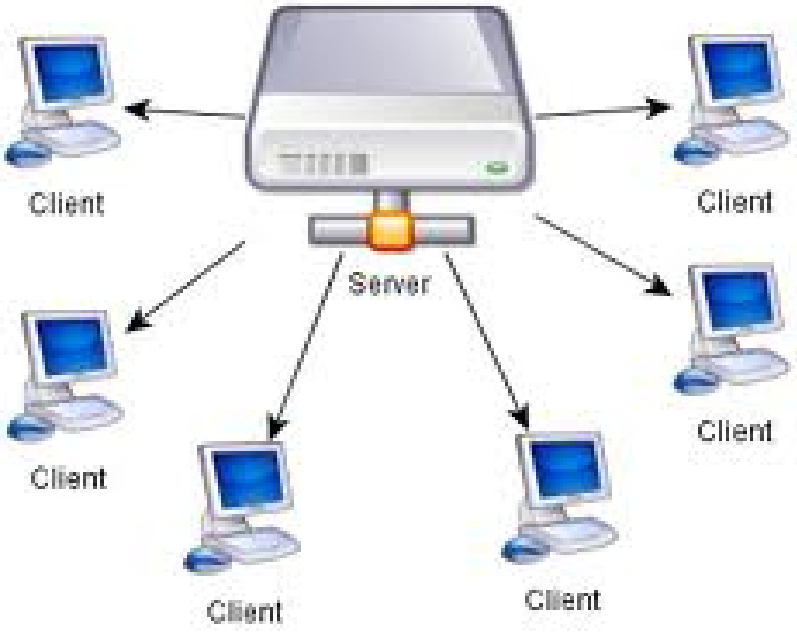
Operating Systems

Assignment - Phase 3: Multi Client - Server Shell



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Soumen Mohanty (sm8966)

D&S Remote shell

Phase 1:-

Description:

For this assignment, we programmed our own local shell / CLI using C. It stimulates the services of the operating system using system calls. We used features such as process creation, interprocess communication, etc. to execute the same. 15 commands that have been listed below can be run, including pipes (upto three pipes).

How to Compile:

We have used makefile to organize the project's code compilation. To run a makefile code, run the following commands in the terminal.

First, run $*make clean*

Then run $*make* to compile the code

Lastly, run the executable. Run using $./shell

List of commands:-

1. ls: Command to display the files in a directory
2. touch: Command to create a file
3. mkdir: Command to create a folder
4. pwd: Command to print the current directory
5. rm: Command to remove objects
6. cp: Command to copy
7. rmdir: Command to remove a directory
8. grep: Command to search for a string of characters in a file
9. wc: Command to find the word count
10. find: Command that locates an object
11. mv: Command that moves an object
12. cat: Command that outputs the contents of a file
13. ps: Command that displays the running processes
14. df: Command to display the display the available disk space
15. whoami: Command to print the name of the current user

Pipe Commands: Used to combine two or more commands. The output of one command is the input of the next command.

1. ls | grep c
2. ls -l | grep d | wc -c
3. cat xyz.txt | grep r | tee abc.txt | wc -l

Test Cases can be found under phase 2 below.

Challenges :-

Along the way, we faced a few challenges we were able to overcome.

1. The first challenge we faced was parsing the entered command(s). We overcame this by using strtok() which broke the string into a series of strings using our given delimiters. We were able to modify this in our pre-built functions to reuse them for extracting commands when pipes were used.
2. Figuring out the right nested forks for triple pipes proved to be a challenging task as well. We were able to overcome this by doing some research as well as using trial and error till we were able to have an error free case.

Phase 2:-

I. Description:

For this assignment, we programmed our own Client-Server remote shell using socket communication in C. It stimulates the services of the Client server network using sockets, ports and local IP addresses to create a remote connection between the client and server. In this phase, we were taking the input from the user client and sending the request to the server. For each input from the client which could either be a comment from our listed menu or a pipe command with up to three pipes. Then the server will process the command and send the output or result back to the client which will be printed on the clients terminal screen

II. How to Compile and Run:

We have used makefile to organize the project's code compilation. To run a makefile code, run the following commands in the terminal.

First, run $*make clean* (this is only if you want to run the code again and clear all the .o files)
Then run $*make* to compile the code

Then, the server should be started first using $./server
Finally start the client using $./client

III. List of commands that the server:-

1. ls: Command to display the files in a directory
2. touch: Command to create a file
3. mkdir: Command to create a folder
4. pwd: Command to print the current directory
5. rm: Command to remove objects
6. cp: Command to copy
7. rmdir: Command to remove a directory
8. grep: Command to search for a string of characters in a file
9. wc: Command to find the word count
10. find: Command that locates an object
11. mv: Command that moves an object
12. cat: Command that outputs the contents of a file

13. ps: Command that displays the running processes
14. df: Command to display the display the available disk space
15. whoami: Command to print the name of the current user

Pipe Commands: Used to combine two or more commands. The output of one command is the input of the next command.

1. ls | wc
2. ls -l | grep d | wc -c
3. cat xyz.txt | grep r | tee abc.txt | wc -l

IV. File Contents:

1. client.c : Contains the main function for running the client side application.
2. server.c : Contains the main function for running the server side application.
3. checkpipe.c : Checks the number of pipes in the entered command
4. pipes.c : Performs execution of commands with pipes. There are separate functions for one, two and three pipes in this file.
5. pipesplitter.c : performs parsing and tokenizing of all entered commands. Also performs the task of splitting pipes commands into separate commands.
6. print.c : Prints the user prompt and current directory during each execution.
7. singlecommand.c : Runs execution of the commands which do not use pipes.

V. Functions and Functionalities:

1. Pipe Checking:
   Pipe checking is done by the file checkpipe.c which checks if an entered string has pipes. If pipes are present, each section of the pipe is parsed and tokenized separately and sent to the appropriate pipe execution function (single pipe, double pipe, etc…).

```
int checkPipe(char* str1){
 int count = 0;
  // int pipeFlag = 0;
  for(int i=0;i<=(strlen(str1));i++){
      if(str1[i]=='|'){
```

```
        ++count;
      }
    }
  return count;
}
```

2. Parsing and Tokenizing:
   We handle parsing and tokenizing of commands in the splitter.c file. Both lineSplitter() and pipeSplitter() functions work in a similar manner. Token sizes are dynamically allocated and the tokens are separated using predefined delimiters for each function. The tokens are returned as an array which is further used by other functions.

```
char **pipeSplitter(char *line, int pipeflag){
  int bufferSize = BUFFER_SIZE, indexPosition = 0;
  char **tokens = malloc(bufferSize * sizeof(char*)); // Array of tokens dynamically allocated
  char *token; // Each token (string between pipes)

  if (!tokens) { // If tokens memory was allocated
    fprintf(stderr, "Token memory allocation error\n");
    exit(EXIT_FAILURE);
  }

   token = strtok(line, PIPE_DELIM); // Strtok breaks string line into a series of tokens using the token delimiters provided as PIPE_DELIM Macro
  while (token != NULL) {
    tokens[indexPosition] = token; // place the token into the array of tokens
    indexPosition++;  // Increment the index position for the token to be saved in the array
    if (indexPosition >= bufferSize) {
      bufferSize += BUFFER_SIZE;
      tokens = realloc(tokens, bufferSize * sizeof(char*));
      if (!tokens) {
        fprintf(stderr, "Token memory allocation error\n");
        exit(EXIT_FAILURE);
      }
    }
     token = strtok(NULL, PIPE_DELIM);   // Strtok NULL tells the function to continue tokenizing the string that was passed first
  }
  tokens[indexPosition] = NULL;
  return tokens; // return the array of tokens (arguments pipe separated )
}
```

3. Piped Commands Execution:
   Commands which pipes are directed to the functions in the pipes.c file. The pipes make use of the concept of process communication to execute multiple commands using multiple child processes. The number of commands determines the number of pipes used. For instance, a single pipe command requires two separate commands to be run, where the output of the first command becomes the input of the second command. This is done using two child processes (forks), which communicate using a file descriptor. The standard output of the first child is redirected to the second child using the dup2() function. The final output is then sent back to the output stream. Double and Triple pipe functions work similarly, except that the number of file descriptors, child processes, output redirections, etc… increase proportionately with the number of pipes.

```
dup2(socket, STDOUT_FILENO); // reading redirected output of ls through pipe 1
dup2(socket, STDERR_FILENO);
```

4. Sockets for Server to Client Communication:
   This function is the core of our program. It demonstrated communication between two nodes (here the Server and Client) over a network. Various functions like listen(), bind(), accept() and connect() are used to enable a successful connection between the server and client. Messages are sent back and forth between the two nodes using send() and recv().

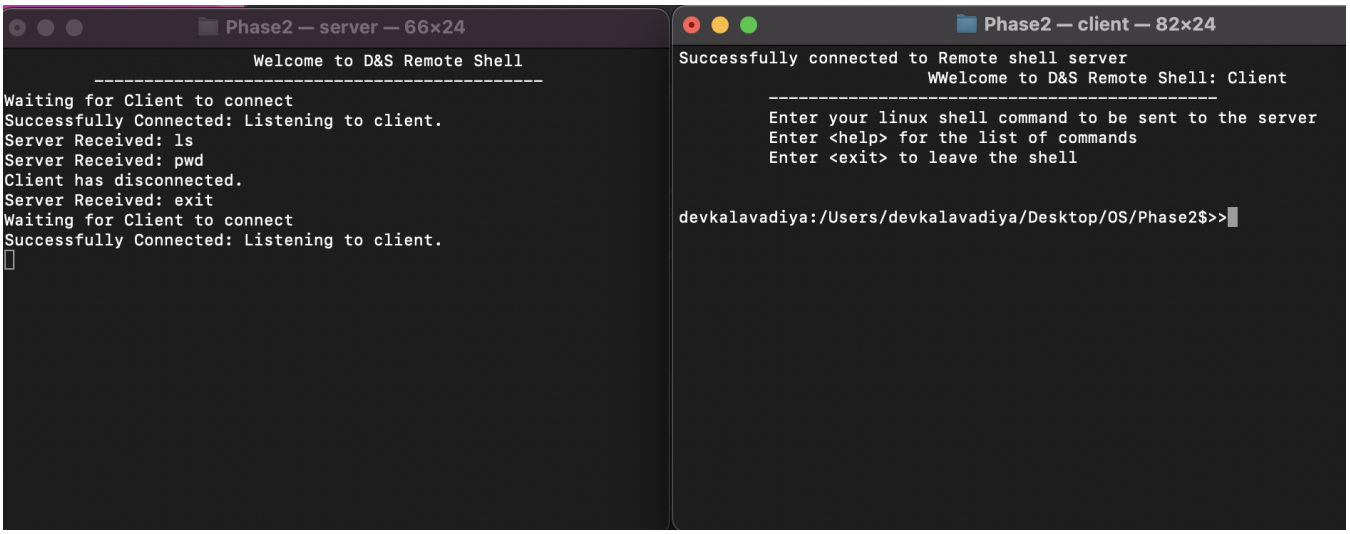
```
int sock1, sock2, valread;
struct sockaddr_in address; // structure for storing address
int addrlen = sizeof(address); // Getting the size off the address
if ((sock1 = socket(AF_INET, SOCK_STREAM, 0)) == 0)
{
  perror("Socket creation failed");
  exit(EXIT_FAILURE);
}
// Setting and defining the address for the socket to bind on
address.sin_family = AF_INET;
address.sin_addr.s_addr = htonl(INADDR_ANY);
address.sin_port = htons(PORT);

if (bind(sock1, (struct sockaddr *)&address, sizeof(address)) < 0)
{
  perror("Binding failed");
  exit(EXIT_FAILURE);
}
```

```
while (1) // to keep server alive forever
{
    if (listen(sock1, 10) < 0) // defining for number of clients in queue (not necessary here since its single client connection)
  {
   perror("Listen Failed");
   exit(EXIT_FAILURE);
  }
  if (connectFlag == 0)
  {
   printf("Waiting for Client to connect\n"); // Server is listening and
   if ((sock2 = accept(sock1, (struct sockaddr *)&address,
                    (socklen_t *)&addrlen)) < 0)
   {
    perror("accept");
    exit(EXIT_FAILURE);
   }
```

5. Client Disconnection and Reconnection

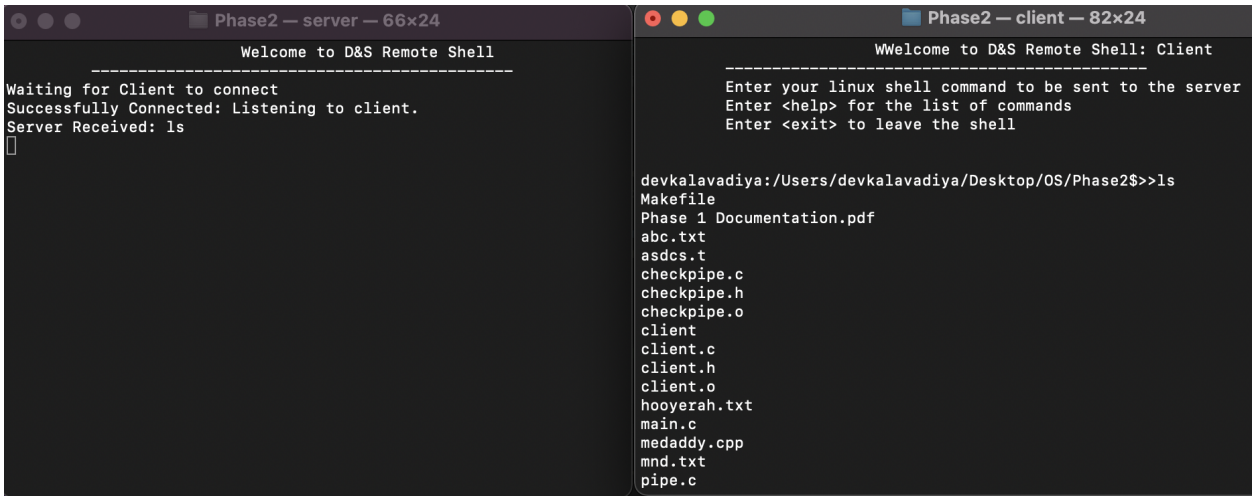
   The server waits for the client to connect and accepts commands as long as it is connected to the. When the client leaves using ‘exit’, the connection is disrupted and the server now goes back to waiting for a client to connect. This functions similar to how an actual server and client system would work. This feature is implemented by using a flag which checks which changes to true if the client sends exit. This makes the client exit and sends the server to waiting for a client.



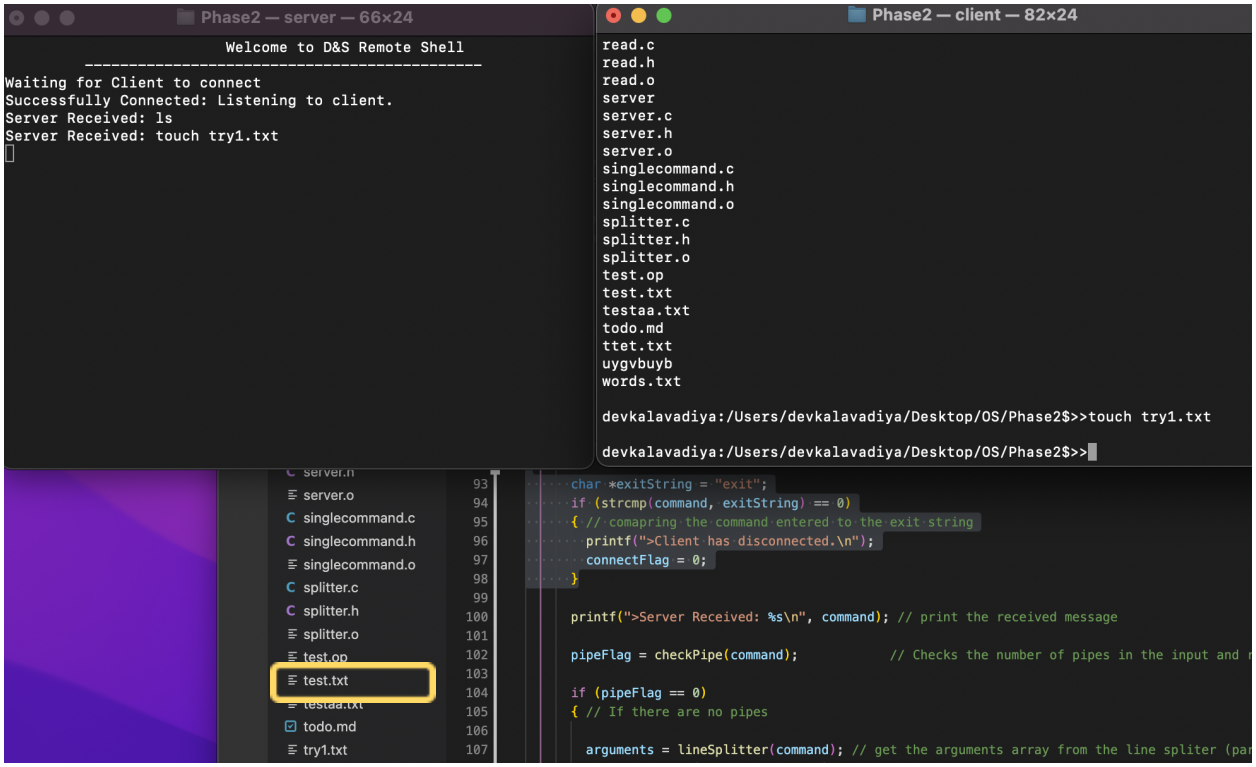
VI. Test Cases:

Here are our commands with screenshots of both our server and client end.

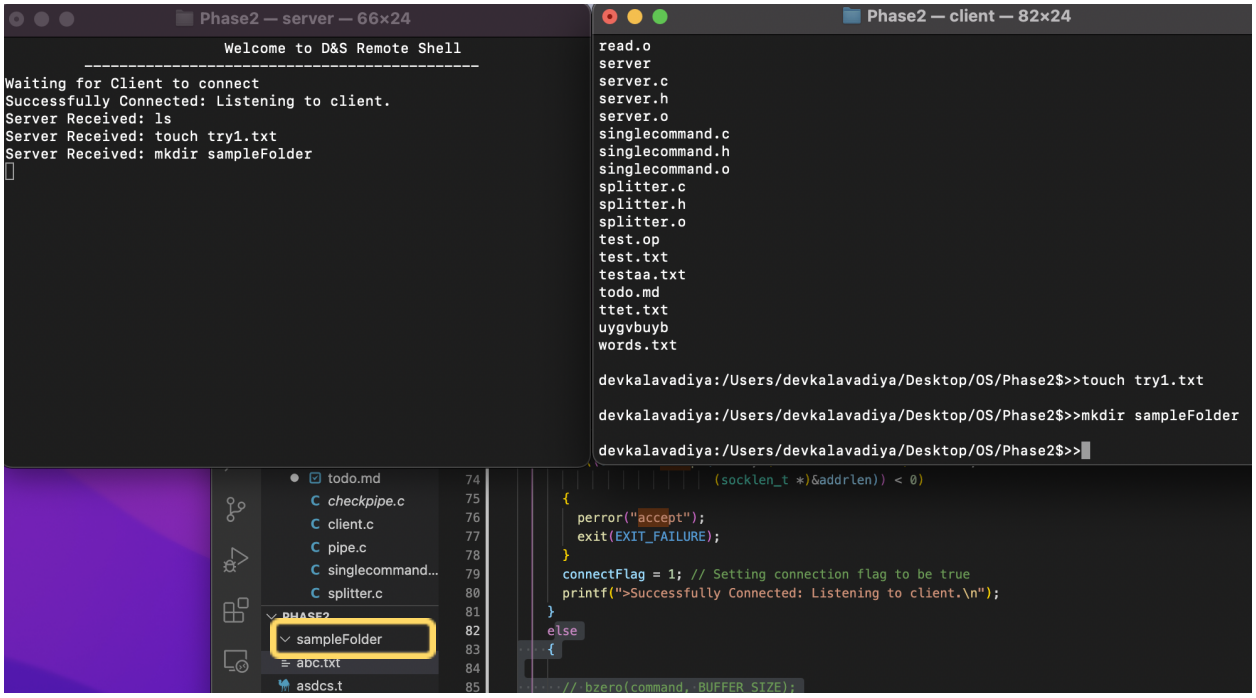
1. ls:



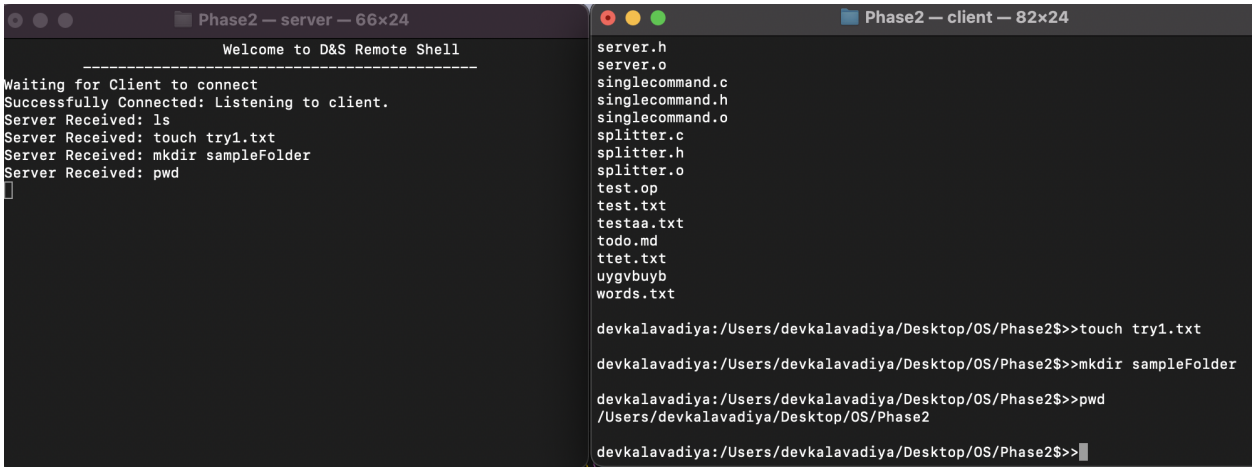
2. touch:



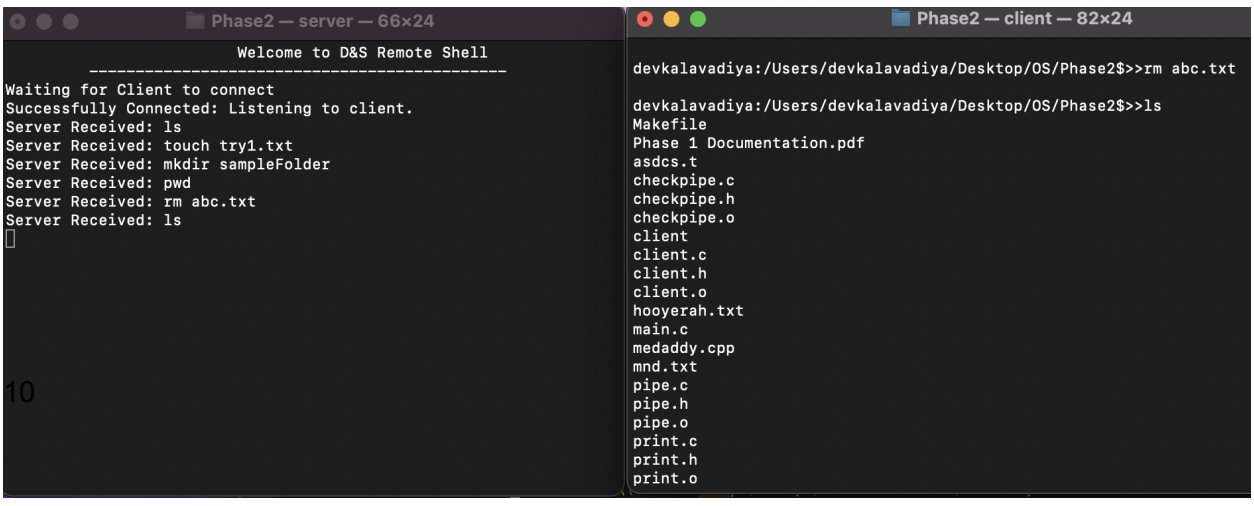
3. mkdir:



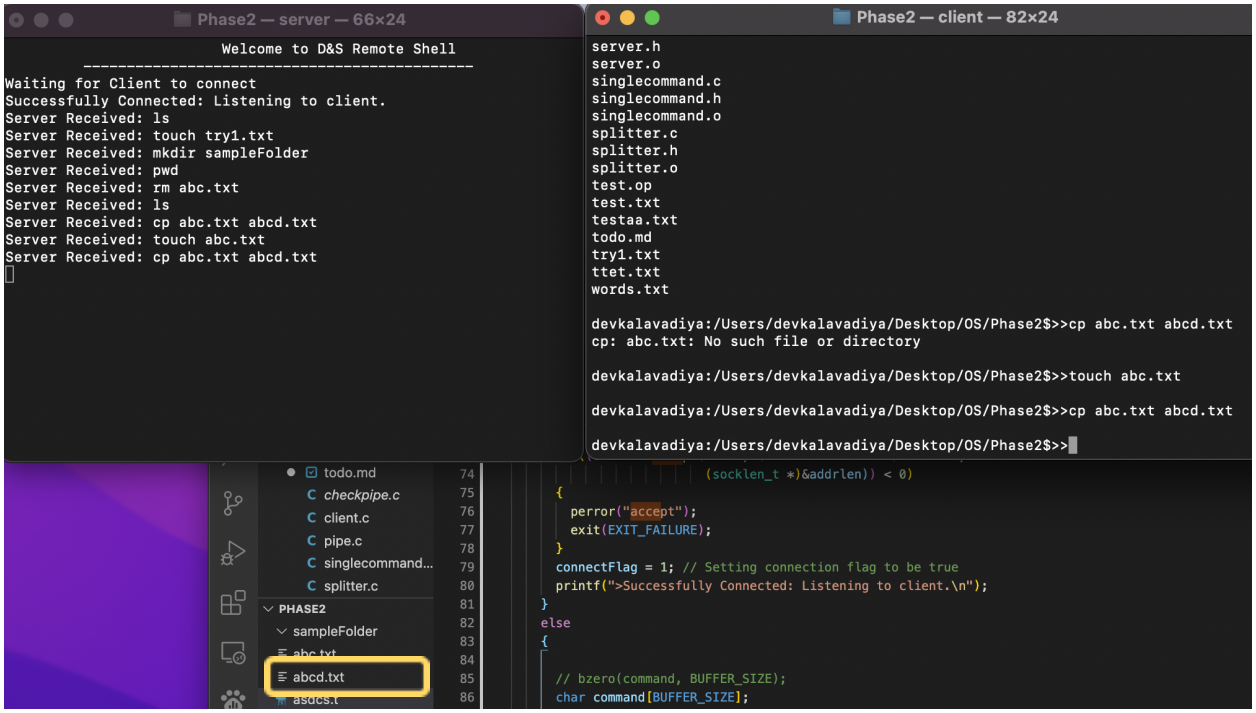
4. pwd:



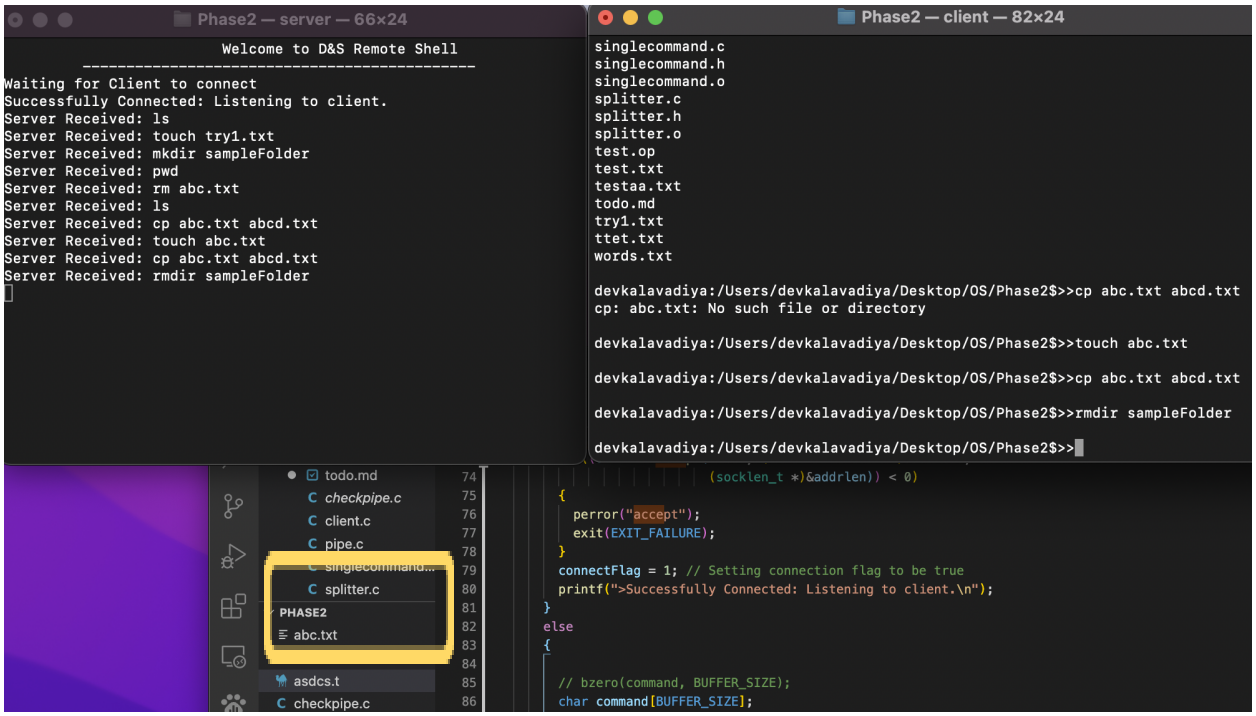
5. rm:



6. cp :


Phase2 — server — 66×24
Welcome to D&S Remote Shell
Waiting for Client to connect
Successfully Connected: Listening to client.
Server Received: ls
Server Received: touch try1.txt
Server Received: mkdir sampleFolder
Server Received: pwd
Server Received: rm abc.txt
Server Received: ls
Server Received: cp abc.txt abcd.txt
Server Received: touch abc.txt
Server Received: cp abc.txt abcd.txt
Phase2 — client — 82×24
server.h
server.o
singlecommand.c
singlecommand.h
singlecommand.o
splitter.c
splitter.h
splitter.o
test.op
test.txt
testaa.txt
todo.md
try1.txt
ttet.txt
words.txt
devkalavadiya:/Users/devkalavadiya/Desktop/OS/Phase2$>>cp abc.txt abcd.txt
cp: abc.txt: No such file or directory
devkalavadiya:/Users/devkalavadiya/Desktop/OS/Phase2$>>touch abc.txt
devkalavadiya:/Users/devkalavadiya/Desktop/OS/Phase2$>>cp abc.txt abcd.txt
devkalavadiya:/Users/devkalavadiya/Desktop/OS/Phase2$>>
todo.md
checkpipe.c
client.c
pipe.c
singlecommand...
splitter.c
PHASE2
sampleFolder
abcd.txt
(socklen_t *)&addrlen)) < 0)
perror("accept");
exit(EXIT_FAILURE);
connectFlag = 1; // Setting connection flag to be true
printf(">Successfully Connected: Listening to client.\n");
else
// bzero(command, BUFFER_SIZE);
char command[BUFFER_SIZE];

7. rmdir :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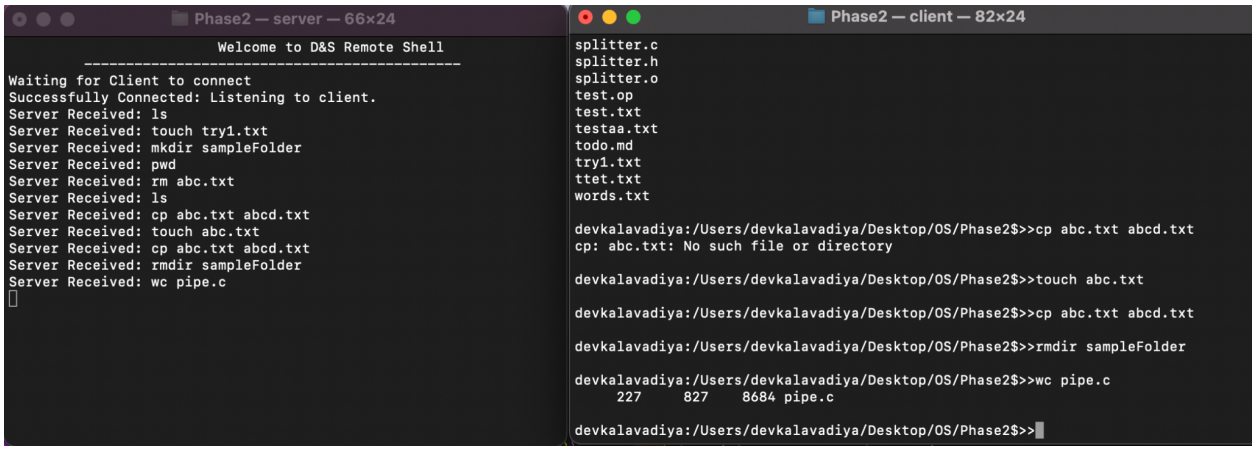
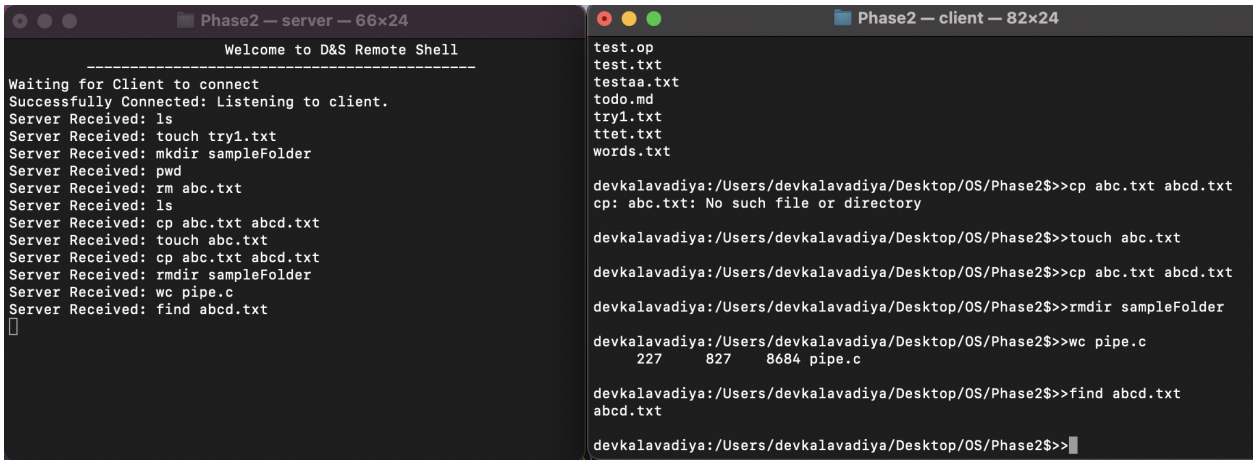
Server Received: cp abc.txt abcd.txt
Server Received: touch abc.txt
Server Received: cp abc.txt abcd.txt
Server Received: rmdir sampleFolder
Phase2 — client — 82×24
singlecommand.c
singlecommand.h
singlecommand.o
splitter.c
splitter.h
splitter.o
test.op
test.txt
testaa.txt
todo.md
try1.txt
ttet.txt
words.txt
devkalavadiya:/Users/devkalavadiya/Desktop/OS/Phase2$>>cp abc.txt abcd.txt
cp: abc.txt: No such file or directory
devkalavadiya:/Users/devkalavadiya/Desktop/OS/Phase2$>>touch abc.txt
devkalavadiya:/Users/devkalavadiya/Desktop/OS/Phase2$>>cp abc.txt abcd.txt
devkalavadiya:/Users/devkalavadiya/Desktop/OS/Phase2$>>rmdir sampleFolder
devkalavadiya:/Users/devkalavadiya/Desktop/OS/Phase2$>>
todo.md
checkpipe.c
client.c
pipe.c
splitter.c
PHASE2
abc.txt
asdcs.t
checkpipe.c
(socklen_t *)&addrlen)) < 0)
perror("accept");
exit(EXIT_FAILURE);
connectFlag = 1; // Setting connection flag to be true
printf(">Successfully Connected: Listening to client.\n");
else
// bzero(command, BUFFER_SIZE);
char command[BUFFER_SIZE];

The folder can was deleted and can not be seen on the highlighted box area. (Previously present in the image for cp)

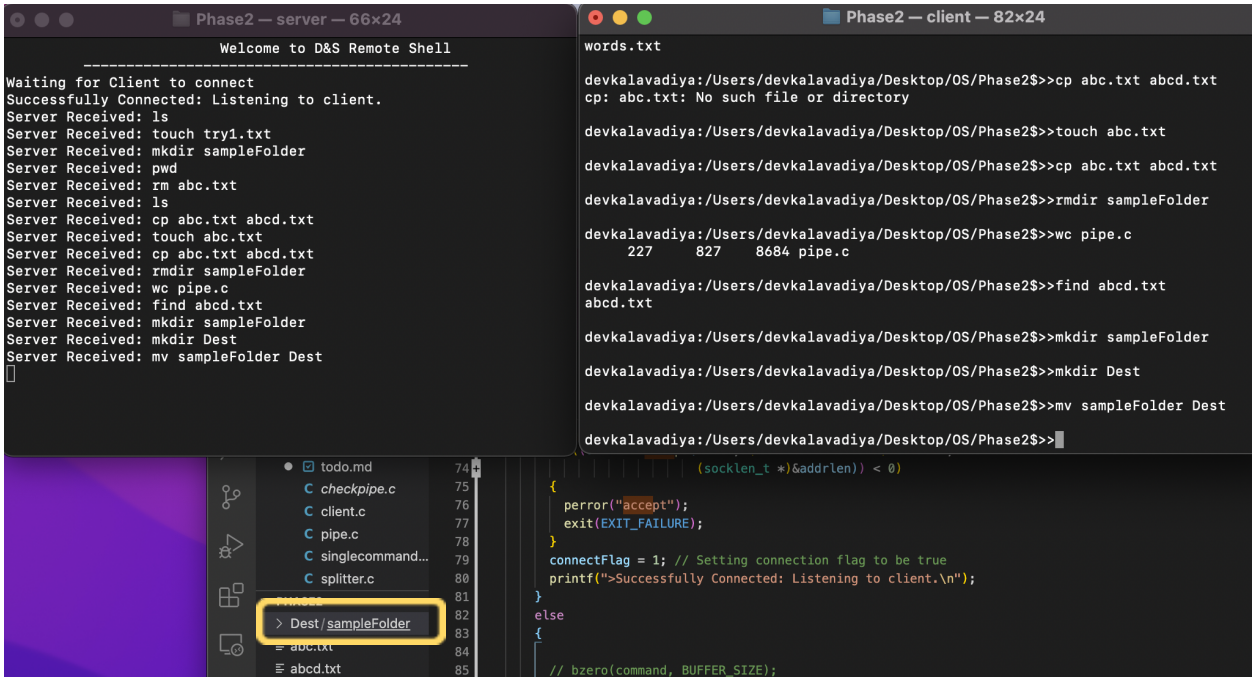
8. wc:



9. find:

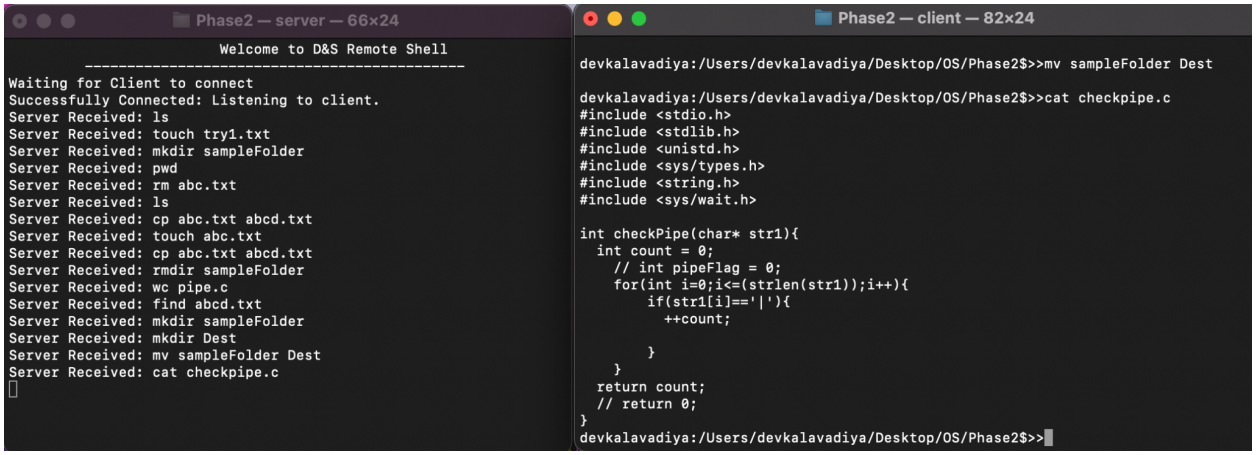


10. mv :

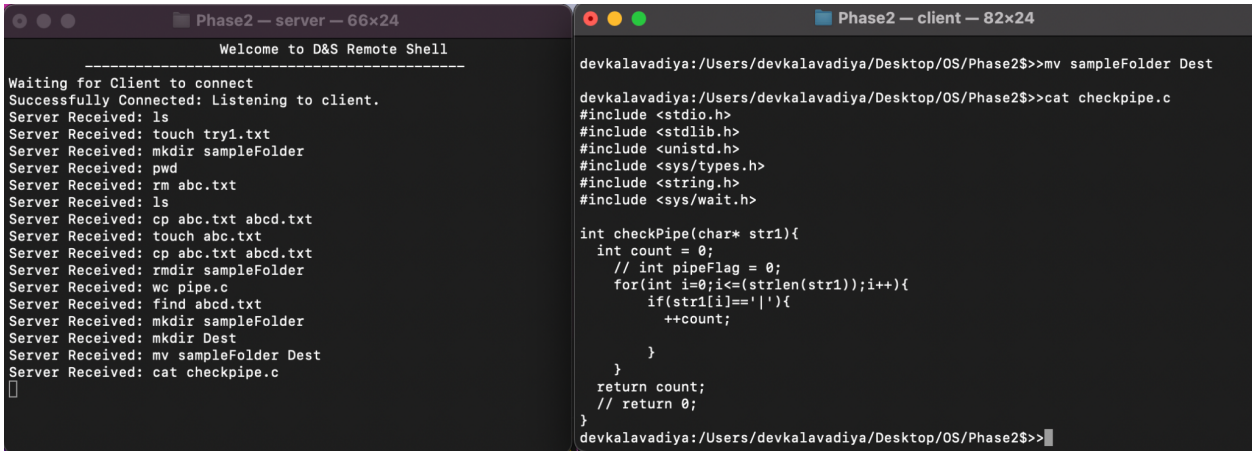


As it can be seen the sample folder was moved inside the Dest directory

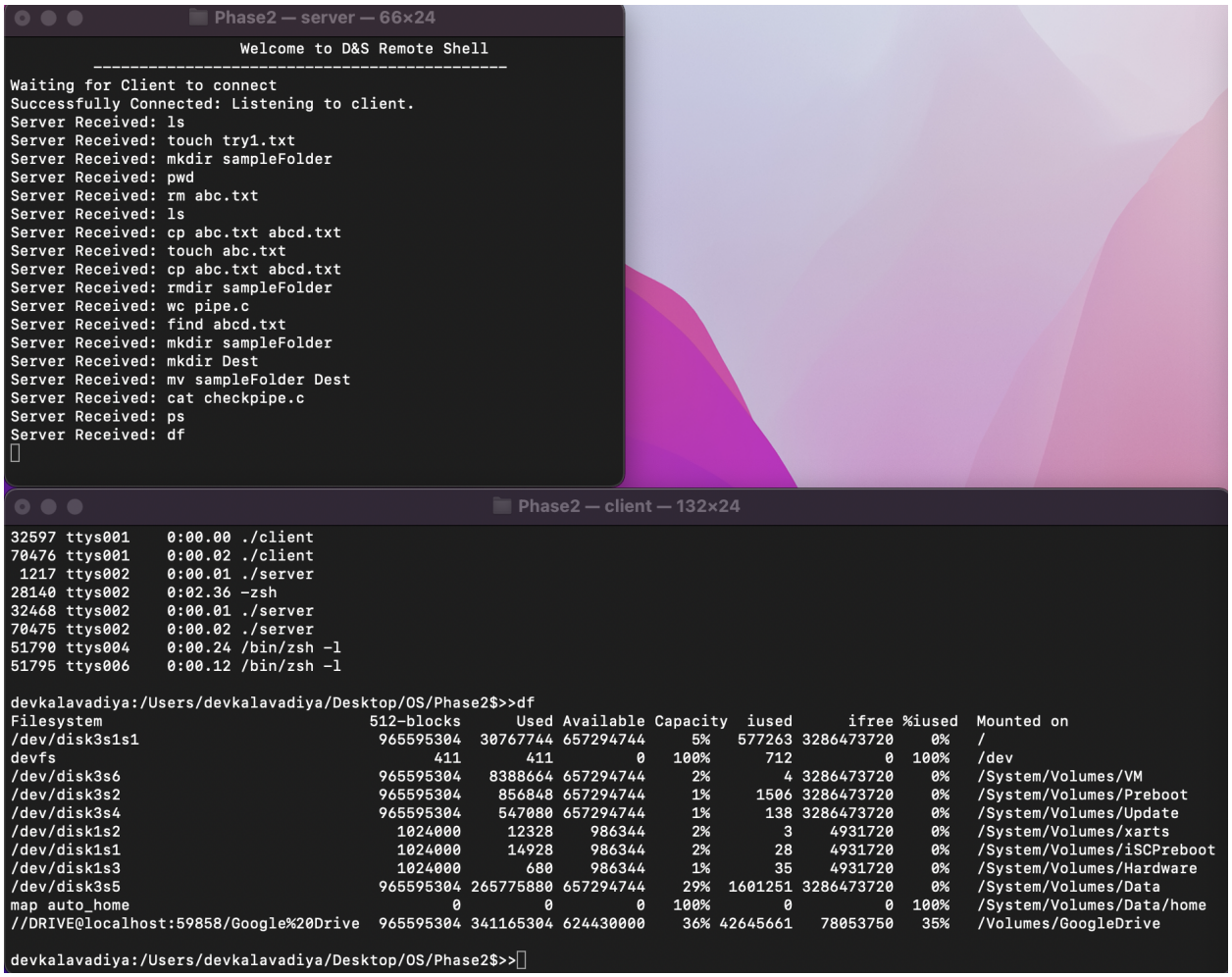
11. cat :



12. ps: :


Phase2 — server — 66×24
Welcome to D&S Remote Shell
Waiting for Client to connect
Successfully Connected: Listening to client.
Server Received: ls
Server Received: touch try1.txt
Server Received: mkdir sampleFolder
Server Received: pwd
Server Received: rm abc.txt
Server Received: ls
Server Received: cp abc.txt abcd.txt
Server Received: touch abc.txt
Server Received: cp abc.txt abcd.txt
Server Received: rmdir sampleFolder
Server Received: wc pipe.c
Server Received: find abcd.txt
Server Received: mkdir sampleFolder
Server Received: mkdir Dest
Server Received: mv sampleFolder Dest
Server Received: cat checkpipe.c
Phase2 — client — 82×24
devkalavadiya:/Users/devkalavadiya/Desktop/OS/Phase2$>>mv sampleFolder Dest
devkalavadiya:/Users/devkalavadiya/Desktop/OS/Phase2$>>cat checkpipe.c
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
#include <sys/types.h>
#include <string.h>
#include <sys/wait.h>
int checkPipe(char* str1){
int count = 0;
// int pipeFlag = 0;
for(int i=0;i<=(strlen(str1));i++){
if(str1[i]=='|'){
++count;
}
}
return count;
// return 0;
}
devkalavadiya:/Users/devkalavadiya/Desktop/OS/Phase2$>>

13. df :


Phase2 — server — 66×24
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Server Received: ls
Server Received: touch try1.txt
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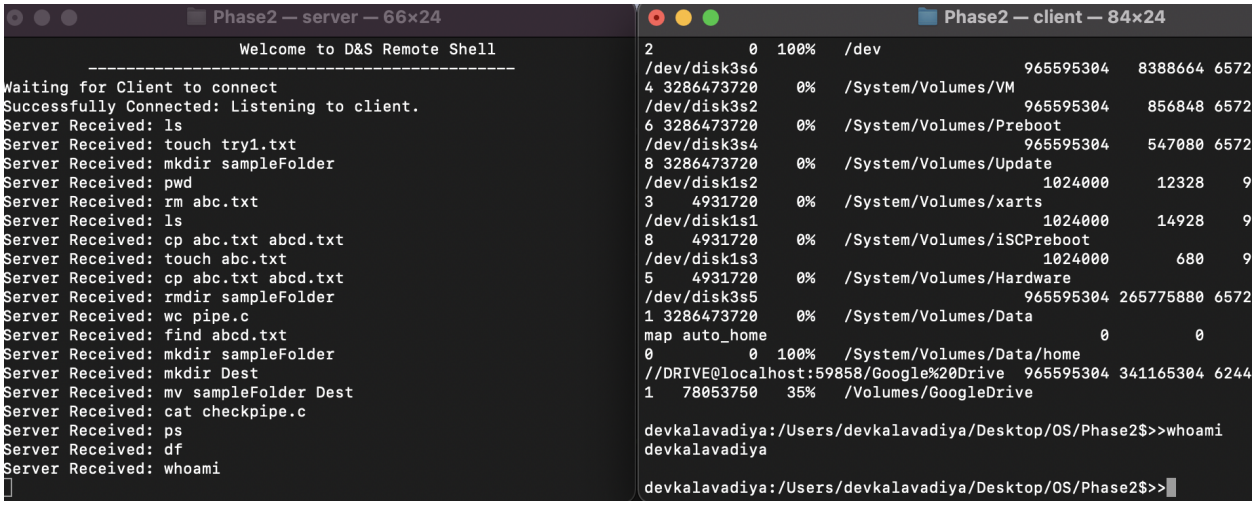
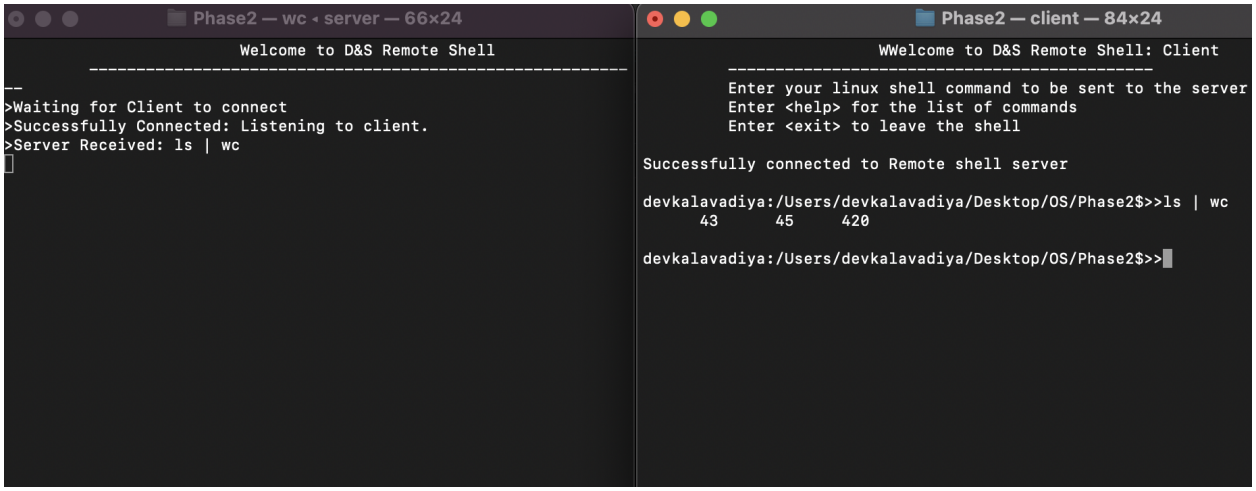
Server Received: pwd
Server Received: rm abc.txt
Server Received: ls
Server Received: cp abc.txt abcd.txt
Server Received: touch abc.txt
Server Received: cp abc.txt abcd.txt
Server Received: rmdir sampleFolder
Server Received: wc pipe.c
Server Received: find abcd.txt
Server Received: mkdir sampleFolder
Server Received: mkdir Dest
Server Received: mv sampleFolder Dest
Server Received: cat checkpipe.c
Server Received: ps
Server Received: df
Phase2 — client — 132×24
32597 ttys001 0:00.00 ./client
70476 ttys001 0:00.02 ./client
1217 ttys002 0:00.01 ./server
28140 ttys002 0:02.36 -zsh
32468 ttys002 0:00.01 ./server
70475 ttys002 0:00.02 ./server
51790 ttys004 0:00.24 /bin/zsh -l
51795 ttys006 0:00.12 /bin/zsh -l
devkalavadiya:/Users/devkalavadiya/Desktop/OS/Phase2$>>df
Filesystem 512-blocks Used Available Capacity iused ifree %iused Mounted on
/dev/disk3s1s1 965595304 30767744 657294744 5% 577263 3286473720 0% /
devfs 411 411 0 100% 712 0 100% /dev
/dev/disk3s6 965595304 8388664 657294744 2% 4 3286473720 0% /System/Volumes/VM
/dev/disk3s2 965595304 856848 657294744 1% 1506 3286473720 0% /System/Volumes/Preboot
/dev/disk3s4 965595304 547080 657294744 1% 138 3286473720 0% /System/Volumes/Update
/dev/disk1s2 1024000 12328 986344 2% 3 4931720 0% /System/Volumes/xarts
/dev/disk1s1 1024000 14928 986344 2% 28 4931720 0% /System/Volumes/iSCPreboot
/dev/disk1s3 1024000 680 986344 1% 35 4931720 0% /System/Volumes/Hardware
/dev/disk3s5 965595304 265775880 657294744 29% 1601251 3286473720 0% /System/Volumes/Data
map auto_home 0 0 0 100% 0 0 100% /System/Volumes/Data/home
//DRIVE@localhost:59858/Google%20Drive 965595304 341165304 624430000 36% 42645661 78053750 35% /Volumes/GoogleDrive
devkalavadiya:/Users/devkalavadiya/Desktop/OS/Phase2$>>

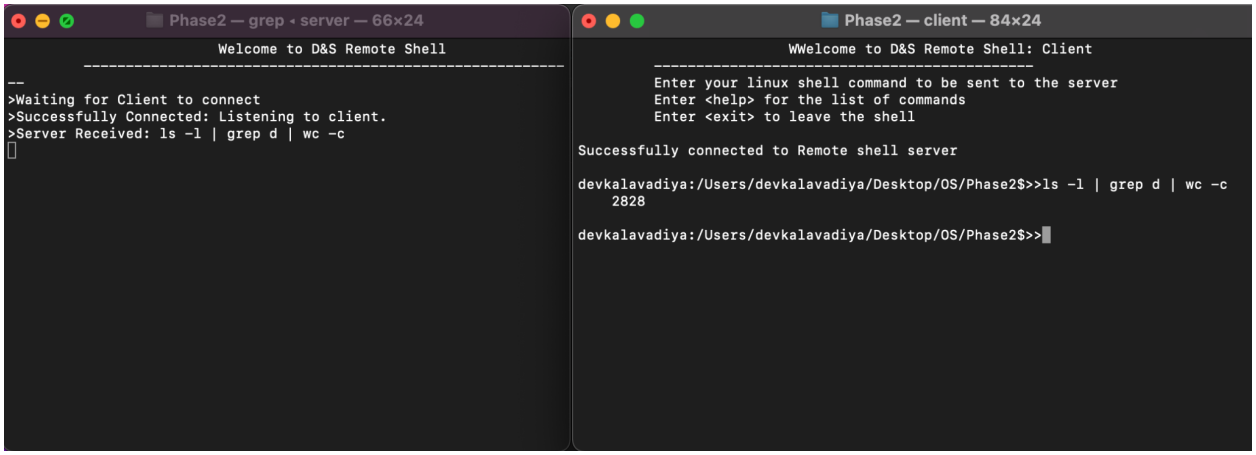
14. who am i:



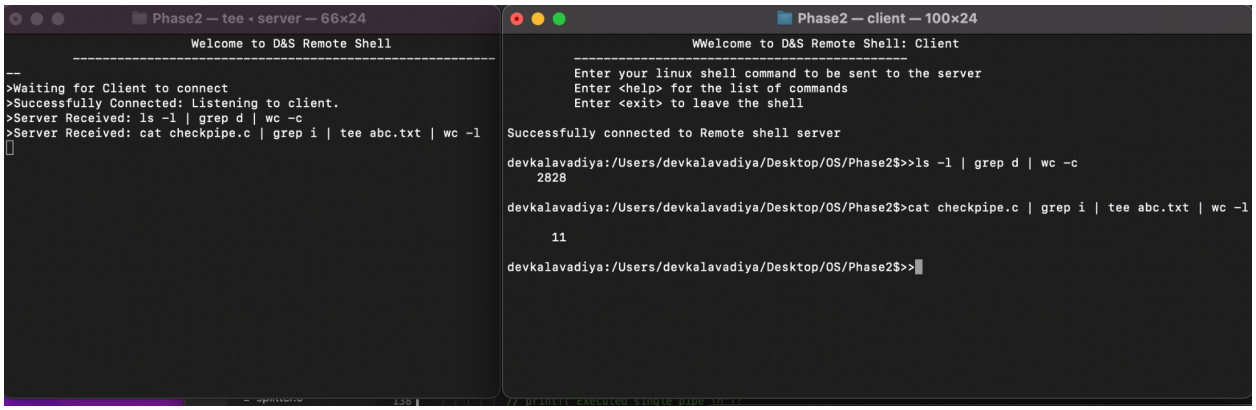
15. Single pipe execution:



16. Double pipes execution:

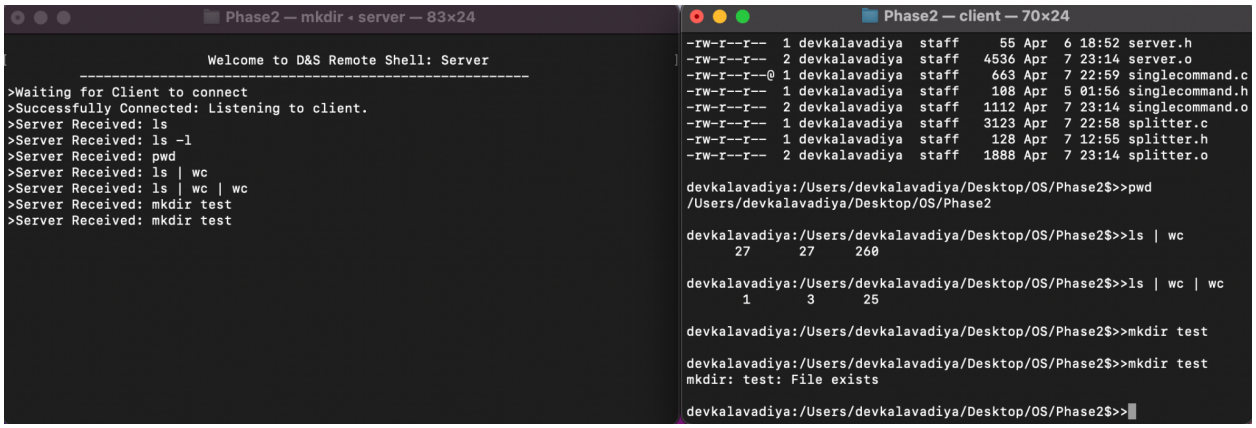


17. Triple pipes execution:

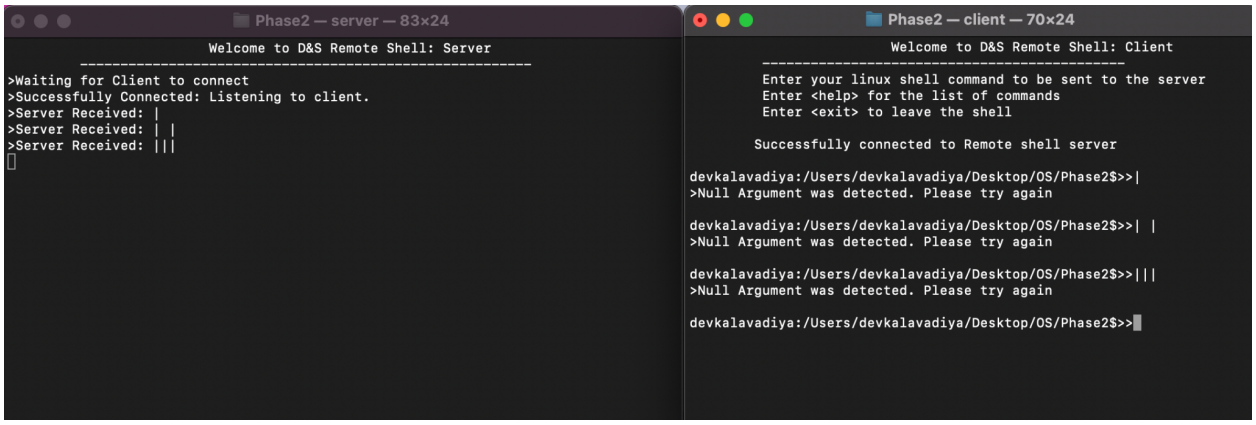


18. Error Handling Test Cases:

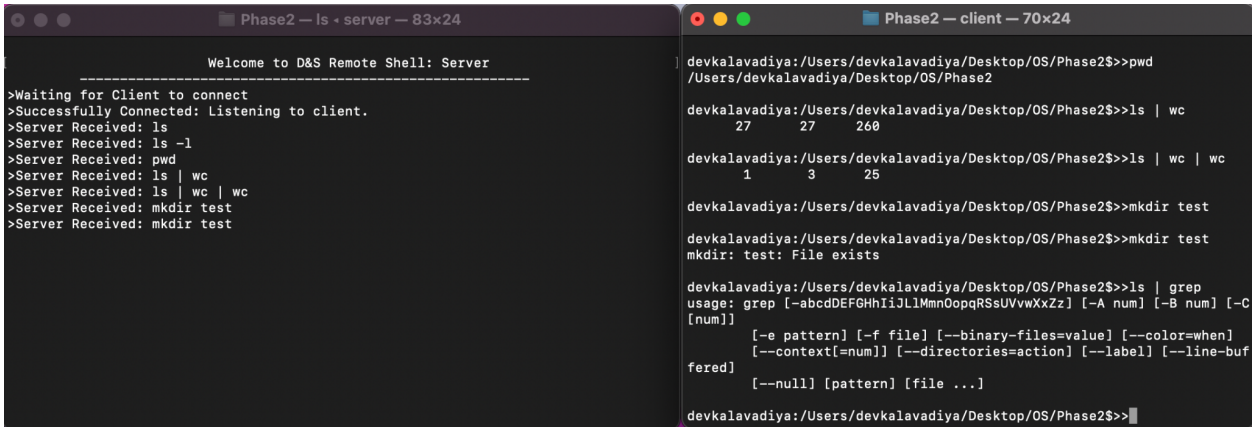
a. When creating same file name error message is relayed back to client



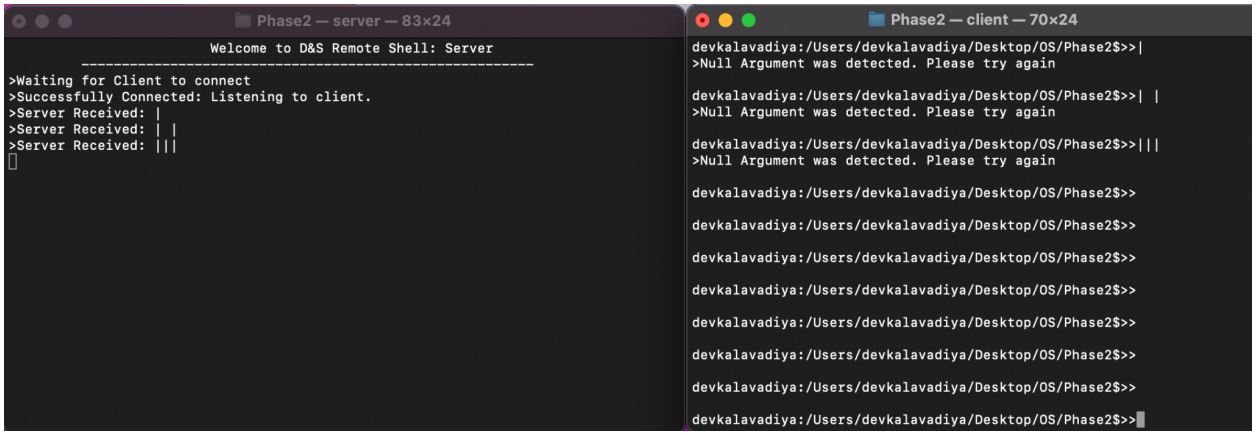
b. Null argument in a piped commands



c. Piped command without all arguments



d. Enter without any command doesn't break code :)



VII. Challenges :-

We ran into a lot of bugs for this Phase. Most were due to the complex working of the c programming language. A few of them are detailed below.

1. The first issue after we connected successfully was the lagging of buffer outputs between the client and server. For instance, when we entered ls, the first command worked as expected and for the next command onwards the buffer was lagging because everything from the server was being output into the client.
   We realized this issue was created by an incorrect placement of the dup2() function which. Placing it in the parent process was creating a problem. We moved it to the child area and fixed the issue.

2. Another challenge we faced was the buffer size problem. The commands output would queue up into the buffer but would not print correctly and commands would be sent in chunks when printing on the client. In order to fix this we started by clearing the buffer and the input before sending and receiving from server and client. Additionally, to fix the problem of large output getting sent as chucks, we added a recv() at the start with a MSG_DONTWAIT argument which didn't block the client from running.

3. We faced a bug where the client kept quitting after entering piped commands. Upon careful debugging we realized that the file descriptors and sockets were not closed properly and in the right area. With a little trial and error we figured this part out successfully.

PHASE 3:-

I. File Contents:

- client.c : Contains the main function for running the client side application.
- server.c : Contains the main function for running the server side application.
- checkpipe.c : Checks the number of pipes in the entered command
- pipes.c : Performs execution of commands with pipes. There are separate functions for one, two and three pipes in this file.
- pipesplitter.c : performs parsing and tokenizing of all entered commands. Also performs the task of splitting pipes commands into separate commands.
- print.c : Prints the user prompt and current directory during each execution. singlecommand.c : Runs execution of the commands which do not use pipes.

II. How to Compile and Run:

We have used makefile to organize the project's code compilation. To run a makefile code, run the following commands in the terminal.

First, run $*make clean* (this is only if you want to run the code again and clear all the .o files)
Then run $*make* to compile the code

Then, the server should be started first using $./server
Finally start clients using $./client

III. Functions and Functionalities:

1. Multithreading for multiple Clients

```
while (1) // to keep server alive forever
{
   printf(">Waiting for Client to connect\n"); // Server is listening and waiting for
connection
   if ((sock2 = accept(sock1, (struct sockaddr *)&address,
                       (socklen_t *)&addrlen)) < 0)
   {
     perror("accept");
     exit(EXIT_FAILURE);
   }
   // connectFlag = 1; // Setting connection flag to be true
   printf(">Successfully Connected: Listening to client.\n");
    int rc;                                          // return value from pthread_create
to check if new thread is created successfully                          */
    pthread_t thread_id;                               // thread's ID (just an integer,
typedef unsigned long int) to identify new thread
    int *new_socket = (int *)malloc(sizeof(int)); // for passing safely the integer
socket to the thread
   if (new_socket == NULL)
   {
     fprintf(stderr, "Couldn't allocate memory for thread new socket argument.\n");
     free(new_socket);
     exit(EXIT_FAILURE);
   }
   *new_socket = sock2;
   printf("New Client has Connected!\n");
    // create a new thread that will handle the communication with the newly accepted
client
   rc = pthread_create(&thread_id, NULL, HandleClient, new_socket);
   if (rc) // if rc is > 0 imply could not create new thread
   {
     printf("\n ERROR: return code from pthread_create is %d \n", rc);
     free(new_socket);
     exit(EXIT_FAILURE);

   }
}
```

2. Exiting Client using “exit” and ^C:

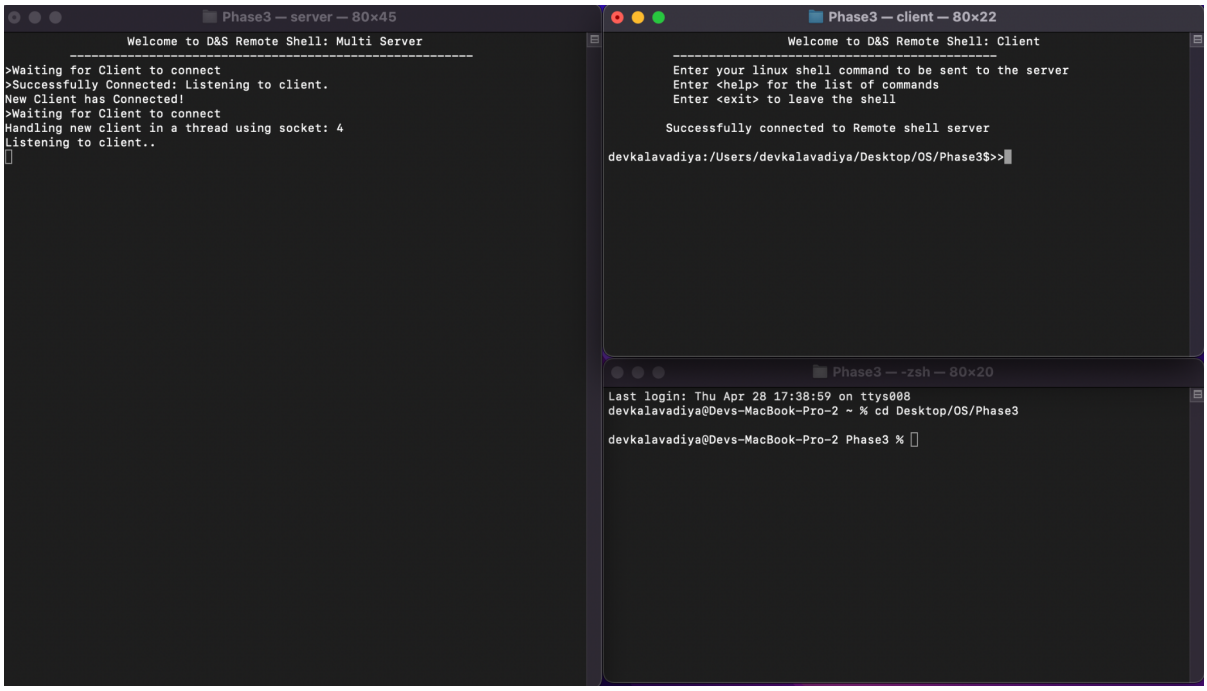
```
void clientExitHandler(int sig_num)
{
 char *exitString = "exit";
 // printf("\nExiting shell successfully \n");
 send(sock, exitString, strlen(exitString) + 1, 0); // sending exit message to
server
 close(sock);                          // close the socket/end the conection
 printf("\n Exiting client.  \n");
 fflush(stdout); // force to flush any data in buffers to the file descriptor
of standard output,, a pretty convinent function
 exit(0);
}
```

```
int main() // main function
{
 printf("\t\t Welcome to D&S Remote Shell: Multi Server\n");
 printf("\t ------------------------------------------------------------\n");
 signal(SIGINT, serverExitHandler);
}
```

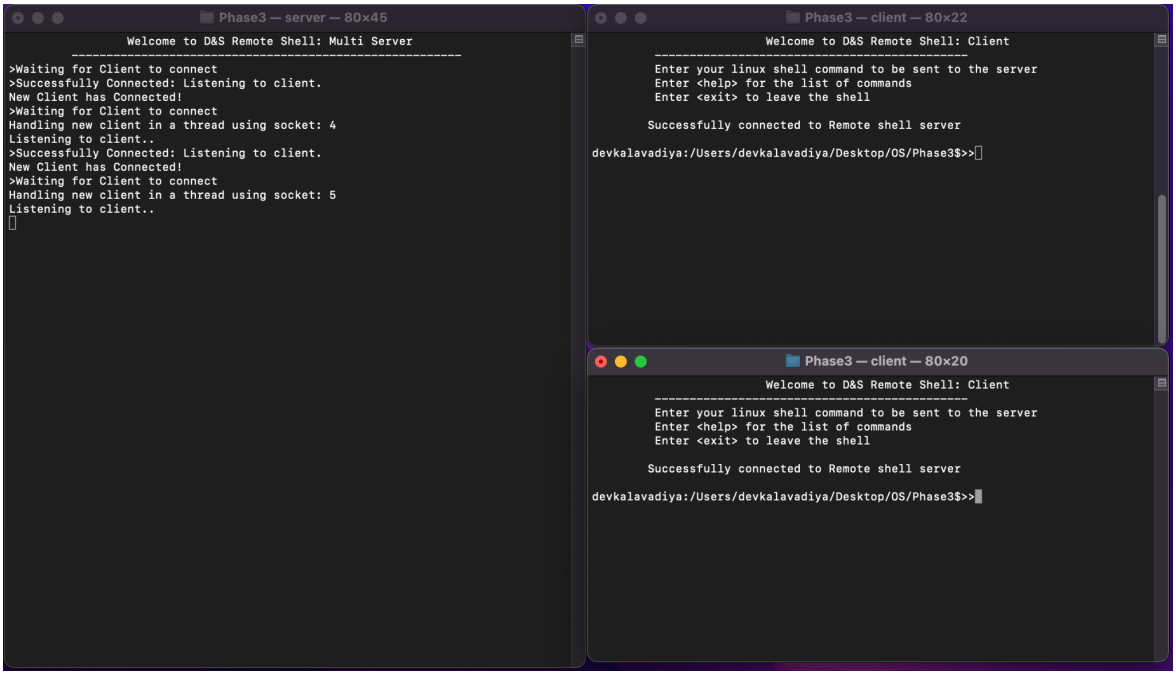
IV. Test Cases:

Here are our commands with screenshots of both our server and client end.

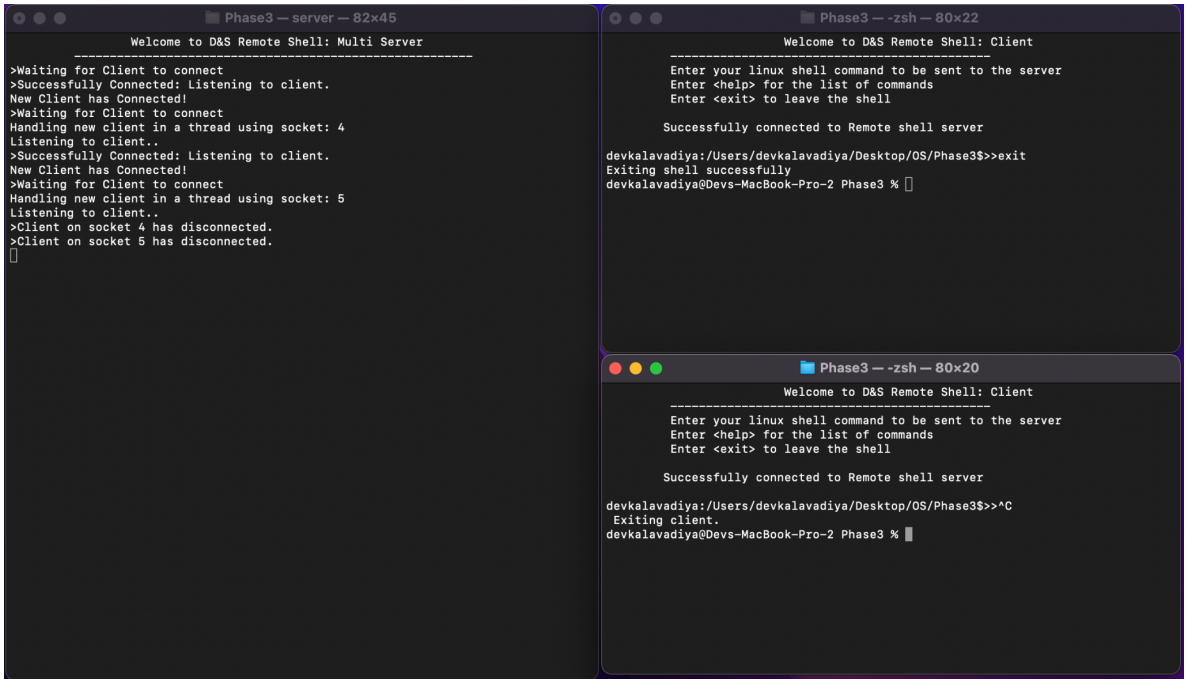
1. Single-client connect:



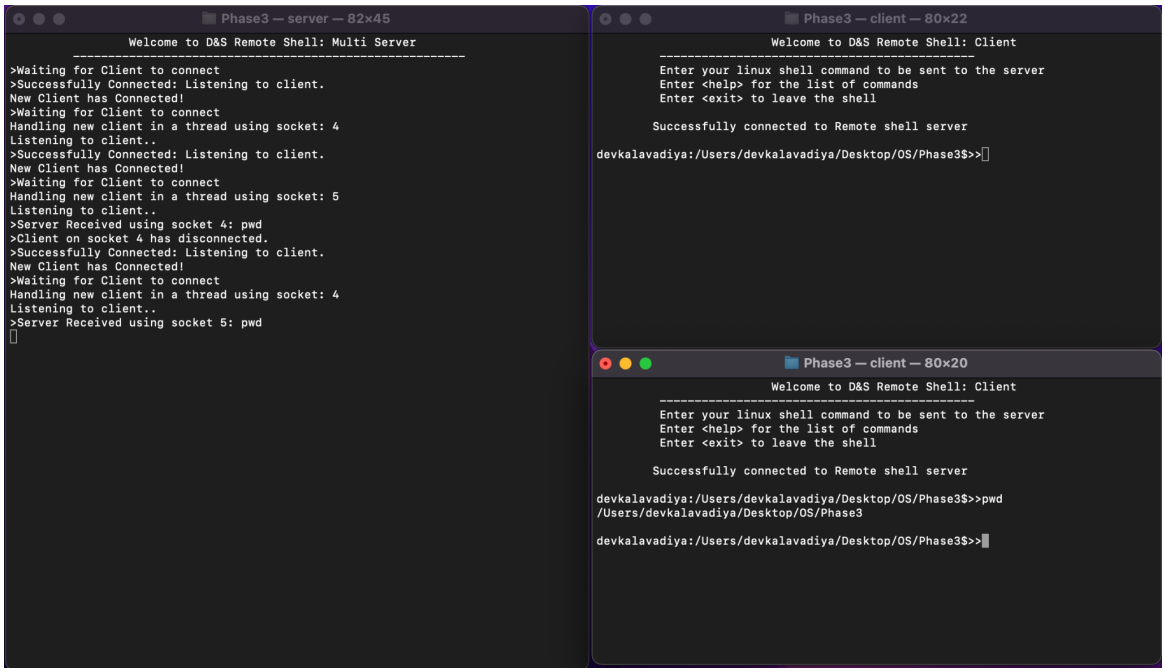
2. Multi-client connect:



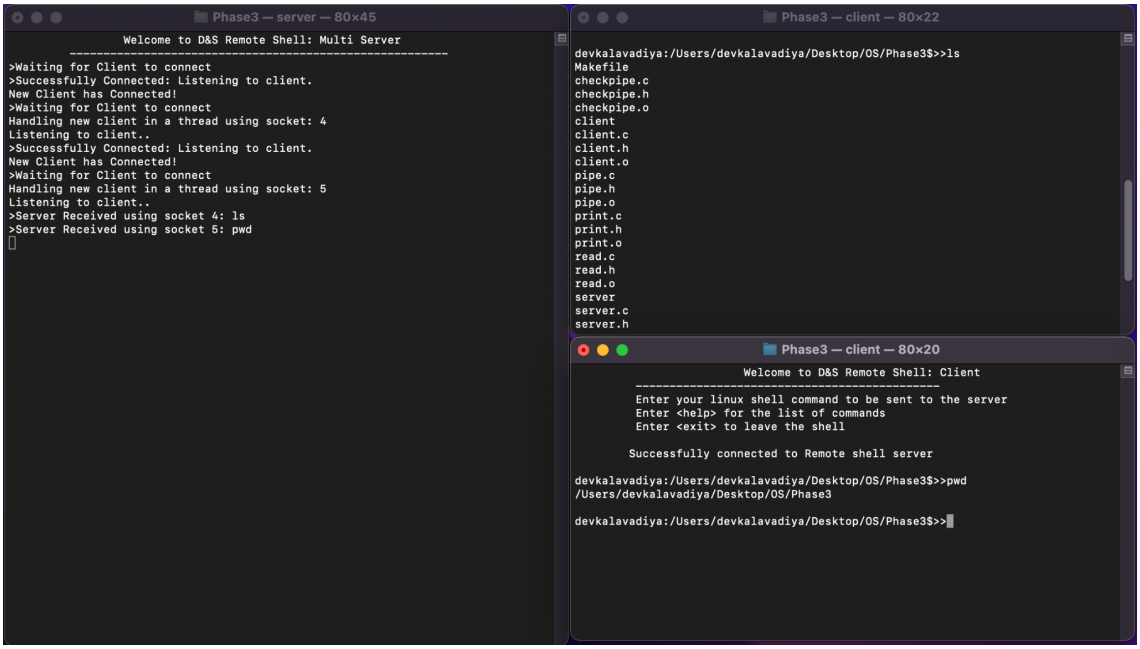
3. Client disconnect:



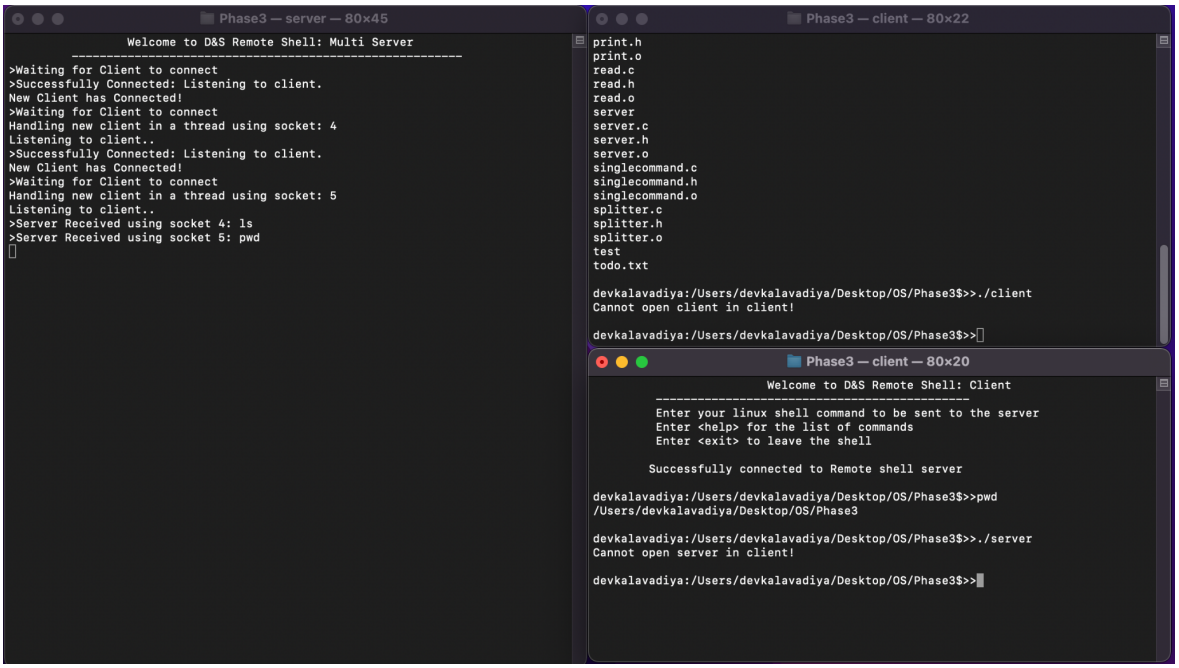
4. Client reconnect:



5. Simultaneous code execution:



6. Specific Error Case : Running Client in client



V. Challenges :-

The challenges faced in this phase were easier to analyze and debug.

1. The first error we came across after merging our Phase 2 code with a multi-client code was while exiting our client. It was causing the server to spam a null character. We fixed this by closing the sockets in the right places and in the right order. The incorrect termination of the threads might have also contributed to the error which we handled correctly.

2. Another thing we struggled with was to get the thread to terminate and have the closing of the socket at the end so that the particular client will successfully quit and disconnect. Once we had this working we realized that the client could reconnect to the server and was assigned the same thread number.

3. The exiting of the client using two different methods, ^c and “exit” gave us different results, which was an error. We figured this problem was caused by using the clientExitHandler() function that worked differently from our exit, and debugged it appropriately.