer value pointed to by *addrlen to the size of the socket address structure pointed to by *cliaddr;
  - **on return from the accept call**: This integer value contains the actual number of bytes stored in the socket address structure.

- **returns** on success: a **new** socket descriptor
  - on error: -1
For `accept` the first argument `sockfd` is the listening socket and the returned value is the connected socket.

The server will have one connected socket for each client connection accepted.

When the server is finished with a client, the connected socket must be closed.

Example:

```c
sfd = accept (sd, NULL, NULL);
if (sfd == -1) err_sys ("accept error");
```
close Function

int close (int sockfd);

**close** marks the socket as closed and returns to the process immediately.

**sockfd**: This socket descriptor is no longer useable.

Note – TCP will try to send any data already queued to the other end before the normal connection termination sequence.

Returns on success: 0

on error: -1

Example:

```c
close (sfd);
```
TCP Echo Server

#include <stdio.h>       /* for printf() and fprintf() */
#include <sys/socket.h> /* for socket(), bind(), and connect() */
#include <arpa/inet.h>  /* for sockaddr_in and inet_ntoa() */
#include <stdlib.h>     /* for atoi() and exit() */
#include <string.h>     /* for memset() */
#include <unistd.h>     /* for close() */

#define MAXPENDING 5    /* Maximum outstanding connection requests */

void DieWithError(char *errorMessage);  /* Error handling function */
void HandleTCPClient(int clntSocket);   /* TCP client handling function */
int main(int argc, char *argv[]) {
    int servSock; /*Socket descriptor for server */
    int clntSock; /* Socket descriptor for client */
    struct sockaddr_in echoServAddr; /* Local address */
    struct sockaddr_in echoClntAddr; /* Client address */
    unsigned short echoServPort; /* Server port */
    unsigned int clntLen; /* Length of client address data structure */

    if (argc != 2) /* Test for correct number of arguments */ {
        fprintf(stderr, "Usage: %s <Server Port>\n", argv[0]);
        exit(1);
    }

    echoServPort = atoi(argv[1]); /* First arg: local port */

    /* Create socket for incoming connections */
    if ((servSock = socket(PF_INET, SOCK_STREAM, IPPROTO_TCP)) < 0) {
        DieWithError("socket() failed");
    }
}

D&C
/* Construct local address structure */
memset(&echoServAddr, 0, sizeof(echoServAddr));  /* Zero out structure */
echoServAddr.sin_family = AF_INET;  /* Internet address family */
echoServAddr.sin_addr.s_addr = htonl(INADDR_ANY);  /* Any incoming interface */
echoServAddr.sin_port = htons(echoServPort);  /* Local port */

/* Bind to the local address */
if (bind(servSock, (struct sockaddr *) &echoServAddr, sizeof(echoServAddr)) < 0)
    DieWithError("bind() failed");

/* Mark the socket so it will listen for incoming connections */
if (listen(servSock, MAXPENDING) < 0)
    DieWithError("listen() failed");
for (;; /* Run forever */)
{
    /* Set the size of the in-out parameter */
    clntLen = sizeof(echoClntAddr);  /* Wait for a client to connect */
    if ((clntSock = accept(servSock, (struct sockaddr *) &echoClntAddr, &clntLen)) < 0)
        DieWithError("accept() failed");

    /* clntSock is connected to a client! */
    printf("Handling client %s\n", inet_ntoa(echoClntAddr.sin_addr));
    HandleTCPClient(clntSock);
}
/* NOT REACHED */
#include <stdio.h>          /* for printf() and fprintf() */
#include <sys/socket.h> /* for socket(), connect(), send(), and recv() */
#include <arpa/inet.h>   /* for sockaddr_in and inet_addr() */
#include <stdlib.h>        /* for atoi() and exit() */
#include <string.h>       /* for memset() */
#include <unistd.h>      /* for close() */

#define RCVBUFSIZE 32   /* Size of receive buffer */

void DieWithError(char *errorMessage);  /* Error handling function */
int main(int argc, char *argv[]) {

    int sock; /* Socket descriptor */
    struct sockaddr_in echoServAddr; /* Echo server address */
    unsigned short echoServPort; /* Echo server port */
    char *servIP; /* Server IP address (dotted quad) */
    char *echoString; /* String to send to echo server */
    char echoBuffer[RCVBUFSIZE]; /* Buffer for echo string */
    unsigned int echoStringLen; /* Length of string to echo */
    int bytesRcvd, totalBytesRcvd; /* Bytes read in single recv() and total bytes read */

    if ((argc < 3) || (argc > 4)) /* Test for correct number of arguments */ {
        fprintf(stderr, "Usage: %s <Server IP> <Echo Word> [<Echo Port>]\n", argv[0]);
        exit(1);
    }
servIP = argv[1];             /* First arg: server IP address (dotted quad) */
echoString = argv[2];         /* Second arg: string to echo */

if (argc == 4)
    echoServPort = atoi(argv[3]); /* Use given port, if any */
else
    echoServPort = 7;  /* 7 is the well-known port for the echo service */

/* Create a reliable, stream socket using TCP */
if ((sock = socket (PF_INET, SOCK_STREAM, IPPROTO_TCP)) < 0)
    DieWithError("socket() failed");

/* Construct the server address structure */
memset(&echoServAddr, 0, sizeof(echoServAddr));    /* Zero out structure */
echoServAddr.sin_family      = AF_INET;             /* Internet address family */
echoServAddr.sin_addr.s_addr = inet_addr(servIP);   /* Server IP address */
echoServAddr.sin_port        = htons(echoServPort); /* Server port */
/* Establish the connection to the echo server */
if (connect (sock, (struct sockaddr *) &echoServAddr, sizeof(echoServAddr)) < 0)
    DieWithError("connect() failed");

echoStringLen = strlen(echoString); /* Determine input length */

/* Send the string to the server */
if (send (sock, echoString, echoStringLen, 0) != echoStringLen)
    DieWithError("send() sent a different number of bytes than expected");

/* Receive the same string back from the server */
totalBytesRcvd = 0;
printf("Received: "); /* Setup to print the echoed string */
while (totalBytesRcvd < echoStringLen)
{
    /* Receive up to the buffer size (minus 1 to leave space for
     a null terminator) bytes from the sender */
    if ((bytesRcvd = recv(sock, echoBuffer, RCVBUFSIZE - 1, 0)) <= 0)
        DieWithError("recv() failed or connection closed prematurely");
    totalBytesRcvd += bytesRcvd;   /* Keep tally of total bytes */
    echoBuffer[bytesRcvd] = '\0';  /* Terminate the string! */
    printf("%s", echoBuffer);     /* Print the echo buffer */
}
printf("\n");    /* Print a final linefeed */
\textbf{close} (sock);
exit(0);