NOTICE: This assignment helps you gain hands-on experience with socket programming in C or C++. As an optional task, it will NOT be graded and you are free to hand in your work anytime, i.e., NO deadline in your submission.

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Computer Networking, Fall 2021

Assignment 1: A Multi-Client File Transfer Application (Optional)

September 28th, 2021

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1 Introduction

In this assignment, we will implement a <u>multi-client</u> file transfer application called *MYFTP*. MYFTP is a simplified version of the File Transfer Protocol (FTP). It includes the basic functionalities of FTP, including authentication, file upload/download, and file listing. It also enables multiple clients to simultaneously connect to the server at the same time. Our objective is to develop hands-on skills of socket programming and multi-threading programming in C or C++.

2 Protocol Description

2.1 Overview

MYFTP is mainly composed of two entities: *client* and *server*. As their names suggest, the server hosts a file repository where the client can request to upload or download files.

Figure 1 is the state diagram that summarizes the client program flow of MYFTP. In a nutshell, the client first opens a connection to the server. It then authenticates itself to the server. If the authentication request is granted, then the client can perform three main functions that include (i)
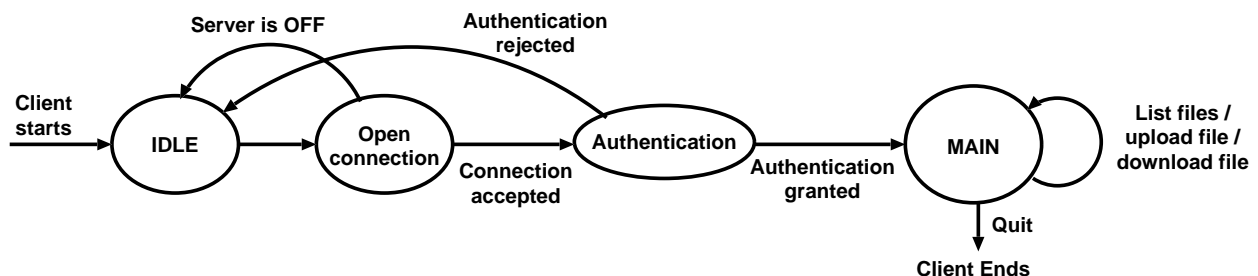

Figure 1: Client program: state diagram.

listing the files that are stored on the server, (ii) uploading files, or (iii) downloading files. When the client finishes, it quits and releases the connection with the server.

2.2 Protocol Messages

The client and the server will exchange protocol messages in order to perform the functions. All protocol messages are preceded with the protocol header shown in Figure 2.

```c
struct message_s {
    char protocol[6];   /* protocol magic number (6 bytes) */
    char type;          /* type (1 byte) */
    char status;        /* status (1 byte) */
    int length;         /* length (header + payload) (4 bytes) */
} __attribute__ ((packed));
```

Figure 2: Protocol header.

- The `protocol` field is always set to be a series of six-byte data (remember, that is NOT a string) that starts with the byte '0xe3', followed by five characters "`myftp`".

- The `type` field has different possible values as specified in Section 2.3.

- The `status` field provides a YES/NO answer toward an incoming request.

- The `length` field is the length of the message (including the header and payload) to be sent over the network. The size of the payload is a variable depending on the message type. You can safely assume that the length is no larger than `INT_MAX`, described in "`limits.h`" in Linux.

告诉编译器取消结构体在编译过程中的优化对齐

We add "`__attribute__ ((packed))`" to avoid *data structure alignment* and pack all variables together without any gap[1]. Defining a packed structure makes our life easier when we calculate the size of a message to be sent over the network.

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[1]See http://en.wikipedia.org/wiki/Data_structure_alignment for details

2.3   Protocol Details

We now explain the functions that MYFTP supports. We also introduce the protocol messages that accompany each function, as well as the formats of the protocol messages. For now, let us assume that there is only one single client.

2.3.1   Open a Connection

The following outlines the steps taken by the client while opening a connection with the server:

1. When a user starts a client and inputs the following command: "open SERVER_IP SERVER_PORT", where SERVER_IP and SERVER_PORT are the IP address and port numbers of the server, respectively, then a TCP connection should be initiated to the server's IP address and port.

2. Next, the client will send a protocol message **OPEN_CONN_REQUEST** to the server to request to open a connection.

3. If the server is running (i.e., it is listening to the server port number), it replies a protocol message **OPEN_CONN_REPLY**.

4. Last, the client receives the server's reply.

Figure 3 illustrates the message flow of how a connection is opened, and the protocol messages are shown in Figure 4. Note that:

- We assume that when a server is up, it always replies the **OPEN_CONN_REPLY** with the status = 1.

- When a field is stated as *unused*, neither the client nor the server would read the field content.
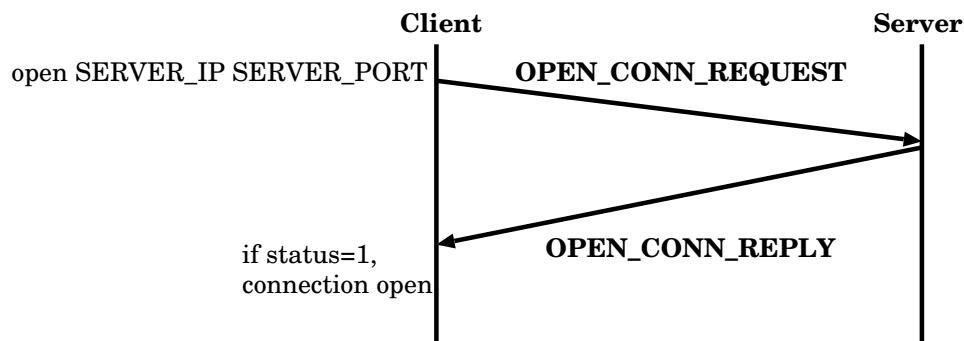

Figure 3: Flow diagram: open a connection.

OPEN_CONN_REQUEST	protocol	0xe3myftp
	type	0xA1
	status	unused
	length	12

OPEN_CONN_REPLY	protocol	0xe3myftp
	type	0xA2
	status	1
	length	12

Figure 4: Protocol messages: open a connection.

2.3.2 Authentication

After the connection is successfully open, the user needs to authenticate himself by issuing the command "auth USER PASS", where USER and PASS are the username and password, respectively. Then, the client will send a protocol message **AUTH_REQUEST**, which contains both the username and password, to the server. The server will then check against an ASCII text file named access.txt which is in the following format:

```
alice pass1
bob pass2
......
```

Each line of access.txt corresponds to a pair of username and password for some particular user. We assume that the username and the password are alphanumeric strings (i.e., strings with only A-Z, a-z, 0-9) separated by **a space character**. The following is a list of assumptions over access.txt.

- Every user ID in access.txt must be unique.

- The password of every user must be non-empty.

- There is always a newline character at the end of each (User ID, Password) duple.

- access.txt is stored in the same directory as the server program, if exists.
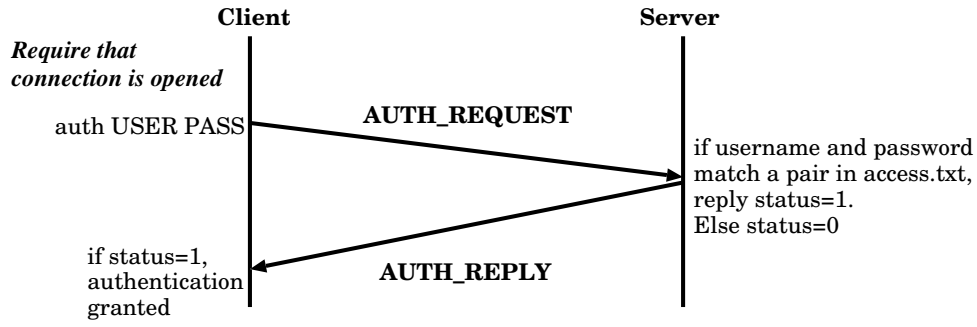
Figure 5: Flow diagram: authentication.

If `access.txt` contains a pair of username and password that matches the pair provided by the client, then the server will reply **AUTH_REPLY** with a status field set to 1. Otherwise, the server will reply **AUTH_REPLY** with the status field set to 0. If *access.txt* does not exist, the server will also reply **AUTH_REPLY** with the status field set to 0.

If the client receives the status equal to 0, then it **closes the connection** immediately (i.e., returning to the IDLE state as in Figure 1). Figure 5 illustrates the message flow of the authentication steps and the protocol messages are shown in Figure 6.

AUTH_REQUEST	`protocol`	0xe3myftp
	`type`	0xA3
	`status`	unused
	`length`	12 + strlen(payload) + 1
	`payload`	USER PASS (as one null-terminated string)

AUTH_REPLY	`protocol`	0xe3myftp
	`type`	0xA4
	`status`	0 or 1
	`length`	12

Figure 6: Protocol message: authentication.

2.3.3 List Files

After the user is authenticated, he can perform the main functions. Suppose that the user wants to list all files that are stored in the server. The user will issue a command "`ls`". Then, the client
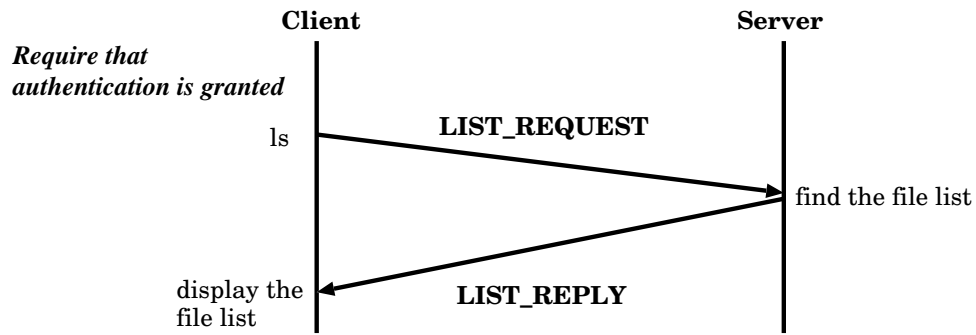
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Figure 7: Flow diagram: list files.

LIST_REQUEST	protocol	0xe3myftp
	type	0xA5
	status	unused
	length	12

LIST_REPLY	protocol	0xe3myftp
	type	0xA6
	status	unused
	length	12 + strlen(payload) + 1
	payload	file names, as one null-terminated string

Figure 8: Protocol message: list files.

will send a protocol message **LIST_REQUEST** to the server. The server will reply a protocol message **LIST_REPLY**, together with the list of available files.

All files are stored in a repository directory called "`filedir`", which is located under the working directory of the server program. The following lists the assumptions over the repository directory:

- The directory has been created before the server starts.

- The directory may contain files when the server starts.

- The directory contains regular files only (i.e., no sub-directories, no link files, etc).

- The server process has the necessary privilege to access the directory as well as the files inside the directory.

- The file names contain the following set of characters only: alphabets (a-z and A-Z) and digits (0-9).

To read the directory on the server side, you may use the function `readdir_r()` (use `man readdir` to see its usage). All file names sent in the **LIST_REPLY** message are followed by a newline character '\n'. Figure 7 shows the message flow of how to list files, and the protocol messages are shown in Figure 8.

2.3.4 Download file

Suppose that the user wants to download a file from the server. Then, he issues a command "`get FILE`", where `FILE` is the name of the file to be downloaded. The client will then send a protocol message **GET_REQUEST** to the server. The server will first check whether the file is available in its repository directory. If not, the server will reply a protocol message **GET_REPLY** with the status field set to 0. If the file exists, the server will reply a protocol message **GET_REPLY** with the status field set to 1, followed by a **FILE_DATA** message that contains the file content.

Note that a file can be in either ASCII or binary mode. You should make sure that both ASCII and binary files are supported. Also, the program will overwrite existing, local files.

Here, we assume that for each client, only one file is downloaded at a time before the user issues the next command. Figure 9 shows the message flow of how to download a file and the protocol messages are shown in Figure 10.
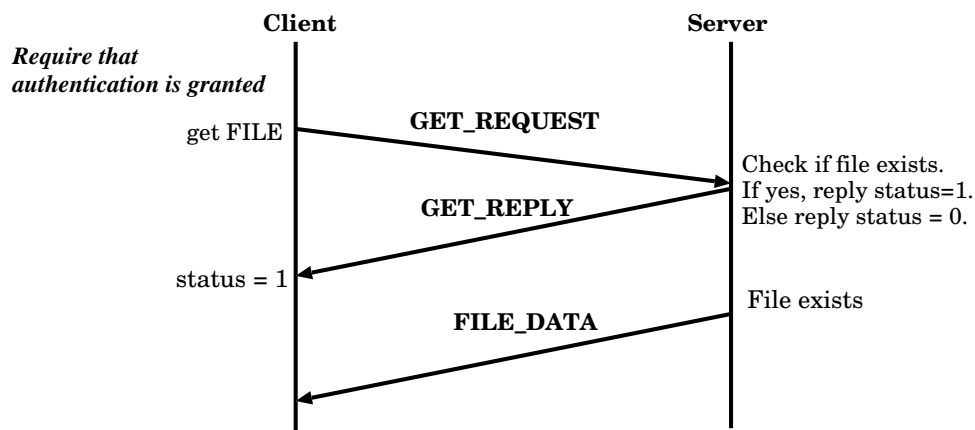

Figure 9: Flow diagram: download a file.

GET_REQUEST	protocol	0xe3myftp
	type	0xA7
	status	unused
	length	12 + strlen(payload) + 1
	payload	one file name, in one null-terminated string

GET_REPLY	protocol	0xe3myftp
	type	0xA8
	status	0 or 1
	length	12

FILE_DATA	protocol	0xe3myftp
	type	0xFF
	status	unused
	length	12 + file size
	payload	file payload

Figure 10: Protocol message: download a file.

2.3.5 Upload file

Suppose that the user wants to upload a file to the server. Then, he issues a command "put FILE", where FILE is the name of the file to be uploaded. First, the client will check whether the file exists locally (i.e., on the client side). If not, the client will display an error message saying the file does not exist. If the file exists locally, then the client will send a protocol message **PUT_REQUEST** to the server. The server will reply a protocol message **PUT_REPLY** and awaits the file. Then the client will send a **FILE_DATA** message that contains the file content.

Here, we assume that the uploaded file resides in the same directory as the client program. Also, only one file is uploaded at a time before the user issues the next command. Last, the server stores the uploaded file in the repository directory "filedir", using the name provided by the user. Note that the server may overwrite existing files. Again, *all files can be either ASCII or binary.* You should make sure that binary files are supported.

Figure 11 shows the message flow of how to upload a file. The protocol messages are defined in Figure 12 (note that **FILE_DATA** is defined in Figure 10).
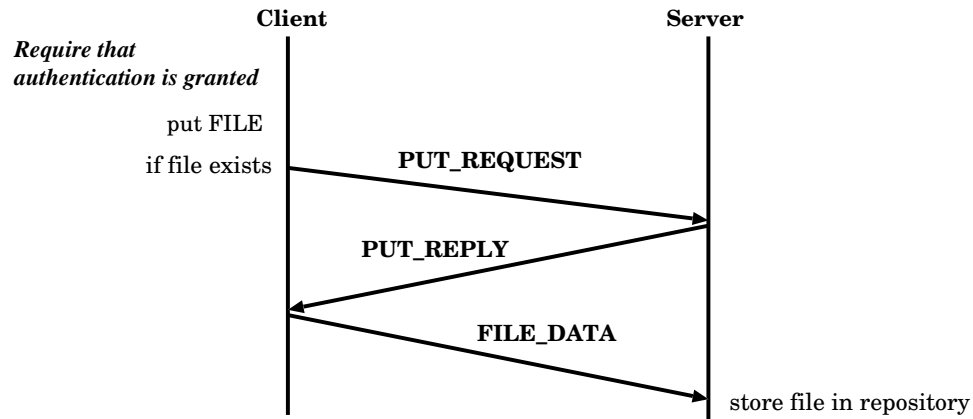
Figure 11: Flow diagram: upload a file.

PUT_REQUEST	protocol	0xe3myftp
	type	0xA9
	status	unused
	length	12 + strlen(payload) + 1
	payload	file name, in null-terminated string

PUT_REPLY	protocol	0xe3myftp
	type	0xAA
	status	unused
	length	12

Figure 12: Protocol message: upload a file.

2.3.6 Close the Connection and Quit

To close the connection, the user issues a command "quit". The client will send a protocol message **QUIT_REQUEST** to the server. The server will reply a protocol message **QUIT_REPLY** to the client, and the client should release the connection (i.e., closing the TCP connection). Last, the client program will quit. Figure 13 shows the message flow of how to close the connection and the protocol messages are defined in Figure 14.
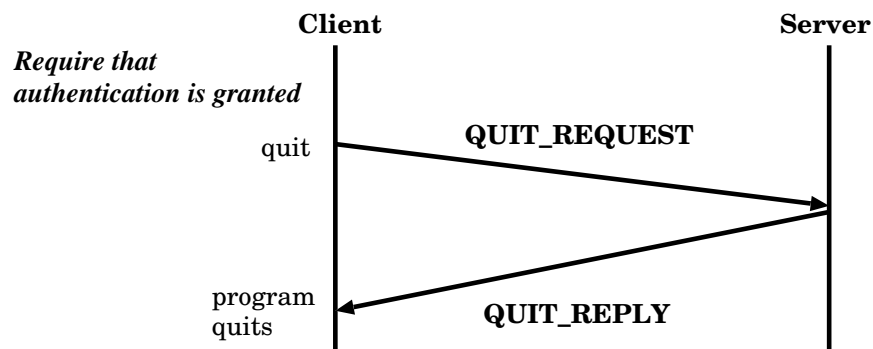

Figure 13: Flow diagram: close the connection.

QUIT_REQUEST	protocol	0xe3myftp
	type	0xAB
	status	unused
	length	12

QUIT_REPLY	protocol	0xe3myftp
	type	0xAC
	status	unused
	length	12

Figure 14: Protocol message: quit.

2.4 Interface

You may first invoke the server as follows:

```
sparc1> ./myftpserver PORT_NUMBER
```

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You may fill in the port number as desired. Although there is no restrictions over the interface of the server program, the server program should at least print the following information to its standard output stream:

- When a client establishes a TCP connection with it successfully, print out the IP address and the port number used by the client.

- When a client tears down a TCP connection, print out the IP address and the port number used by the client.

The following is a sample interface of the client program. While you might design your own user interface, a fancy interface is NOT required (and NOT recommended).

```
sparc1> ./myftpclient
Client> open 137.189.99.9 12345
Server connection accepted.
Client> get file.txt
ERROR: authentication not started. Please issue an authentication command.
Client> auth alice passpass
ERROR: Authentication rejected. Connection closed.
Client> open 137.189.99.9 12345
Server connection accepted.
Client> auth alice pass1
Authentication granted.
Client> ls
----- file list start -----
file1.txt
file2.txt
----- file list end -----
Client> get file1.txt
File downloaded.
Client> put file1.txt
File uploaded.
Client> quit
Thank you.
sparc1>
```

The above example shows that if the client program does not receive an authentication command after the connection is open, it will ask the user to issue the authentication command. At this

point, the connection remains open. On the other hand, if the user is rejected in authentication, then the client program will terminate the connection. It needs to re-initiate the connection again.

2.5 Further Implementation Issues

The client and the server can reside in different machines with different operating systems (e.g., Linux VS Unix), and all functions should remain correct. *Make sure all byte ordering issues are properly addressed.*

3 Milestones

3.1 Milestone 1 (70%)

In this milestone, we assume that only one client connects to the server at any given time. Your implementation should have the following functions:

- The client can open a connection to the server.

- The client can authenticate:

  - Authentication can be done only if a connection is opened
  - The server can either accept or reject the authentication

- The client can list files in the repository directory of the server.

- The client can download a file (either an ASCII or binary file) from the server. If the file doesn't exist, the server replies with an error message.

- The client can upload a file (either an ASCII or binary file) to the server. If the file doesn't exist, the client displays an error message.

- The client can list files, download/upload files only if authentication is granted.

- The client and the server can reside in different machines with different operating systems.

Aside the above functions, you may make assumptions to address the features that are not mentioned in this specification.

3.2 Milestone 2 - Multi-Client Support (30%)

Now the server needs to support N active, concurrent connections. You will have to implement a multi-client version using POSIX threads. The assumptions and the requirements are as follows.

- During the grading process, we will set $N < 10$. Of course, you are not required to keep the number of concurrent connection always below 10.

- You must use POSIX threads to realize the implementation of the server. The server should concurrently serve requests from N clients at the same time. A suggested implementation is to create a thread per connected client.

- Multiple clients must be able to concurrently upload and download files at the same time. The client program used in this milestone should be the same as the one used in the previous milestone.

- Multiple users will be using the same repository directory and you are NOT required to implement any locking mechanism over the directory nor the files inside the directory.

On top of that, your multi-client version of the server program needs to support all functions described in Milestone 1.

4 Submission Guidelines

You *must* at least submit the following files, though you may submit additional files that are needed:

- *myftp.h*: the header file that includes all definitions shared by the client and the server (e.g., the message header)

- *myftpclient.c*: the client program

- *myftpserver.c*: the server program

- *Makefile*: a makefile to compile both client and server programs

Your programs must be implemented in C/C++. They must be compilable on 32-bit Unix/Linux machines (and you are welcome to support 64-bit machines) in the department. Please refer to the course website for the submission instructions.

You are encouraged to test your implementation against your classmates' work. Of course, you should exchange the compiled program, NOT SOURCE CODES. Have fun! :)

Deadline: NO deadline at all! This assignment will NOT be graded.