

# FILE TRANSFER APPLICATION

## ELEN4017 Project Report

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**Abstract:** This paper presents the design, implementation and testing of a File Transfer Application, consisting of a server and a graphical user interface client. The developed system follows the guidelines set out in RFC 959, and exceeds the required minimum specifications. Wireshark was used to obtain results, and from the collected packets, it was clear that the request and response messages follow the correct order. The implemented server is able to interact with a standard FTP client, and the client is able to interact with a standard FTP server. The server is also able to handle multiple simultaneous control connections and data connections. Future recommendations include the implementation of multiple transmission modes and file structures.

**Key words:** client, file transfer protocol, server, Wireshark

### 1. INTRODUCTION

The File Transfer Protocol (FTP) is essential in the implementation of a File Transfer Application. The File Transfer Protocol allows for the transfer of files between two end systems [1]. The FTP protocol runs on top of TCP and, uniquely, makes use of two TCP connections: a control connection and a data connection [1]. The data connection is non-persistent, and is created when the transfer of data is required [1]. A File Transfer Application consists of an FTP server and an FTP client. This report presents the design, implementation and testing of a File Transfer Application, including an overview of the system, details of the implemented code, results and a critical analysis of the system. The division of labour between group members is also discussed.

### 2. SYSTEM OVERVIEW

The implemented system follows the guidelines set out in RFC 959 - File Transfer Protocol (FTP) [2]. This document specifies the minimum required FTP implementation as well as the full list of FTP commands and replies.

#### 2.1 FTP Server

*Unimplemented Features:*

#### 2.2 FTP Client

The FTP client runs from the user's local host and allows the user to interact with the FTP server in order to transfer files. In order to improve user experience, a client with a graphical user interface (GUI) was implemented.

The client allows the user to specify the FTP server address that they wish to connect to, as well as the port that the server is running on. The user is also able to input their username and password for the FTP server they are connecting to.

Once the user has successfully connected to the FTP server, they are able to view their local file system as well as the remote file system within the client GUI. The user is also able to navigate both file systems. Once the required file is found, the user is able to upload the file to the remote server from the local file system, or

download the file from the remote system to the local storage. When uploading a file, the file is saved to the currently selected directory on the server. If a directory has not been selected by the user, the file is saved to the home directory of the user's remote repository. Likewise, when the user is downloading a file, the file is saved to the current local folder, or if none is selected, to the user's home directory. On Mac OS X operating systems, this home directory is found at `/Users/Username`. If a file is selected rather than a directory, the downloaded file is saved in the directory in which the selected file is found.

The user also has the ability to delete files or folders, as well as to recursively remove a folder and all of its contents. Finally, the user is able to create a folder on the server in the base directory of their choosing. If a file is selected rather than a base directory, the new directory is saved in the directory containing the selected file.

Once the client has finished using the FTP connection, they can disconnect from the server and connect to another server if they wish to.

*Unimplemented Features:* The feature to change the file structure from file to record or page was not implemented. This was not implemented since the implementation was complex and deemed unnecessary since any file can be transferred using the file structure. Furthermore, since the file structure is the default type, any server that the client wishes to interact with will be compatible with the file structure type [2]. The client also does not allow the user the opportunity to change the transmission mode from stream to block or compression. Once again, since stream mode is the default mode, any FTP server must accept stream mode, meaning that implementation of the other types is unnecessary [2]. The client also does not have implementation to allow the user to append data onto the end of an existing text file.

### 3. COMMANDS AND REPLY CODES

There are five groups of reply codes determined by the first digit of the three digit code [2]. These groups indicate whether the response is positive or negative and allow the client to make an informed decision as to its course of action.

The groups are as follows:

|     |                                     |
|-----|-------------------------------------|
| 1xx | Positive Preliminary Reply          |
| 2xx | Positive Completion Reply           |
| 3xx | Positive Intermediate reply         |
| 4xx | Transient Negative Completion reply |
| 5xx | Permanent Negative Completion reply |

At least one reply code from each group has been implemented. A list of the implemented commands and the reply codes is given in *Table B1*. The table also contains a brief description of the purpose of each command.

#### 4. IMPLEMENTATION DETAILS

The server and the client were both implemented using Python 3. On both systems, all communication sockets are created using the Python `socket` module [3]. The sending and receiving of messages are also performed using methods from this module. Interfacing with the operating system is performed using the `os` module [4]. This module allows for the traversing of paths in the operating system, as well as for saving and opening files [4].

##### 4.1 Server

##### 4.2 Client

In order to connect to the server, once the user has supplied the server address and port, a TCP connection is created between the server and the client. This TCP connection acts as a control connection to transfer FTP commands and replies between the client and the server [1]. When sending FTP commands to the server, the messages are formatted using the format in *Figure 1*. In the figure, SP indicates a space and CRLF is the end of line sequence (`\r\n`). A `send()` function was created which takes in a string containing the FTP command, a space and the arguments. The end of line sequence is then appended to the string and the resulting string is transmitted to the server. The use of this function ensures that all messages sent to the server have the correct format. Once any control message has been sent to the server, the client receives the response, and decodes it into a string in the `receive()` function. To allow the user to see the responses from the server, all received responses are printed onto the GUI. In order to ensure that the `receive()` function is called after every message is sent, an `action()` function was created which calls the `send()` function and then the `receive()` function.

|         |    |           |      |
|---------|----|-----------|------|
| Command | SP | Arguments | CRLF |
|---------|----|-----------|------|

Figure 1: FTP Command Format

Before uploading or downloading a file, the client sends a `PASV` command, which requests that the server creates a new data port and listens on that port for a connection from the client [2]. As a response to the command, the server sends the client the IP address and port number of the new socket. The port number, which is a 16 bit number, is sent to the client as two eight bit numbers [2]. The port is therefore calculated by multiplying

the first number (the most significant byte) by 256 and adding the result to the second number [2]. Thereafter, the client connects to the port so that data can be transferred.

*Uploading files:* In order to upload a file, it is necessary to inform the server of whether an ASCII or binary file (image type) is being transmitted, so that the correct encoding can be used. In order to determine the type of the file to be uploaded, the `magic` module is used. The module determines the type of a file by classifying the file's headers [5]. If the type is found to be text, `TYPE A` is sent to the server. Otherwise, `TYPE I` is transmitted. Thereafter, a `STOR` command is sent to the server along with the full path of the file to be uploaded. Thereafter, the file is uploaded to the server. During the upload process, the file is divided up into chunks and each chunk transmitted to the server. A flow chart detailing the upload process is given in *Figure A1*.

*Downloading files:* When downloading files, it is again necessary to specify the file type. Since the files lie on the server, the `magic` module could not be used to determine the file type. Rather, the file type was deduced from the file extension, using the `mimetypes` module. This file type is then compared to a list of ASCII file types, and if the file type is found in the list, `TYPE A` is sent to the server. Otherwise, `TYPE I` is transmitted. Once the file type has been sent, a `RETR` command is sent along with the full path of the file to be downloaded. A new file with the filename of the file to be downloaded is then opened. Chunks of data are received by the client and then written to the open file. Once no more data is received, the file is closed and the download is completed.

*Deleting folders and files and making folders:* The user is able to delete a file or folder on the remote system. They do so by selecting the file or folder and then pressing the *Delete* button. The client then uses the method described below to determine whether the user is trying to delete a file or a folder. If a file is to be deleted, the `DELE` command is sent to the server. Likewise, for a folder, the `RMD` command is sent. Both of these commands are followed by the full path to the item to be deleted. The user is also able to create a folder by pressing the *Create Directory* button. The pressing of this button prompts the user to input the name of the new folder. This folder is created using the `MKD` command, which is sent along with the path to the new directory.

*Differentiating between files and folders:* In many instances in the client, it is necessary to differentiate between a folder and a file on the server. Once such example of this is in deciding whether a `DELE` or `RMD` command should be sent, as described above. In order to differentiate, the response codes of the `CWD` command are used. If the response to a `CWD` command has a 550 code, it implies that the path points to a file and not a folder. If the response has a 250, the path points to a folder.

Thus, this method is used as a differentiator wherever one is needed.

*GUI:* The client was implemented as a GUI using the PyQt4 module. The GUI provided a simple user interface consisting of push buttons that allow the user to perform functions such as uploading and downloading files, and two file systems. The file systems of the server and client were created by taking the current path and creating a directory item for each of the directories in the path. The final directory is then populated with the folders and files contained in it. For the server file system, this information was obtained using the `PWD` and `LIST` commands. For the client file system, the information was obtained using the `walk` method of the `os` module. In order to change directories in the remote file system, a `CWD` command is sent along with the path to the directory of interest.

## 5. DIVISION OF WORK

Since the FTP server has two clear parts, the server and the client, the work was divided accordingly. Jared Ping wrote all of the code for the server, as well as the sections in the report pertaining to the server. Kayla-Jade Butkow wrote the code for the client, as the sections of the report related to the client. Kayla-Jade also wrote the section pertaining to the commands and reply codes and the introduction, while Jared detailed the structure of the code and wrote the conclusion. The critical analysis and results sections and the abstract were written by the partners together.

## 6. RESULTS

In order to test the system, it was necessary to test all of the implemented functionality on both the server and the client, as well as to test the interaction between the server and a standard FTP client, and between the client and a standard FTP server. This functionality was tested by performing actions on the various clients and then viewing the messages sent and responses receiving using Wireshark.

### 6.1 Interaction between the implemented FTP server and client

Figure C1 presents an image of the client interacting with the implemented server. From the image, it is clear that there is a unique repository for the user, and that the user is unable to navigate to other user's repositories.

### 6.2 Interaction between a standard FTP server and the implemented client

In testing this interaction, it was necessary to ensure that the created client and the standard server were compatible and that all of the functionality implemented in the client functioned correctly when paired with a standard server. The server used can be found at `ELEN4017.ug.eie.wits.ac.za`.

The most important functionality to be tested is the ability to log into the server, navigate through the remote file system and upload and download files. Furthermore, the ability to create a directory, delete files and directories and to log out of the server were also tested. Wire-shark screenshots indicating this functionality is given in Section C2. From the images in Section C2, it is evident that all functionality works as expected when paired with a standard FTP server.

### 6.3 Interaction between the implemented FTP server and a standard FTP client

The testing of this interaction is essential to ensure that the server can interact with clients other than the one created. A main purpose of this testing is to ensure that the server returns the correct error code when a requested command has not been implemented.

## 7. CRITICAL ANALYSIS

An analysis of the successes and limitations of the implemented system is given below.

### 7.1 Successes

The system is a fully functional, stable and well implemented solution. As proven in Section 6., it fulfills all of the requirements for a file transfer application, namely:

- A client and a server that are able to meet all of the requirements of a minimal FTP implementation, as defined in [2], including server reply messages and error handling
- A client with a simple user interface and that is able to interact with a standard FTP server
- A server that maintains repositories for different users and that is able to interact with a standard FTP client
- A server that can handle multiple clients simultaneously using multi-threading
- The ability to upload and download various file types
- The use of Wireshark to obtain results
- The ability to use the system when the client and the server lie on different hosts within the same network

The system also performs all of these actions without the use of any high-level FTP libraries.

Furthermore, both the server and the client implement features beyond those mentioned in the minimum FTP implementation, which is regarded as a large success of the system. It was stipulated that five reply code should be implemented, however on account of the large number of features implemented, many reply code were implemented (as indicated in Table B1). This allows for a more informative and complete system, and is also seen as a success.

Another large success of the project is aspect of multi-threading within the server. Not only is the server able to maintain control connections with multiple clients si-

multaneously, it is also able to handle multiple simultaneous upload and download processes. This enhances the user friendliness of the system, as multiple users can use it at the same time without their processes being affected.

### 7.2 Limitations

The largest limitation of the implemented system is that the client only functions correctly on Mac OS X operating systems. This is a limitation as it reduces the number of people who are able to use the developed client.

A limitation of the server is that it does not have the functionality to implement a file structure other than file, nor a data transmission mode other than stream. The implications of this is that a standard FTP client will be required to use the default mode and structure, which may limit the functionality of the client.

Since the append command is never sent by the client, if the user tries to upload a file with a name that already exists in the current directory, the preexisting file will be overwritten. This could result in the accidental loss of the user's data. Another limitation lies within the file systems in the client GUI. After a file or directory has been modified, it does not update automatically. It needs to be reselected in order for the modifications to be loaded.

### 7.3 Future Development

For future development, the server should be enhanced to handle different file structures and transmission modes. The client should implement an automatic re-

fresh every time a file or folder is modified. Furthermore, the functionality of the client should be enhanced to cater for more FTP commands.

## 8. CODE STRUCTURE

## 9. CONCLUSION

The design, implementation and testing of a File Transfer Application was presented. The system was deemed to be a success since it met all of the basic requirements, and also implemented many additional features. Through the use of Wireshark, it is clear that the system implemented all of the required FTP reply codes and that the codes and responses are sent in the correct order. For future development, more FTP commands should be implemented in order to develop a complete File Transfer Application.

## REFERENCES

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- [4] Python. "os - Miscellaneous operating system interfaces." URL <https://docs.python.org/3.6/library/os.html>. Last accessed: 17/03/2018.
- [5] A. Hupp. "python-magic.", 2001. URL <https://github.com/ahupp/python-magic>. Last accessed: 17/03/2018.

## Appendix

### A Client Algorithms

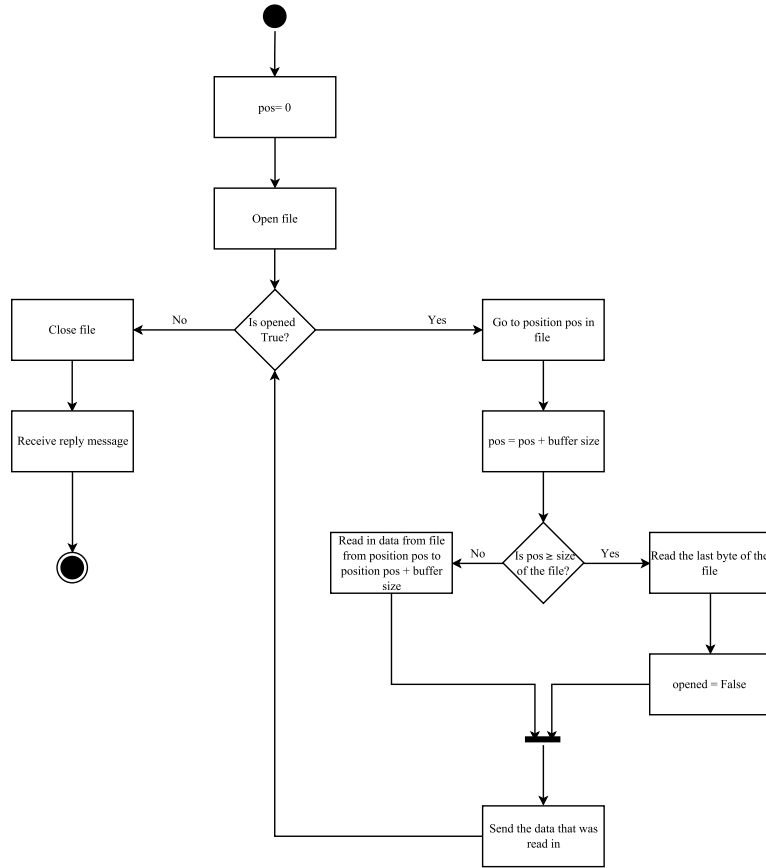


Figure A1: Flow chart depicting the process of uploading a file to the server

### B Implemented Commands and Reply Codes

Table B1: Table detailing the implemented commands and reply codes

| Command | Description  | Reply Code  |
|---------|--|---|
| USER    | Allows the user to input their username in order to be authenticated   | 501 Syntax error in parameters or arguments.<br>331 User name okay, need password.                            |
| PASS    | Allows the user to input their password for authentication   | 501 Syntax error in parameters or arguments.<br>503 Bad sequence of commands.<br>230 User logged in, proceed. |
| TYPE    | Its argument is used to specify the file type of the file to be retrieved or stored  | 200 Binary file mode.<br>200 Ascii file mode.<br>501 Syntax error in parameters or arguments.                 |
| PASV    | Requests that the server listens on a new data port and waits for a connection   | 227 Entering Passive Mode ( <i>IP Address, Port</i> )   |
| MODE    | Its argument is used to specify the data transfer type. Only stream transfer mode was implemented                            | 200 Stream transfer mode.<br>502 Command not implemented.<br>501 Syntax error in parameters or arguments.     |
| STRU    | Its argument is used to specify the file structure of the file to be retrieved or stored. Only the File type was implemented | 200 File Structure = File.<br>502 Command not implemented.  |

|      |   |  |
|------|---|--|
| STAT | The command causes a status response to be sent over the control connection. The functionality for this command was not implemented   | 502 Command not implemented.   |
| PORT | The argument specifies the data port to be used in the data connection  | 200 Get port.  |
| LIST | Returns a list of the contents of a directory. The argument is used to specify the path in which the contents should be returned. If an argument is not provided, a list of the contents of the current working directory is supplied | 530 User not logged in.<br>550 LIST failed Path name not exists.<br>150 Here is listing.<br>226 List done.                                   |
| NLST | Calls the LIST command  | 530 User not logged in.<br>550 LIST failed Path name not exists.<br>150 Here is listing.<br>226 List done.                                   |
| CWD  | Changes the working directory of the server. The argument is used to specify the new working directory.   | 550 CWD failed. Directory does not exist.<br>250 CWD Command successful.   |
| PWD  | Returns the current working directory   | 257 <i>Path to current working directory</i>   |
| CDUP | Changes the working directory to the parent of the current directory.   | 200 OK.  |
| DELE | Deletes a file off the remote host. Its argument is used to specify the file to be deleted  | 530 User not logged in.<br>550 DELE failed File <i>file name</i> does not exist.<br>450 DELE failed delete not allowed.<br>250 File deleted. |
| MKD  | Makes a file on the remote host. Its argument specifies the path to the new file and the name of the file to be created   | 530 User not logged in.<br>257 Directory created.<br>550 MKD failed. Directory " <i>directory name</i> " already exists.                     |
| RMD  | Deletes a directory off the remote host. Its argument is used to specify the directory to be deleted  | 530 User not logged in.<br>450 Invalid permissions.<br>250 Directory deleted.  |
| RNFR | Its argument specifies a file to be renamed   | 550 RNFR failed. File or Directory <i>file or directory name</i> does not exist.<br>350 RNFR successful - awaiting RNT0                      |
| RNT0 | Its argument specifies the new name of file. The file to be renamed was indicated using the RNFR command prior to calling the RNT0 command  | 550 RNT0 failed. File or Directory <i>file or directory name</i> does not exist.<br>250 RNT0 successful                                      |
| REST | The argument field represents the checkpoint at which the file transfer is to be restarted.   | 250 File position reset.   |
| RETR | This command causes the server to send a copy of a file over the data connection. The argument specifies the name of the file to be downloaded  | 150 Opening data connection.<br>226 Transfer complete.   |
| STOR | This command causes the server to save a copy of a file that is sent over the data connection. The argument specifies the name of the file that is being uploaded   | 530 STOR failed. User is not logged in.<br>150 Opening data connection.<br>226 Transfer completed.   |

|      |  |  |
|------|--|--|
| APPE | This command causes the server to save a copy of a file that is sent over the data connection. If the file name exists at the path on the server, data is appended to the file. Otherwise, a new file is created | 530 APPE failed. User is not logged in.<br>150 Opening data connection.<br>226 Transfer completed. |
| SYST | Used to find the server's operating system type  | 215 <i>server operating system</i> type.   |
| NOOP | Prompts a 200 OK response from the server.   | 200 OK.  |
| HELP | Displays help information  |  |
| QUIT | Terminates the control connection between the user and the server  | 221 Goodbye.   |

## C Results

This section contains all of the results collected during the testing of the system. This includes Wireshark excerpts and an image of the client GUI.

### *C1 Interaction between the implemented FTP server and client*

This section contains images and Wireshark screenshots depicting the interaction between the implemented client and server when running on two different hosts within the same network.

### *C2 Interaction between a standard FTP server and the implemented client*

Wireshark screenshots depicting the interaction between the created client and the standard FTP server are given in this section.

### *C3 Interaction between the implemented FTP server and a standard FTP client*

This section contains Wireshark excerpts depicting the interaction between the server and a standard clients when running on two different hosts within the same network.

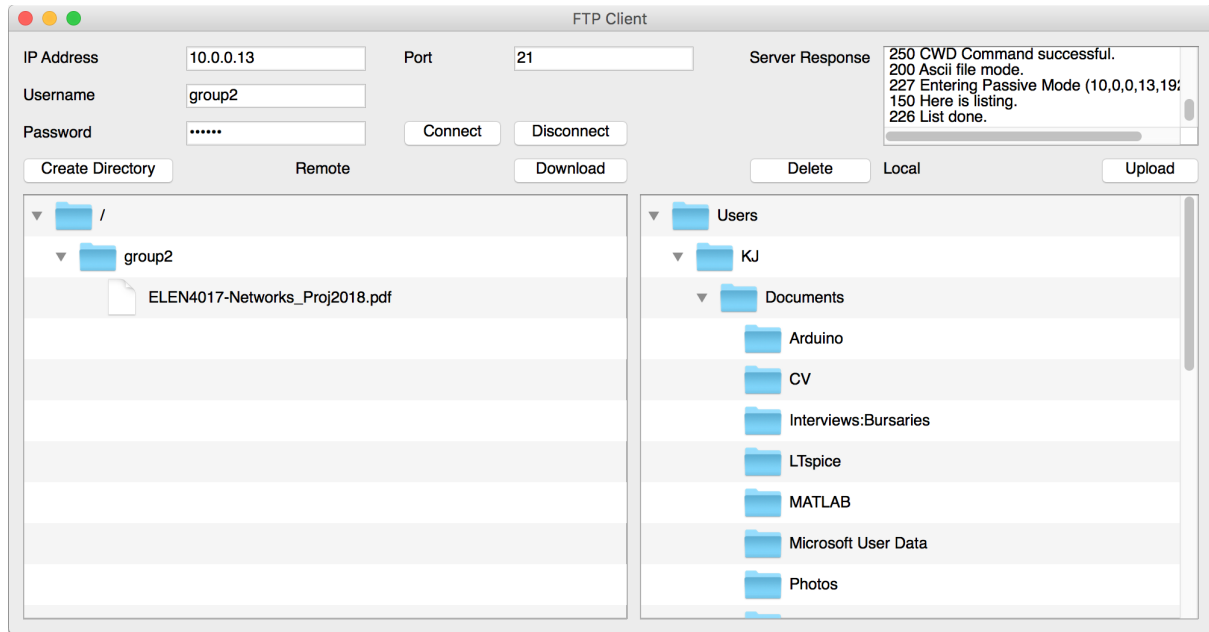


Figure C1: GUI client interacting with the implemented FTP server

|     |                 |                 |                 |     |     |  |
|-----|-----------------|-----------------|-----------------|-----|-----|--|
| 135 | 15:41:09.486825 | 146.141.119.215 | 192.168.66.115  | FTP | 86  | Response: 220 (vsFTPd 3.0.3)               |
| 137 | 15:41:09.487968 | 192.168.66.115  | 146.141.119.215 | FTP | 79  | Request: USER group2                       |
| 139 | 15:41:09.489203 | 146.141.119.215 | 192.168.66.115  | FTP | 100 | Response: 331 Please specify the password. |
| 141 | 15:41:09.490231 | 192.168.66.115  | 146.141.119.215 | FTP | 81  | Request: PASS ei9keNge                     |
| 143 | 15:41:09.611068 | 146.141.119.215 | 192.168.66.115  | FTP | 89  | Response: 230 Login successful.            |

Figure C2: FTP commands and replies when logging in

|     |                 |                       |                       |     |     |  |
|-----|-----------------|-----------------------|-----------------------|-----|-----|--|
| 149 | 15:41:09.616097 | 192.168.66.115        | 146.141.119.215       | FTP | 71  | Request: PWD   |
| 150 | 15:41:09.618075 | 146.141.119.215       | 192.168.66.115        | FTP | 100 | Response: 257 "/" is the current directory                   |
| 152 | 15:41:09.618351 | 192.168.66.115        | 146.141.119.215       | FTP | 74  | Request: TYPE A  |
| 153 | 15:41:09.621553 | 146.141.119.215       | 192.168.66.115        | FTP | 96  | Response: 200 Switching to ASCII mode.                       |
| 155 | 15:41:09.622506 | 192.168.66.115        | 146.141.119.215       | FTP | 72  | Request: PASV  |
| 156 | 15:41:09.624119 | 146.141.119.215       | 192.168.66.115        | FTP | 119 | Response: 227 Entering Passive Mode (146,141,119,215,193,98) |
| 161 | 15:41:09.626864 | 192.168.66.115        | 146.141.119.215       | FTP | 72  | Request: LIST  |
| 162 | 15:41:09.629701 | 146.141.119.215       | 192.168.66.115        | FTP | 105 | Response: 150 Here comes the directory listing.              |
| 169 | 15:41:09.633317 | 146.141.119.215       | 192.168.66.115        | FTP | 90  | Response: 226 Directory send OK.                             |
| 193 | 15:41:14.380620 | 192.168.66.115        | elen4017.ug.eie.wi... | FTP | 78  | Request: CWD /files  |
| 194 | 15:41:14.382077 | elen4017.ug.eie.wi... | 192.168.66.115        | FTP | 103 | Response: 250 Directory successfully changed.                |
| 196 | 15:41:14.433748 | 192.168.66.115        | elen4017.ug.eie.wi... | FTP | 71  | Request: PWD   |
| 197 | 15:41:14.435388 | elen4017.ug.eie.wi... | 192.168.66.115        | FTP | 105 | Response: 257 "/files" is the current directory              |

Figure C3: FTP commands and replies when navigating the remote file system

|      |                 |                       |                       |     |     |  |
|------|-----------------|-----------------------|-----------------------|-----|-----|--|
| 1024 | 15:42:36.066964 | 192.168.66.115        | elen4017.ug.eie.wi... | FTP | 74  | Request: TYPE A  |
| 1025 | 15:42:36.068311 | elen4017.ug.eie.wi... | 192.168.66.115        | FTP | 96  | Response: 200 Switching to ASCII mode.                       |
| 1027 | 15:42:36.069383 | 192.168.66.115        | elen4017.ug.eie.wi... | FTP | 72  | Request: PASV  |
| 1028 | 15:42:36.070818 | elen4017.ug.eie.wi... | 192.168.66.115        | FTP | 120 | Response: 227 Entering Passive Mode (146,141,119,215,181,11) |
| 1033 | 15:42:36.073271 | 192.168.66.115        | elen4017.ug.eie.wi... | FTP | 86  | Request: STOR textfiles.txt                                  |
| 1034 | 15:42:36.075036 | elen4017.ug.eie.wi... | 192.168.66.115        | FTP | 88  | Response: 150 Ok to send data.                               |
| 1041 | 15:42:36.130252 | elen4017.ug.eie.wi... | 192.168.66.115        | FTP | 90  | Response: 226 Transfer complete.                             |

Figure C4: FTP commands and replies when uploading an ASCII type file

|     |                 |                       |                       |     |     |  |
|-----|-----------------|-----------------------|-----------------------|-----|-----|--|
| 265 | 15:41:36.365523 | 192.168.66.115        | elen4017.ug.eie.wi... | FTP | 74  | Request: TYPE I  |
| 266 | 15:41:36.366900 | elen4017.ug.eie.wi... | 192.168.66.115        | FTP | 97  | Response: 200 Switching to Binary mode.                      |
| 268 | 15:41:36.367947 | 192.168.66.115        | elen4017.ug.eie.wi... | FTP | 72  | Request: PASV  |
| 269 | 15:41:36.369445 | elen4017.ug.eie.wi... | 192.168.66.115        | FTP | 120 | Response: 227 Entering Passive Mode (146,141,119,215,168,13) |
| 274 | 15:41:36.372084 | 192.168.66.115        | elen4017.ug.eie.wi... | FTP | 107 | Request: STOR 714227 - ELEN4017 Laboratory 1.pdf             |
| 275 | 15:41:36.374309 | elen4017.ug.eie.wi... | 192.168.66.115        | FTP | 88  | Response: 150 Ok to send data.                               |
| 750 | 15:41:36.484973 | elen4017.ug.eie.wi... | 192.168.66.115        | FTP | 90  | Response: 226 Transfer complete.                             |

Figure C5: FTP commands and replies when uploading an image type file



|        |                 |                       |                       |     |  |
|--------|-----------------|-----------------------|-----------------------|-----|--|
| 194... | 15:43:35.624143 | 192.168.66.115        | elen4017.ug.eie.wi... | FTP | 92 Request: CWD /files/textfiles.txt                             |
| 194... | 15:43:35.627860 | elen4017.ug.eie.wi... | 192.168.66.115        | FTP | 99 Response: 550 Failed to change directory.                     |
| 194... | 15:43:36.706359 | 192.168.66.115        | elen4017.ug.eie.wi... | FTP | 74 Request: TYPE A   |
| 194... | 15:43:36.710722 | elen4017.ug.eie.wi... | 192.168.66.115        | FTP | 96 Response: 200 Switching to ASCII mode.                        |
| 194... | 15:43:36.712182 | 192.168.66.115        | elen4017.ug.eie.wi... | FTP | 72 Request: PASV   |
| 194... | 15:43:36.718027 | elen4017.ug.eie.wi... | 192.168.66.115        | FTP | 120 Response: 227 Entering Passive Mode (146,141,119,215,183,24) |
| 194... | 15:43:36.723170 | 192.168.66.115        | elen4017.ug.eie.wi... | FTP | 86 Request: RETR textfiles.txt                                   |
| 194... | 15:43:36.726238 | elen4017.ug.eie.wi... | 192.168.66.115        | FTP | 138 Response: 150 Opening BINARY mode data connection for textf  |
| 194... | 15:43:36.748169 | elen4017.ug.eie.wi... | 192.168.66.115        | FTP | 90 Response: 226 Transfer complete.                              |

Figure C6: FTP commands and replies when downloading an ASCII type file

|        |                 |                 |                 |     |   |
|--------|-----------------|-----------------|-----------------|-----|---|
| 193806 | 15:43:28.940... | 192.168.66.1... | elen4017.ug.... | FTP | 113 Request: CWD /files/714227 - ELEN4017 Laboratory 1.pdf                      |
| 193807 | 15:43:28.964... | elen4017.ug.... | 192.168.66.1... | FTP | 99 Response: 550 Failed to change directory.                                    |
| 193809 | 15:43:30.654... | 192.168.66.1... | elen4017.ug.... | FTP | 74 Request: TYPE A  |
| 193810 | 15:43:30.659... | elen4017.ug.... | 192.168.66.1... | FTP | 96 Response: 200 Switching to ASCII mode.                                       |
| 193812 | 15:43:30.661... | 192.168.66.1... | elen4017.ug.... | FTP | 72 Request: PASV  |
| 193814 | 15:43:30.675... | elen4017.ug.... | 192.168.66.1... | FTP | 120 Response: 227 Entering Passive Mode (146,141,119,215,187,190).              |
| 193819 | 15:43:30.683... | 192.168.66.1... | elen4017.ug.... | FTP | 107 Request: RETR 714227 - ELEN4017 Laboratory 1.pdf                            |
| 193820 | 15:43:30.696... | elen4017.ug.... | 192.168.66.1... | FTP | 162 Response: 150 Opening BINARY mode data connection for 714227 - ELEN4017 Lab |
| 194243 | 15:43:31.180... | elen4017.ug.... | 192.168.66.1... | FTP | 90 Response: 226 Transfer complete.   |

Figure C7: FTP commands and replies when downloading an image type file

|        |                 |                       |                       |     |   |
|--------|-----------------|-----------------------|-----------------------|-----|---|
| 194... | 15:43:43.070695 | 192.168.66.115        | elen4017.ug.eie.wi... | FTP | 76 Request: MKD Test                                |
| 194... | 15:43:43.074969 | elen4017.ug.eie.wi... | 192.168.66.115        | FTP | 93 Response: 257 "/files/Test" created              |
| 194... | 15:43:44.685884 | 192.168.66.115        | elen4017.ug.eie.wi... | FTP | 78 Request: CWD /files                              |
| 194... | 15:43:44.689825 | elen4017.ug.eie.wi... | 192.168.66.115        | FTP | 103 Response: 250 Directory successfully changed.   |
| 194... | 15:43:44.741558 | 192.168.66.115        | elen4017.ug.eie.wi... | FTP | 71 Request: PWD                                     |
| 194... | 15:43:44.742806 | elen4017.ug.eie.wi... | 192.168.66.115        | FTP | 105 Response: 257 "/files" is the current directory |

Figure C8: FTP commands and replies when creating a directory

|        |                 |                 |                 |     |  |
|--------|-----------------|-----------------|-----------------|-----|--|
| 194386 | 15:43:52.779... | 192.168.66.1... | elen4017.ug.... | FTP | 83 Request: RMD /files/Test                              |
| 194387 | 15:43:52.780... | elen4017.ug.... | 192.168.66.1... | FTP | 110 Response: 250 Remove directory operation successful. |

Figure C9: FTP commands and replies when deleting a directory

|        |                 |                 |                 |     |  |
|--------|-----------------|-----------------|-----------------|-----|--|
| 194439 | 15:43:58.311... | 192.168.66.1... | elen4017.ug.... | FTP | 92 Request: CWD /files/textfiles.txt           |
| 194440 | 15:43:58.315... | elen4017.ug.... | 192.168.66.1... | FTP | 99 Response: 550 Failed to change directory.   |
| 194442 | 15:43:58.367... | 192.168.66.1... | elen4017.ug.... | FTP | 93 Request: DELE /files/textfiles.txt          |
| 194443 | 15:43:58.369... | elen4017.ug.... | 192.168.66.1... | FTP | 100 Response: 250 Delete operation successful. |

Figure C10: FTP commands and replies when deleting a file

|        |                 |                       |                       |     |                           |
|--------|-----------------|-----------------------|-----------------------|-----|---------------------------|
| 194... | 15:44:10.263529 | 192.168.66.115        | elen4017.ug.eie.wi... | FTP | 72 Request: QUIT          |
| 194... | 15:44:10.264920 | elen4017.ug.eie.wi... | 192.168.66.115        | FTP | 80 Response: 221 Goodbye. |

Figure C11: FTP commands and replies when logging out from the server