BÁO CÁO LINUX SYSTEM PROGRAMING

VŨ NGỌC CƯỜNG

Mã nguồn: https://github.com/cuongvungoc/Network-Programing.git

MỤC LỤC

DANH SÁCH HÌNH VẼ

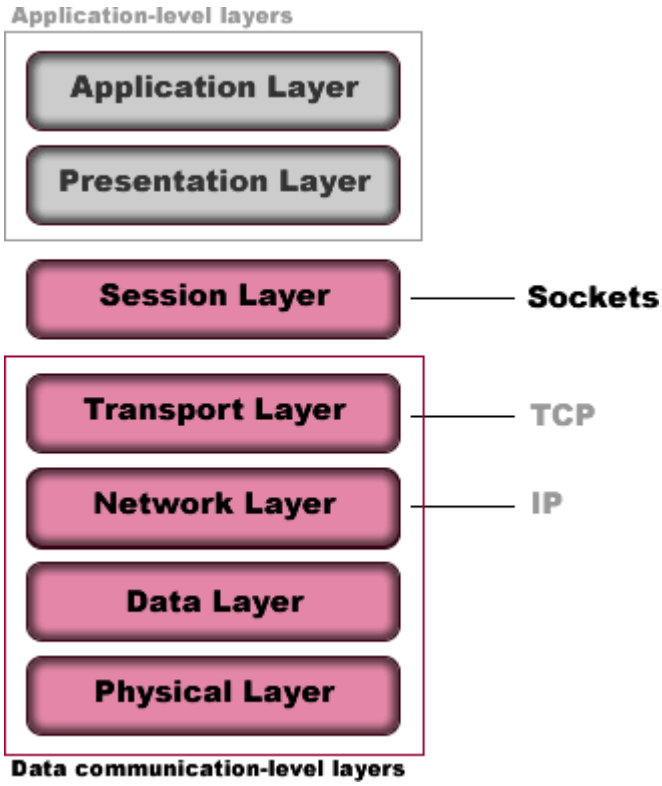
DANH SÁCH BẢNG BIỂU

CHƯƠNG 1. SOCKET INTRODUCTION

1.1 Socket overview

Socket programing is a way of connecting two nodes on a network to communicate with each other.

One socket (node) listens on a particular port at an IP address, while the other socket reaches out to the other from a connection.



Hình 1-1 Socket in OSI model

1.2 Communication domain

Bảng 1-1 Communication domain

Domain	Communication performed	Communication between applications	Address format	Address structure
AF_UNIX	Within kernel	On same host	pathname	Sockaddr_un
AF_INET	Via IPv4	On host connected via an IPv4 network	32 bit IPv4 + 16 bit port number	Sockaddr_in

AF_INET6	Via IPv6	On host connected via an IPv4 network	128 bit IPv4 + 16 bit port number	Sockaddr_in6

1.3 Socket types

Bảng 1-2 Socket type

Property	Socket type	
	Stream	Datagram
Reliable delivery	Y	N
Message boundaries preserved	N	Y
Connection-oriented	Y	N

Stream socket: (SOCK_STREAM)

- Provide a reliable, bidirectional, bytes stream communication channel.
- Connection oriented

Datagram Socket (SOCK_DGRAM)

- Allow data to be exchanged in the form of messages called datagrams.
- Message boundaries are preserved, but data transmission is not reliable.
- It doesn't need to be connected to another socket in order to be used (Connectionless).

1.4 Socket address structure

The sockaddr structure is typically defined as follows:

```
struct sockaddr {
sa_family_t sa_family; /* Address family (AF_* constant) */
char sa_data[14]; /* Socket address (size varies according to socket domain) */
};
```

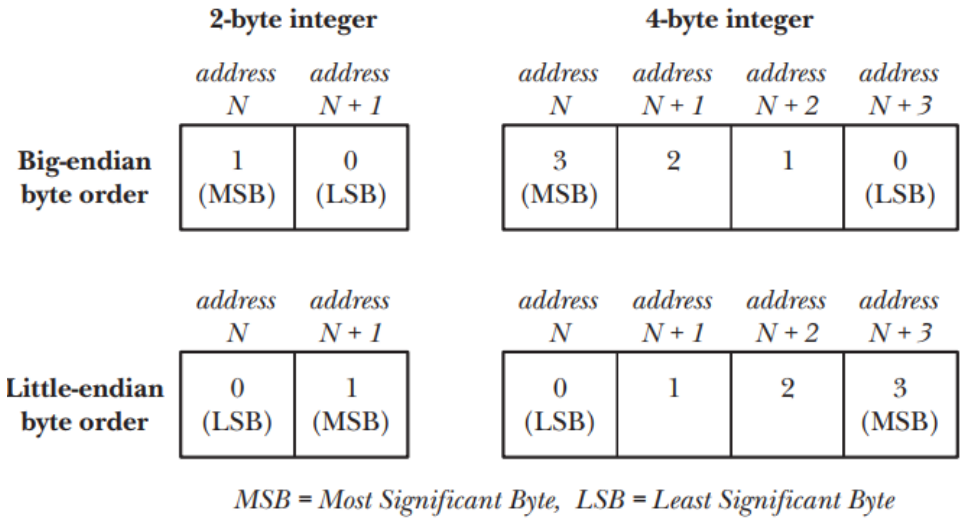
This structure serves as a template for all of the domain-specific address structures.

Each of these address structures begins with a family field corresponding to the sa_family field of the sockaddr structure. (The sa_family_t data type is an integer type specified in SUSv3.)

The value in the family field is sufficient to determine the size and format of the address stored in the remainder of the structure.

1.5 Network byte order

- IP addresses and port numbers are integer values.
- One problem we encounter when passing these values across a network is that different hardware architectures store the bytes of a multibyte integer in different orders.
  The most notable example of a little-endian architecture is x86.
- Most other architectures are big endian.
- A few hardware architectures are switchable between the two formats.
- The byte ordering used on a particular machine is called the host byte order



Hình 1-2 Big-endian and little-endian byte order for 2-byte and 4 -byte integers

Since port numbers and IP addresses must be transmitted between, and understood by, all hosts on a network, a standard ordering must be used. This ordering is called network byte order and happens to be big endian.

The htons(), htonl(), ntohs(), and ntohl() functions are defined (typically as macros) for converting integers in either direction between host and network byte order.

```
#include <arpa/inet.h>
uint16_t htons(uint16_t host_uint16);

                                    Returns host_uint16 converted to network byte order

uint32_t htonl(uint32_t host_uint32);

                                    Returns host_uint32 converted to network byte order

uint16_t ntohs(uint16_t net_uint16);

                                    Returns net_uint16 converted to host byte order

uint32_t ntohl(uint32_t net_uint32);

                                    Returns net_uint32 converted to host byte order
```

Htons: host to network short

Htonl: host to network long

Short integer: 16 bits

Long integer: 32 bits

1.6 Address conversion fucntions

1.6.1 The inet_aton() and inet_ntoa() functions

The inet_aton() and inet_ntoa() functions convert IPv4 addresses between dotted-decimal notation and binary form (in network byte order). These functions are nowadays made obsolete by inet_pton() and inet_ntop().

Inet_aton(ASCII to network): convert the dotted-decimal string pointed to by str into an IPv4 address in network byte order, which is returned in the in_addr structure pointed to by addr.

```
#include<arpa/inet.h>
int inet_aton(const char *str, struct in_addr *addr);
```

Returns 1 (true) if str is a valid dotted-decimal address, or 0 (false) on error

The inet_aton() function returns 1 if the conversion was successful, or 0 if str was invalid.
The inet_ntoa() ("network to ASCII") function performs the converse of inet_aton().

```
#include<arpa/inet.h>
char *inet_ntoa(struct in_addr addr);
```

Returns pointer to (statically allocated) dotted-decimal string version of addr

1.6.2 The inet_pton() and inet_ntop() functions

The inet_pton() and inet_ntop() functions allow conversion of both IPv4 and IPv6 addresses between binary form and dotted-decimal or hex-string notation.

```
#include<arpa/inet.h>
int inet_pton(int domain, const char *src_str, void *addrptr);
```

Returns 1 on successful conversion, 0 if src_str is not in presentation format, or –1 on error

```
const char *inet_ntop(int domain, const void *addrptr, char *dst_str,
size_t len);
```

Returns pointer to dst_str on success, or NULL on error

P: presentation

N: network

Presentaion form is human-readable string:

- 204.152.189.116 (IPv4 dotted-decimal address);
- ::1 (an IPv6 colon-separated hexadecimal address); or
- ::FFFF:204.152.189.116 (an IPv4-mapped IPv6 address)

1.6.3 The inet_addr function

The inet_addr() function shall convert the string pointed to by cp, in the standard IPv4 dotted decimal notation, to an integer value suitable for use as an Internet address.

```
#include<arpa/inet.h>

in_addr_t inet_addr(const char *cp);
                                Return the internet address on success, -1 on error
```

1.6.4 The sock_ntop function

```
#include "unp.h"
char *sock_ntop(const struct sockaddr *sockaddr, socklen_t addrlen);
                                Return NON-NULL pointer on success, NULL on error
```

1.7 Socket creation

The socket() system call creates a new socket

```
#include<sys/socket.h>
int socket(int domain, int type, int protocol);
                                Returns file descriptor on success, or –1 on error
```

Protocol argument always specified as 0 for socket types.

Example: int socket(AF_INET, SOCK_STREAM, 0)

1.8 Binding a socket to an address: bind()

The bind() system call binds a socket to an address.

```
#include<sys/socket.h>
int bind(int sockfd, const struct sockaddr *addr, socklen_t addrlen);
                                Returns 0 on success, or –1 on error
```

- The sockfd argument is a file descriptor obtained from a previous call to socket().
- The addr argument is a pointer to a structure specifying the address to which this socket is to be bound.
- The addrlen argument specifies the size of the address structure.
- The addr argument is a pointer to a structure specifying the address to which this socket is to be bound.

1.9 Connection termination: close() and shutdown()

The usual way of terminating a stream socket connection is to call close() Calling close() on a socket closes both halves of the bidirectional communication channel. Sometimes, it is useful to close one half of the connection, so that data can be transmitted in just one direction through the socket. The shutdown() system call provides this functionality.

```
#include<sys/socket.h>
int shutdown(int sockfd, int how);
                                    Returns 0 on success, or –1 on error
```

The shutdown() system call closes one or both channels of the socket sockfd, depending on the value of how.

Bảng 1-3 How in shutdown() system call

SHUT_RD	Close the reading half of the connection. Subsequent reads will return end-of-file (0). Data can still be written to the socket.
SHUT_WR	Close the writing half of the connection. Once the peer application has read all outstanding data, it will see end-of-file.
SHUT_RDW	Close both the read and the write halves of the connection. This is the same as performing a SHUT_RD followed by a SHUT_WR.

Aside from the semantics of the how argument, shutdown() differs from close() in another important respect: it closes the socket channel(s) regardless of whether there are other file descriptors referring to the socket. (In other words, shutdown() is performing an operation on the open file description, rather than the file descriptor.)

1.10 Read and write function

```
#include"rdwrn.h"
ssize_t readn(int fd, void *buffer, size_t count);
                        Returns number of bytes read, 0 on EOF, or –1 on error
ssize_t writen(int fd, void *buffer, size_t count);
                                Returns number of bytes written, or –1 on error
```

The readn() and writen() functions take the same arguments as read() and write(). However, they use a loop to restart these system calls, thus ensuring that the requested

number of bytes is always transferred (unless an error occurs or end-offile is detected on a read()).

```
#include"read_line.h"
ssize_t readLine(int fd, void *buffer, size_t n);
                    Returns number of bytes copied into buffer (excluding
                    terminating null byte), or 0 on end-of-file, or –1 on error
```

The readLine() function reads bytes from the file referred to by the file descriptor argument fd until a newline is encountered. The input byte sequence is returned in the location pointed to by buffer, which must point to a region of at least n bytes of memory.

1.11 Socket-specific I/O system call: recv() and send()

```
#include<sys/socket.h>
ssize_t recv(int sockfd, void *buffer, size_t length, int flags);
                    Returns number of bytes received, 0 on EOF, or –1 on error
ssize_t send(int sockfd, const void *buffer, size_t length, int flags);
                    Returns number of bytes sent, or –1 on error
```

Flags, is a bit mask that modifies the behavior of the I/O operation.

For recv():

Bảng 1-4 Flags for recv() system call

MSG_DONTWAIT	Perform a nonblocking recv(). If no data is available, then instead of blocking, return immediately with the error EAGAIN
MSG_OOB	Receive out-of-band data on the socket.
MSG_PEEK	Retrieve a copy of the requested bytes from the socket buffer, but don't actually remove them from the buffer. The data can later be reread by another recv() or read() call.

MSG_WAITALL	causes the system call to block until length bytes have been received.

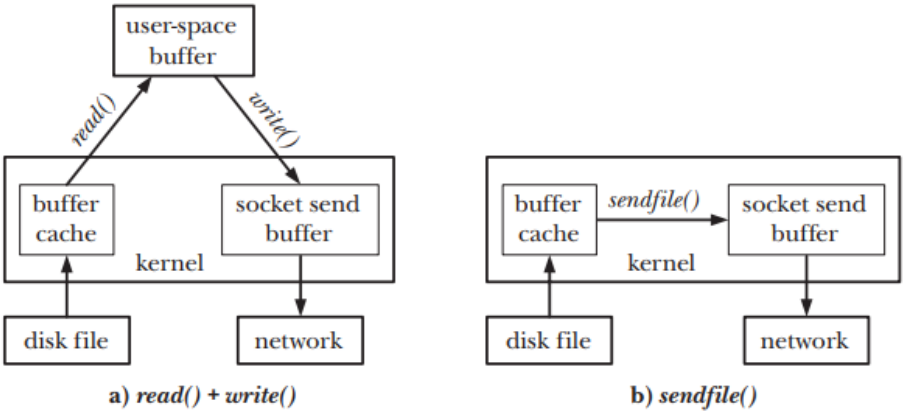
For send()

Bảng 1-5 Flags for send() system call

MSG_DONTWAIT	Perform a nonblocking send(). If the data can't be immediately transferred (because the socket send buffer is full), then, instead of blocking, fail with the error EAGAIN.
MSG_MORE	This flag is used with TCP sockets to achieve the same effect as the TCP_CORK socket option with the difference that it provides corking of data on a per-call basis.
MSG_NOSIGNAL	When sending data on a connected stream socket, don't generate a SIGPIPE signal if the other end of the connection has been closed.
MSG_OOB	Send out-of-band data on a stream socket.

1.12 The sendfile() system call

When an application calls sendfile(), the file contents are transferred directly to the socket, without passing through user space.



Hình 1-3 Sendfile() system call

```
#include                                                    <sys/sendfile.h>
ssize_t sendfile(int out_fd, int in_fd, off_t *offset, size_t count);
                                        Returns number of bytes transferred, or –1 on error
```

The sendfile() system call transfers bytes from the file referred to by the descriptor in_fd to the file referred to by the descriptor out_fd.

Offset:

- If not NULL: point to an off_t that specifies the starting file offset from which bytes should be transferred from in_fd.
- If offset is NULL: then bytes are transferred from in_fd starting at the current file offset, and the file offset is updated to reflect the number of bytes transferred.

Count: specifies the number of bytes to be transferred.

1.13 Select and poll function

1.13.1 Select() system call

The select() system call blocks until one or more of a set of file descriptors becomes ready.

```
#include <sys/time.h> /* For portability */
#include <sys/select.h>
int select(int nfds, fd_set *readfds, fd_set *writefds, fd_set *exceptfds,
                                                    struct timeval *timeout);

Returns number of ready file descriptors, 0 on timeout, or –1 on error
```

The nfds, readfds, writefds, and exceptfds arguments specify the file descriptors that select() is to monitor.

The timeout argument can be used to set an upper limit on the time for which select() will block

- readfds is the set of file descriptors to be tested to see if input is possible;
- writefds is the set of file descriptors to be tested to see if output is possible; and
- exceptfds is the set of file descriptors to be tested to see if an exceptional condition has occurred.

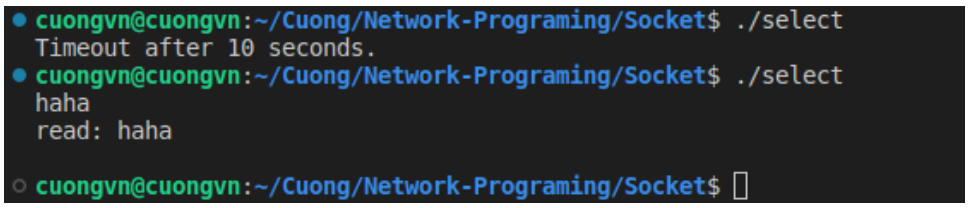
Fd_set: bit mask

```
#include<sys/select.h>
void FD_ZERO(fd_set *fdset);
void FD_SET(int fd, fd_set *fdset);
void FD_CLR(int fd, fd_set *fdset);
int FD_ISSET(int fd, fd_set *fdset);
                    Returns true (1) if fd is in fdset, or false (0) otherwise
```

- FD_ZERO() initializes the set pointed to by fdset to be empty.
- FD_SET() adds the file descriptor fd to the set pointed to by fdset.
- FD_CLR() removes the file descriptor fd from the set pointed to by fdset.
- FD_ISSET() returns true if the file descriptor fd is a member of the set pointed to by fdset.

Example:

```c
#include <stdio.h>
#include <sys/time.h>
#include <sys/types.h>
#include <unistd.h>

#define TIMEOUT 10      /* Timeout for select()*/

#define BUF_LEN 1024    /* buffer length */

int main (void)
{
    struct timeval tv;
    fd_set readfds;
    int ret = -1;

    /* Khởi tạo tập hợp readfds và thêm mô tả file stdin vào readfds*/
    FD_ZERO(&readfds);

    FD_SET(STDIN_FILENO, &readfds);

    /* Thiết lập timeout */
    tv.tv_sec = TIMEOUT;
    tv.tv_usec = 0;

    /*Block stdin đến khi stdin sẵn sàng đọc*/

    /*Tập hợp mô tả file writefds và exceptfds truyền vào NULL*/
    ret = select (STDIN_FILENO + 1, &readfds, NULL, NULL, &tv);

    if (-1 == ret)
    {
        perror("Select error.\n" );
        return 1;
    }
    else if (0 == ret)
    {
        printf("Timeout after %d seconds.\n" , TIMEOUT);
        return 0;
    }

    if (FD_ISSET(STDIN_FILENO, &readfds))
    {
        char buf[BUF_LEN+1];
        int len = -1;

        /* Đọc dữ liệu từ mô tả file của stdin */

        len = read(STDIN_FILENO, buf, BUF_LEN);

        if (-1 == len)
        {
            perror("Read fd error.\n" );
            return 1;
        }

        if(len)
        {
            buf[len] = '\0' ; /*manual vì read() không thêm ký tự null vào cuối string*/
            printf ("read: %s\n" , buf);
        }
        return 0;
    }
    return 1;
}
```



Hình 1-4 Ví dụ chương trình về select() system call

1.13.2 Poll() system call

Performs a similar task to select().

Select(): three sets, each marked to indicate the fd of interest.

Poll(): Provide a list of fd, each marked with the set of events of interest.

```
#include<poll.h>
int poll(struct pollfd fds[], nfds_t nfds, int timeout);
                    Returns number of ready file descriptors, 0 on timeout, or –1 on error
```

1.13.3 Select() vs poll()

Within Linux kernel, select() and poll() employ same set of kernel internal poll routine.

Note:

Poll routines are destined from the poll() system call itself

Poll routine is a list of actions corresponding to each file.

Each poll routine execute and return the information of fd see if it ready to read or write.

Poll() has higher performance:

select pass fd-set, nfds

Poll pass fds[]

However, select is more common in practice because it compatible with more system.

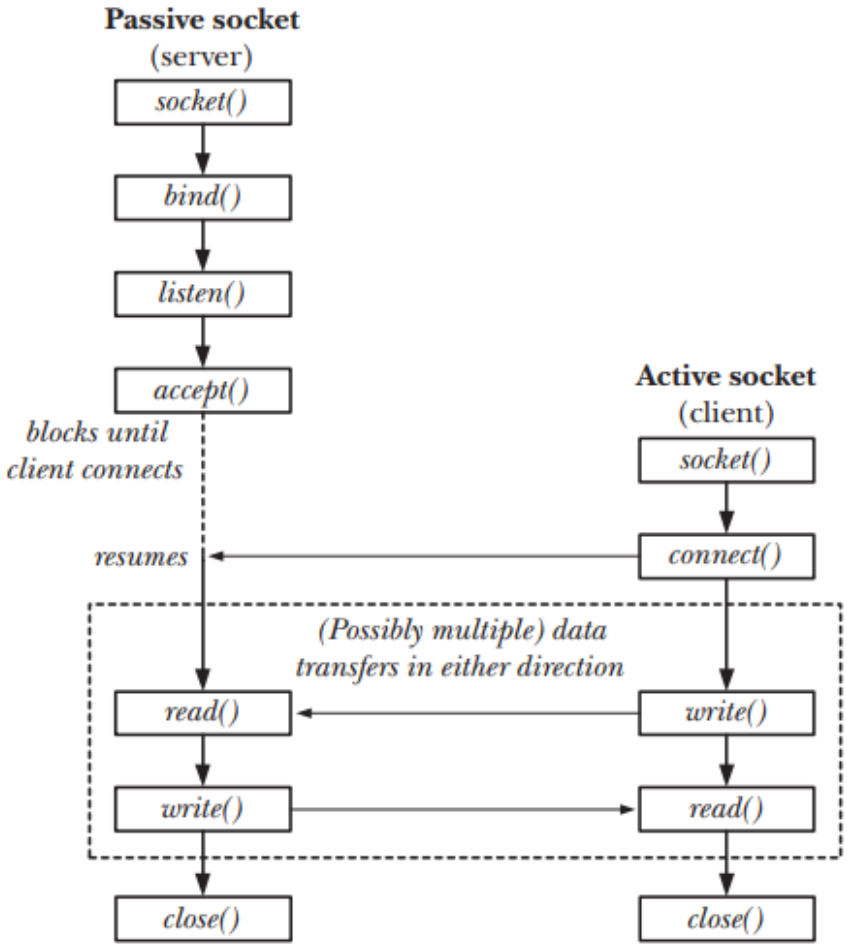
Example:

```c
#include <stdio.h>
#include <unistd.h>
#include <sys/poll.h>

#define TIMEOUT 5 /*timeout 5 seconds*/

int main(void)
{
    struct pollfd fds[2];
    int ret = -1;

    /* Kiểm tra stdin sẵn sàng đọc */
    fds[0].fd = STDIN_FILENO;
    fds[0].events = POLLIN;

    /* kiểm tra stdout sẵn sàng ghi */
    fds[1].fd = STDOUT_FILENO;
    fds[1].events = POLLOUT;

    ret = poll(fds, 2, TIMEOUT * 1000);

    if (-1 == ret)
    {
        perror("poll() error!");
        return -1;
    }
    if (0 == ret)
    {
        printf("poll() timeout after %d seconds.\n", TIMEOUT);
        return 0;
    }

    /*Kiem tra revents cho stdin va stdout*/
    if (fds[0].revents & POLLIN)
    {
        printf("stdin ready to read\n");
    }
    if (fds[1].revents & POLLOUT)
    {
        printf("stdout ready to write\n");
    }

    return 0;
}
```

```
cuongvn@cuongvn:~/Cuong/Network-Programing/Socket$ ./poll
stdout ready to write
cuongvn@cuongvn:~/Cuong/Network-Programing/Socket$ ./poll < poll.c
stdin ready to read
stdout ready to write
cuongvn@cuongvn:~/Cuong/Network-Programing/Socket$
```

Hình 1-5 Ví dụ về chương trình poll() system call

CHƯƠNG 2. TCP SOCKET



Hình 2-1 Luồng hoạt động của Stream Socket

Over view of system calls used with stream socket

2.1 Listening for Incoming connections: listen()

The listen() system call marks the stream socket referred to by the file descriptor sockfd as passive. The socket will subsequently be used to accept connections from other (active) sockets.

```
#include<sys/socket.h>
int listen(int sockfd, int backlog);
                                    Returns 0 on success, or –1 on error
```

- Backlog: maximum length to which the queue of pending connections for sockfd may grow.

- Connection arrive when queue full - ECONNREFUSED

2.2 Accepting a connection: accept()

The accept() system call accepts an incoming connection on the listening stream socket referred to by the file descriptor sockfd. If there are no pending connections when accept() is called, the call blocks until a connection request arrives.

```
#include<sys/socket.h>
int accept(int sockfd, struct sockaddr *addr, socklen_t *addrlen);
                                        Returns file descriptor on success, or –1 on error
```

It extracts the first connection request on the queue of pending connections for the listening socket, sockfd, creates a new connected socket, and returns a new file descriptor referring to that socket.

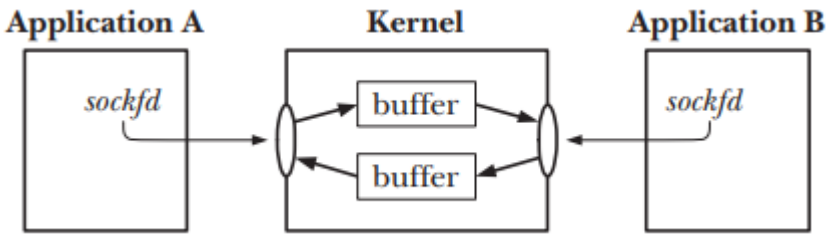
2.3 Connecting to a peer socket: connect()

The connect() system call connects the active socket referred to by the file descriptor sockfd to the listening socket whose address is specified by addr and addrlen.

```
#include<sys/socket.h>
int connect(int sockfd, const struct sockaddr *addr, socklen_t addrlen);
                                        Returns 0 on success, or –1 on error
```

The addr and addrlen arguments same as bind().

I/O on stream socket



Hình 2-2 I/O on stream socket

Stream sockets provide a bidirectional communication channel.

Example:

Server side

```c
int main(int argc, char const *argv[])
{
    int server_fd, new_socket;
    int e;
    struct sockaddr_in address;
    int opt = 1;
    int addrlen = sizeof(address);

    FILE *fp;
    char filename[] = "send.txt";

    // Creating socket file descriptor
    server_fd = socket(AF_INET, SOCK_STREAM, 0);
    if (server_fd < 0)
    {
        perror("socket failed");
        exit(EXIT_FAILURE);
    }
    printf("Server socket created successfully. \n");

    // Forcefully attaching socket to the port 8080
    if (setsockopt(server_fd, SOL_SOCKET,
                   SO_REUSEADDR | SO_REUSEPORT, &opt,
                   sizeof(opt)))
    {
        perror("setsockopt");
        exit(EXIT_FAILURE);
    }

    address.sin_family = AF_INET;
    address.sin_addr.s_addr = INADDR_ANY;
    address.sin_port = htons(PORT);

    // Forcefully attaching socket to the port 8080
    e = bind(server_fd, (struct sockaddr *)&address, sizeof(address));
    if (e < 0)
    {
        perror("bind failed");
        exit(EXIT_FAILURE);
    }
    printf("Binding successfull.\n");

    if (listen(server_fd, 3) == 0)
    {
        printf("Listening...\n");
    }
    else
    {
        perror("Error in listening\n");
        exit(EXIT_FAILURE);
    }

    new_socket = accept(server_fd, (struct sockaddr *)&address, (socklen_t *)&addrlen);
    if (new_socket < 0)
    {
        perror("accept");
        exit(EXIT_FAILURE);
    }

    struct sockaddr_in *pV4Addr = (struct sockaddr_in *)&address;
    struct in_addr ipAddr = pV4Addr->sin_addr;
    char str[INET_ADDRSTRLEN];
    inet_ntop(AF_INET, &ipAddr, str, INET_ADDRSTRLEN);
    printf("Listening from client with IP: %s, PORT: %d\n", str, ntohs(pV4Addr->sin_port));
```

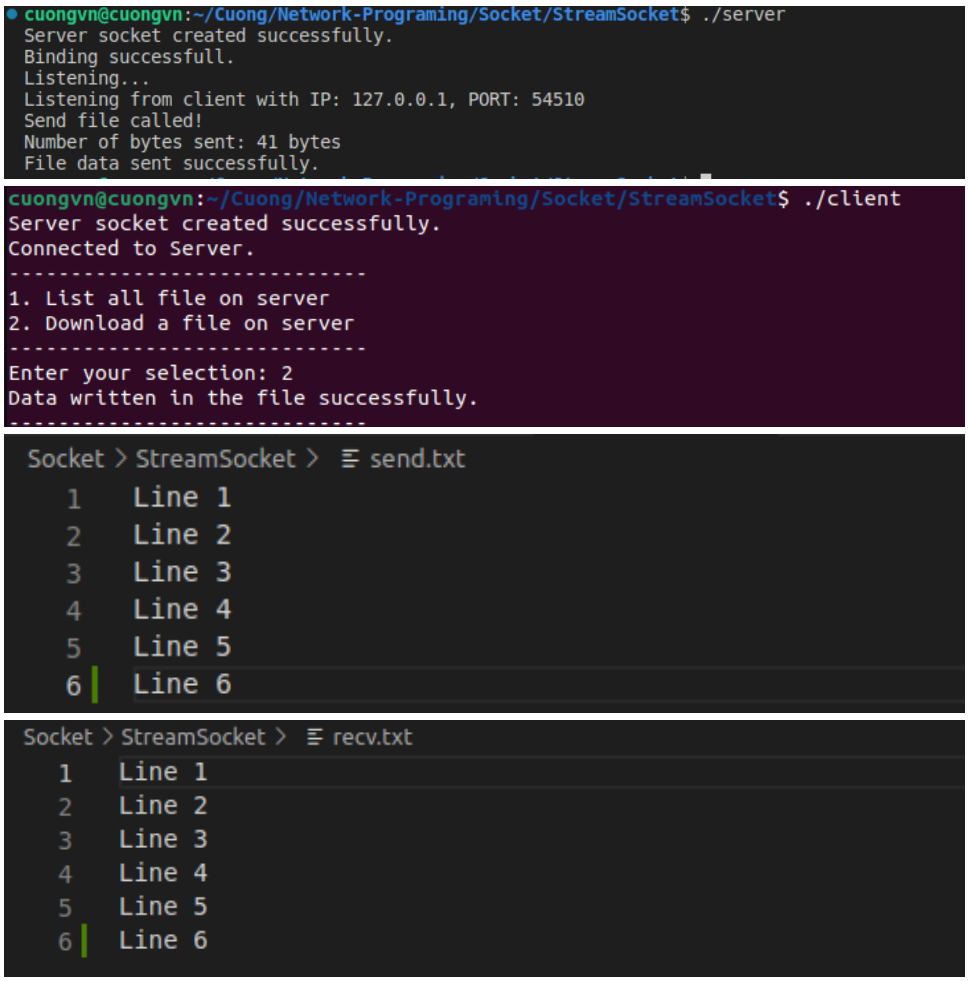
```c
void send_file(FILE *fp, int sockfd)
{
    printf("Send file called!\n");
    char data[SIZE] = {0};

    while (fgets(data, SIZE, fp) != NULL)
    {
        if (send(sockfd, data, sizeof(data), 0) == -1)
        {
            perror("Error in sending file");
            exit(1);
        }
        bzero(data, SIZE);
    }
    fseek(fp, 0L, SEEK_END);    // seek to the EOF
    int size = ftell(fp);
    rewind(fp);

    printf("Number of bytes sent: %d bytes\n", size);
    printf("File data sent successfully.\n");
}
```

Hình 2-3 Stream socket server side

Client side

```
68      char *ip = "127.0.0.1";
69      int e;
70
71      int sockfd;
72      struct sockaddr_in server_addr;
73
74      sockfd = socket(AF_INET, SOCK_STREAM, 0);
75      if (sockfd < 0)
76      {
77          printf("\n Socket creation error \n");
78          return -1;
79      }
80      printf("Server socket created successfully.\n");
81
82      server_addr.sin_family = AF_INET;
83      server_addr.sin_port = htons(PORT);
84      server_addr.sin_addr.s_addr = inet_addr(ip);
85
86      e = connect(sockfd, (struct sockaddr *)&server_addr, sizeof(server_addr));
87      if (e == -1)
88      {
89          printf("\nConnection Failed \n");
90          return -1;
91      }
92      printf("Connected to Server.\n");
93
42  void wirte_file(int sockfd)
43  {
44      int n;
45      FILE *fp;
46      char *filename = "recv.txt";
47      char buffer[SIZE];
48      fp = fopen(filename, "w");
49
50      while (1)
51      {
52          n = recv(sockfd, buffer, SIZE, 0);
53          if (n <= 0)
54          {
55              break;
56              return;
57          }
58          fprintf(fp, "%s", buffer);
59          // fwrite(buffer, SIZE, 1, fp);
60          bzero(buffer, SIZE);
61      }
62      printf("Data written in the file successfully.\n");
63      return;
64  }
```

Hình 2-4 Stream socket client side

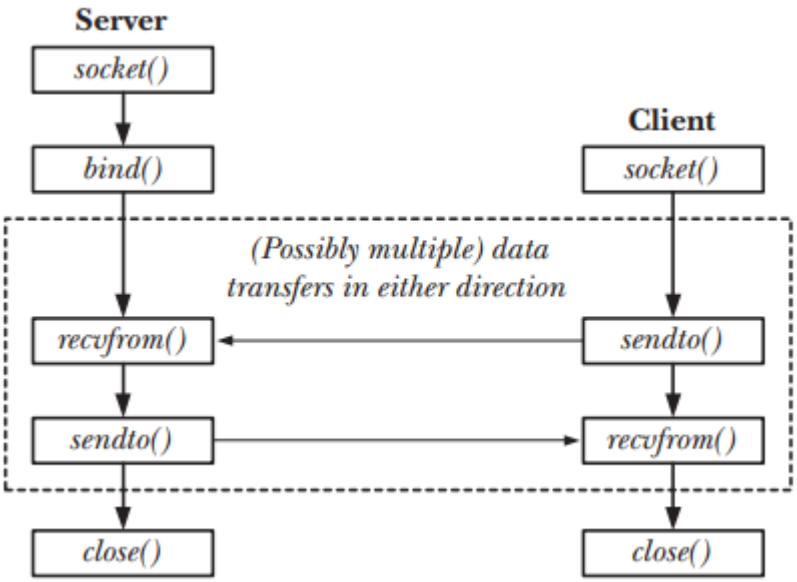


Hình 2-5 Kết quả chạy chương trình stream socket

CHƯƠNG 3. UDP SOCKET

Datagram Socket is also known by another name which is a connectionless Socket. Accordingly, this is a Socket that works over the User Datagram Protocol (UDP).

It can work at its best even without establishing a connection between the two machines.



Hình 3-1 Luồng hoạt động datagram socket

Overview of system calls used with datagram sockets

3.1 Exchange datagrams: recvfrom() and sendto()

The recvfrom() and sendto() system calls receive and send datagrams on a datagram socket.

```
#include<sys/socket.h>
ssize_t recvfrom(int sockfd, void *buffer, size_t length, int flags,
                 struct sockaddr *src_addr, socklen_t *addrlen);
                                  Returns number of bytes received, 0 on EOF, or –1 on error

ssize_t sendto(int sockfd, const void *buffer, size_t length, int flags,
               const struct sockaddr *dest_addr, socklen_t addrlen);
                                  Returns number of bytes sent, or –1 on error
```

Flags – a bit mask controlling socket-specific I/O features. Cam specify flags as 0 if don’t require any of these features.

Example:

Server side

```
int sockfd, nBytes;
struct sockaddr_in addr_con;
int addrlen = sizeof(addr_con);
addr_con.sin_family = AF_INET;
addr_con.sin_port = htons(PORT_NO);
addr_con.sin_addr.s_addr = INADDR_ANY;
char net_buf[NET_BUF_SIZE];
FILE *fp;

// socket()
sockfd = socket(AF_INET, SOCK_DGRAM, IP_PROTOCOL);

if (sockfd < 0)
    printf("\nfile descriptor not received!!\n");
else
    printf("\nfile descriptor %d received\n", sockfd);

// bind()
if (bind(sockfd, (struct sockaddr *)&addr_con, sizeof(addr_con)) == 0)
    printf("\nSuccessfully binded!\n");
else
    printf("\nBinding Failed!\n");
```

```
while (1)
{
    printf("\nWaiting for file name...\n");

    // receive file name
    clearBuf(net_buf);

    nBytes = recvfrom(sockfd, net_buf,
                      NET_BUF_SIZE, sendrecvflag,
                      (struct sockaddr *)&addr_con, &addrlen);

    fp = fopen(net_buf, "r");
    printf("\nFile Name Received: %s\n", net_buf);
    if (fp == NULL)
        printf("\nFile open failed!\n");
    else
        printf("\nFile Successfully opened!\n");
```

```
    while (1)
    {

        // process
        if (sendFile(fp, net_buf, NET_BUF_SIZE))
        {
            sendto(sockfd, net_buf, NET_BUF_SIZE,
                   sendrecvflag,
                   (struct sockaddr *)&addr_con, addrlen);
            break;
        }

        // send
        sendto(sockfd, net_buf, NET_BUF_SIZE,
               sendrecvflag,
               (struct sockaddr *)&addr_con, addrlen);
        clearBuf(net_buf);
    }
    if (fp != NULL)
        fclose(fp);
}
```

```
32  // function sending file
33  int sendFile(FILE *fp, char *buf, int s)
34  {
35      int i, len;
36      if (fp == NULL)
37      {
38          strcpy(buf, nofile);
39          len = strlen(nofile);
40          buf[len] = EOF;
41          for (i = 0; i <= len; i++)
42              buf[i] = Cipher(buf[i]);
43          return 1;
44      }
45
46      char ch, ch2;
47      for (i = 0; i < s; i++)
48      {
49          ch = fgetc(fp);
50          ch2 = Cipher(ch);
51          buf[i] = ch2;
52          if (ch == EOF)
53              return 1;
54      }
55      return 0;
56  }
```

Hình 3-2 Code server side datagram socket

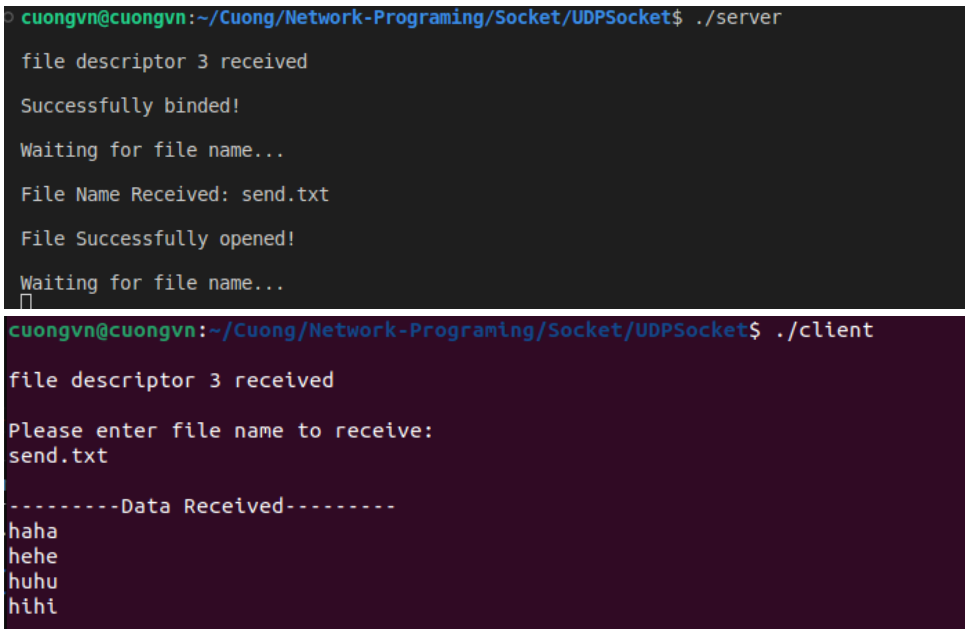
Client side

```c
int main()
{
    int sockfd, nBytes;
    struct sockaddr_in addr_con;
    int addrlen = sizeof(addr_con);
    addr_con.sin_family = AF_INET;
    addr_con.sin_port = htons(PORT_NO);
    addr_con.sin_addr.s_addr = inet_addr(IP_ADDRESS);
    char net_buf[NET_BUF_SIZE];
    FILE *fp;

    // socket()
    sockfd = socket(AF_INET, SOCK_DGRAM,
                    IP_PROTOCOL);

    if (sockfd < 0)
        printf("\nfile descriptor not received!!\n");
    else
        printf("\nfile descriptor %d received\n", sockfd);
```

```c
    while (1)
    {
        printf("\nPlease enter file name to receive:\n");
        scanf("%s", net_buf);
        sendto(sockfd, net_buf, NET_BUF_SIZE,
               sendrecvflag, (struct sockaddr *)&addr_con,
               addrlen);

        printf("\n---------Data Received---------\n");

        while (1)
        {
            // receive
            clearBuf(net_buf);
            nBytes = recvfrom(sockfd, net_buf, NET_BUF_SIZE,
                              sendrecvflag, (struct sockaddr *)&addr_con,
                              &addrlen);

            // process
            if (recvFile(net_buf, NET_BUF_SIZE))
            {
                break;
            }
        }
        printf("\n-------------------------------\n");
    }
```

```c
// function to receive file
int recvFile(char *buf, int s)
{
    int i;
    char ch;
    for (i = 0; i < s; i++)
    {
        ch = buf[i];
        ch = Cipher(ch);
        if (ch == EOF)
            return 1;
        else
            printf("%c", ch);
    }
    return 0;
}
```

Hình 3-3 Code client side datagram socket



Hình 3-4 Kết quả chạy chương trình datagram socket

Example:

Server chứa một số danh sách file binary. Client có thể request danh sách các file binary hiện có trên server. Client có thể nhập tên file và tải về từ server. File nhận được ở Client phải giữ nguyên tính toàn vẹn.

Cho phép nhiều client cùng truy cập

Server side

```c
#include <netinet/in.h>
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <sys/socket.h>
#include <unistd.h>
#include <arpa/inet.h>
#include <pthread.h>
#include <dirent.h>

#define PORT 8080
#define SIZE 1024
#define LIST_FILES '1'
#define DOWNLOAD '2'
#define QUIT 'q'
```

```c
int server_fd, new_socket;
int e;
struct sockaddr_in address;
int opt = 1;
int addrlen = sizeof(address);

FILE *fp;

// Creating socket file descriptor
server_fd = socket(AF_INET, SOCK_STREAM, 0);
if (server_fd < 0)
{
    perror("socket failed");
    exit(EXIT_FAILURE);
}
printf("Server socket created successfully. \n");
```

```c
// Forcefully attaching socket to the port 8080
if (setsockopt(server_fd, SOL_SOCKET,
               SO_REUSEADDR | SO_REUSEPORT, &opt,
               sizeof(opt)))
{
    perror("setsockopt");
    exit(EXIT_FAILURE);
}

address.sin_family = AF_INET;
address.sin_addr.s_addr = INADDR_ANY;
address.sin_port = htons(PORT);
```

```c
// Forcefully attaching socket to the port 8080
e = bind(server_fd, (struct sockaddr *)&address, sizeof(address));
if (e < 0)
{
    perror("bind failed");
    exit(EXIT_FAILURE);
}
printf("Binding successfull.\n");

if (listen(server_fd, 3) == 0)
{
    printf("Listening...\n");
}
else
{
    perror("Error in listening\n");
    exit(EXIT_FAILURE);
}
```

```c
new_socket = accept(server_fd, (struct sockaddr *)&address, (socklen_t *)&addrlen);
if (new_socket < 0)
{
    perror("accept");
    exit(EXIT_FAILURE);
}

struct sockaddr_in *pV4Addr = (struct sockaddr_in *)&address;
struct in_addr ipAddr = pV4Addr->sin_addr;
char str[INET_ADDRSTRLEN];
inet_ntop(AF_INET, &ipAddr, str, INET_ADDRSTRLEN);
printf("Listening from client with IP: %s, PORT: %d\n", str, ntohs(pV4Addr->sin_port));
```

```c
pthread_t threads[MAX_THREAD];
int n_thread = 0;
// pthread_t thread_id;
while (1)
{
    new_socket = accept(server_fd, (struct sockaddr *)&address, (socklen_t *)&addrlen);
    if (new_socket < 0)
    {
        perror("accept");
        exit(EXIT_FAILURE);
    }
    printf("Connection accepted from: %s, PORT: %d\n", inet_ntoa(address.sin_addr), ntohs(address.sin_port));
    pthread_create(&threads[n_thread++], NULL, handle_client, (int *)new_socket);
}

pthread_exit(NULL);

// closing the connected socket
close(new_socket);
// closing the listening socket
shutdown(server_fd, SHUT_RDWR);
return 0;
```

```c
void send_file(FILE *fp, int sockfd)
{
    printf("Send file called!\n");
    char data[SIZE] = {0};

    while (fgets(data, SIZE, fp) != NULL)
    {
        if (send(sockfd, data, sizeof(data), 0) == -1)
        {
            perror("Error in sending file");
            exit(1);
        }
        bzero(data, SIZE);
    }
    fseek(fp, 0L, SEEK_END); // seek to the EOF
    int size = ftell(fp);
    rewind(fp);

    printf("Number of bytes sent: %d bytes\n", size);
    printf("File data sent successfully.\n");
}
```

```c
void list_file(int sockfd, int new_socket)
{
    struct dirent *dir;
    DIR *d;
    d = opendir(".");
    char quit[100] = "q";
    if (d)
    {
        while ((dir = readdir(d)) != NULL)
        {
            char buffer[SIZE] = {0};
            send(new_socket, dir->d_name, strlen(dir->d_name), 0);
            read(new_socket, buffer, SIZE);
        }
    }
    send(new_socket, quit, strlen(quit), 0);

    free(dir);
    free(d);
}
```

```c
void *handle_client(void *param)
{
    char buffer[SIZE] = {0};
    int new_socket = (int *)param;
    read(new_socket, buffer, SIZE);
    if (buffer[0] == QUIT)
    {
        printf("Disconnected from client\n");
        pthread_exit(NULL);
    }
    else if (buffer[0] == LIST_FILES)
    {
        printf("Reading from client!\n");
        list_file(new_socket);
    }
    else if (buffer[0] == DOWNLOAD)
    {
        char file_name[SIZE];
        read(new_socket, file_name, SIZE);
        FILE *fp;
        fp = fopen(file_name, "r");
        if (fp == NULL)
        {
            perror("Error in reading file.\n");
            exit(EXIT_FAILURE);
        }
        send_file(fp, new_socket);
        pthread_exit(NULL);
        // break;
    }
```

Hình 3-5 Code ví dụ server side bài thực hành

Client side

```c
#include <arpa/inet.h>
#include <stdio.h>
#include <string.h>
#include <sys/socket.h>
#include <unistd.h>
#include <stdlib.h>

#define PORT 8080
#define SIZE 1024
#define LIST_FILES '1'
#define DOWNLOAD '2'
#define QUIT 'q'
```

```c
    char *ip = "127.0.0.1";
    int e;

    int sockfd;
    struct sockaddr_in server_addr;

    sockfd = socket(AF_INET, SOCK_STREAM, 0);
    if (sockfd < 0)
    {
        printf("\n Socket creation error \n");
        return -1;
    }
    printf("Server socket created successfully.\n");

    server_addr.sin_family = AF_INET;
    server_addr.sin_port = htons(PORT);
    server_addr.sin_addr.s_addr = inet_addr(ip);

    e = connect(sockfd, (struct sockaddr *)&server_addr, sizeof(server_addr));
    if (e == -1)
    {
        printf("\nConnection Failed \n");
        return -1;
    }
    printf("Connected to Server.\n");
```

```c
    while (1)
    {
        printf("-----------------------------\n");
        printf("1. List all file on server\n");
        printf("2. Download a file on server\n");
        printf("q. Quit the program\n");
        printf("-----------------------------\n");
        printf("Enter your selection: ");
        scanf("%s", select);

        if (select[0] == QUIT)
        {
            send(sockfd, select, sizeof(select), 0);

            close(sockfd);
            return 0;
        }
        else if (select[0] == LIST_FILES)
        {
            send(sockfd, select, sizeof(select), 0);

            recv_list(sockfd);
        }
```

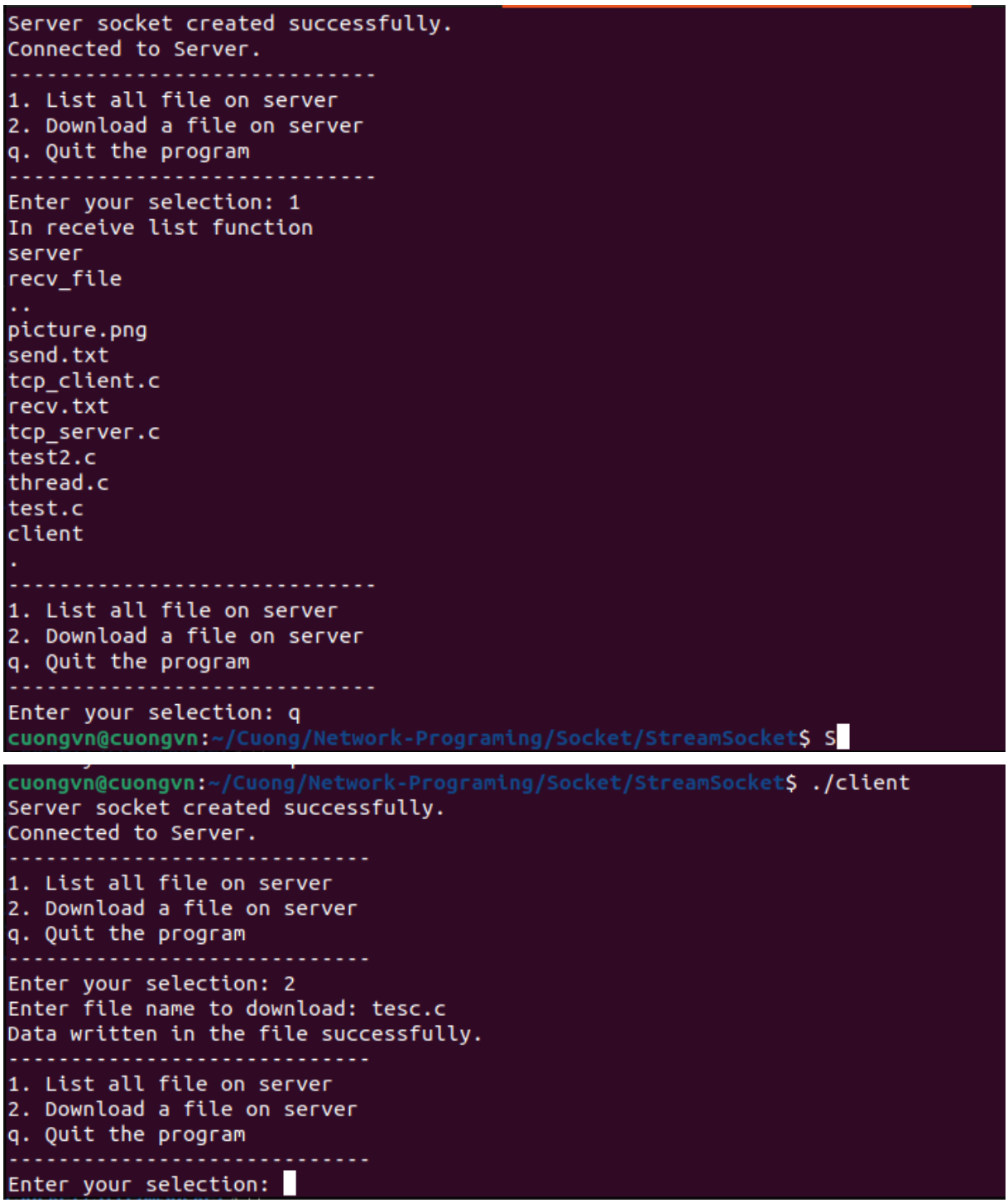
```c
        else if (select[0] == DOWNLOAD)
        {
            char dir[SIZE] = "./recv_file/";
            char file_name[SIZE];
            send(sockfd, select, sizeof(select), 0);
            printf("Enter file name to download: ");
            scanf("%s", file_name);
            send(sockfd, file_name, sizeof(select), 0);
            strcat(dir, file_name);
            fp = fopen(dir, "w");
            wirte_file(fp, sockfd);
            // break;
        }
    }

    // closing the connected socket
    free(fp);
    close(sockfd);
    return 0;
}
```

```c
void recv_list(int new_socket)
{
    int valread;
    char received[1024] = "Received!";
    printf("In receive list function\n");
    while (1)
    {
        char buffer[1024] = {0};
        valread = read(new_socket, buffer, 1024);
        if (valread > 0)
        {
            send(new_socket, received, sizeof(received), 0);
        }

        if (buffer[0] == 'q')
        {
            break;
        }
        printf("%s\n", buffer);
    }
}
```

```c
void wirte_file(FILE *fp, int sockfd)
{
    int n;
    char buffer[SIZE];

    while (1)
    {
        n = recv(sockfd, buffer, SIZE, 0);
        if (n <= 0)
        {
            break;
            return;
        }
        fprintf(fp, "%s", buffer);
        // fwrite(buffer, SIZE, 1, fp);
        bzero(buffer, SIZE);
    }
    printf("Data written in the file successfully.\n");
    return;
}
```

Hình 3-6 Code client side bài thực hành

```
cuongvn@cuongvn:~/Cuong/Network-Programing/Socket/StreamSocket$ ./server
Server socket created successfully.
Binding successfull.
Listening...
Connection accepted from: 127.0.0.1, PORT: 41458
Connection accepted from: 127.0.0.1, PORT: 41466
Reading from client!
Disconnected from client
Connection accepted from: 127.0.0.1, PORT: 49946
Error in reading file.
: No such file or directory
```



Hình 3-7 Kết quả chạy bài thực hành

TÀI LIỆU THAM KHẢO

[1] "Socket Programming in C/C++ - GeeksforGeeks." https://www.geeksforgeeks.org/socket-programming-cc/ (accessed Feb. 21, 2023).

[2] "Socket Programming in C/C++: Handling multiple clients on server without multi threading," *GeeksforGeeks*, Aug. 29, 2016. https://www.geeksforgeeks.org/socket-programming-in-cc-handling-multiple-clients-on-server-without-multi-threading/ (accessed Feb. 21, 2023).

[3] M. Kerrisk, *The Linux programming interface: a Linux and UNIX system programming handbook*. San Francisco: No Starch Press, 2010.