

# CSE 589 Fall 2014

## Programming Assignment 1

### Remote File Sharing System

Due Time: 09/26/2014 @ 23:59:59 EDT

## 1. Objectives

**Getting Started:** Familiarize yourself with socket programming.

**Implement:** Develop a simple application for file sharing among remote hosts and observe some network characteristics using it.

**Analyze:** Understand the packet-switching network behavior and compare the results of your file sharing application with those of a standard tool, iperf, used for measuring network performance.

## 2. Getting Started

### 2.1 Socket Programming

Beej Socket Guide: <http://beej.us/guide/bgnet>

### 2.2 iPerf

Iperf Homepage: <http://iperf.sourceforge.net/>

## 3. Implement

### 3.1 Programming environment

You will write C (or C++) code that compiles under the GCC (GNU Compiler Collection) environment. Furthermore, you should ensure that your code compiles and operates correctly on the CSE student servers (dokken.cse.buffalo.edu, euston.cse.buffalo.edu, embankment.cse.buffalo.edu, underground.cse.buffalo.edu and highgate.cse.buffalo.edu). This means that your code should properly compile by using the version of gcc (for C code) or g++ (for C++ code) found on the CSE student servers and should function correctly when executed.

**NOTE:** If you're using C++, you are not allowed to use any STLs (Standard Template Library) for the socket programming part. If you use any STLs for the socket programming part, your project will not be graded.

### 3.2 Running your program

Your process (your program when it is running in memory) will take 2 command line parameters:

1. The first parameter (s/c) indicates whether your program instance should run as a server or a client.
2. The second parameter (number) is the port number on which your process will listen for incoming connections.

E.g., if your executable is named assignment1, then:

- To run as a server listening on port 4322  
./assignment1 s 4322
- To run as a client listening on port 4322  
./assignment1 c 4322

**NOTE:** Use TCP Sockets only for your implementation. You should **use only the select() API** for handling multiple socket connections. Please don't use multi-threading or fork-exec.

**NOTE:** Please run your **server version of the program only on dokken.cse.buffalo.edu**. Your client versions should be stored/tested on any of these 4 servers only:

underground.cse.buffalo.edu  
euston.cse.buffalo.edu  
embankment.cse.buffalo.edu  
highgate.cse.buffalo.edu

Also, use your own directory with your UBIT name in /local/Fall\_2014/ on each of the 4 servers listed above. Change the access permission to this directory so that only you are allowed to access the contents of the directory (chmod -R 700 /local/Fall\_2014/<UBIT\_name>. This is to prevent others from copying your code). **Use only this directory to store/run your programs. However, on dokken use your default (home) folder.**

### 3.3 Functionality of your program

When launched, your process should work like a UNIX shell. It should accept incoming connections and at the same time provide a user interface that will offer the following command options:  
(Note that specific examples are used for clarity.)

**1. CREATOR** Display your full name, your UBIT name, and your UB email address, followed by the sentence "I have read and understood the course academic integrity policy located at [http://www.cse.buffalo.edu/faculty/dimitrio/courses/cse4589\\_f14/index.html#integrity](http://www.cse.buffalo.edu/faculty/dimitrio/courses/cse4589_f14/index.html#integrity)".

**Your submission will not be graded without the CREATOR command.**

*Use this printf statement:*

```
printf("I have read and understood the course academic integrity policy located at  
http://www.cse.buffalo.edu/faculty/dimitrio/courses/cse4589_f14/index.html#integrity");
```

**2. HELP** Display information about the available user interface options.

**3. MYIP** Display the IP address of this process.

**NOTE:** The IP should not be your "lo" address (127.0.0.1). It should be the actual IP of the server.

*Use this printf statement:*

```
printf("IP address:%s", ip_addr); //where ip_addr is a null-terminated char array storing IP
```

**4. MYPOR** Display the port on which this process is listening for incoming connections.

*Use this printf statement:*

```
printf("Port number:%d", port_num); //where port_num is an integer storing listening port num.
```

**5. REGISTER <server IP> <port\_no>:** This command is used by the client to register itself with the server and to get the IP and listening port numbers of all the peers currently registered with the server. The REGISTER command takes 2 arguments. The first argument is the IP address of the server and the second argument is the listening port of the server.

The first task of every client is to register itself with the server by sending a TCP message to the server that contains its listening port number. The server should maintain a list of the IP addresses and the listening ports of all the registered clients. Let's call this list as "Server-IP-List". Whenever a new client registers or a registered client exits, the server should update its Server-IP-List appropriately and then send this updated list to all the registered clients. Clients should always listen to such updates from the server and update their own local copy of the available peers. **Any such update which is received by the client should be displayed by the client.**

**NOTE:** The REGISTER command works only on the client and should not work on the server.

**6. CONNECT <destination> <port no>:** This command establishes a new TCP connection to the specified <destination> at the specified <port no>. The <destination> can be either an IP address or a hostname, e.g., CONNECT euston.cse.buffalo.edu 3456 or CONNECT 192.168.45.55 3456. The specified IP/hostname should be a valid and listed in the Server-IP-List sent to the client by the server. Any attempt to connect to an invalid IP/hostname or an IP/hostname not listed by the server in its Server-IP-List should be rejected and suitable error message should be displayed. Success or failure in connections between two peers should be indicated by both the peers using suitable messages. Self-connections and duplicate connections should be flagged with suitable error messages. Every client can maintain up-to 3 connections with its peers. Any request for more than 3 connections should be rejected. However, every client should always maintain a constant connection with the server.

**7. LIST** Display a numbered list of all the connections this process is part of. This numbered list will include connections initiated by this process and connections initiated by other processes. The output should display the hostname, IP address, and listening port of all the peers the process is connected to. Also, this should include the server details. E.g.:

ID	Hostname	IP Address	Port No.
1	dokken.cse.buffalo.edu	128.205.36.32	4545
2	embankment.cse.buffalo.edu	128.205.36.35	5454
3	highgate.cse.buffalo.edu	128.205.36.33	5000
4	euston.cse.buffalo.edu	128.205.36.34	5100

**NOTE:** Connection id 1 should always be your server running on dokken.cse.buffalo.edu. The remaining connections should be the peers who you are connected to.

*Use this printf statement:*

```
/* The following printf will print out one host. Repeat this printf statement to print all hosts
 * host_id: integer with host's assigned ID
 * hostname: null-terminated char array containing hostname
 * ip_addr: null-terminated char array storing IP
 * port_num: integer storing listening port num */
printf("%-5d%-35s%-20s%-8d\n", host_id, hostname, ip_addr, port_num);
```

**8. TERMINATE <connection id>** This command will terminate the connection listed under the specified number when LIST is used to display all connections, e.g., TERMINATE 2 should terminate the connection which has the connection id 2. In the example shown above in the LIST command, the connection id 2 is with embankment.cse.buffalo.edu. So, a command TERMINATE 2 should terminate the connection with embankment. An error message should be displayed if a valid connection does not exist for the specified connection id. If a remote machine terminates one of your connections, you should also display a message.

**9. EXIT** Close all connections and terminate the process. When a client exits, the server de-registers the client and sends the updated "Server-IP-List" to all the clients. Clients on receiving the updated list from the server should display the updated list.

**10. UPLOAD <connection id> <file name>** For example, 'UPLOAD 3 /local/Fall\_2014/dimitrio/a.txt' will upload the file a.txt which is located in /local/Fall\_2014/dimitrio/, to the host on the connection that has connection id 3. An error message is displayed if the file was inaccessible or if 3 does not represent a valid connection. **The remote machine will automatically accept the file and save it under the original name in the same directory where your program is.** When the upload is complete, this process will display a message indicating so. Also, the remote machine will display a message in its user interface indicating that a file (called a.txt) has been downloaded. When an upload is occurring, the user interface of the uploading process will remain unavailable until the upload is complete. Upon completion, a message is displayed. If the upload fails for some reason, an error message should be displayed. When an upload is occurring, a message should be displayed on the remote machine when the upload begins. If the upload fails for some reason, an error message should be displayed on the remote machine.

At the end of each successful upload, you will print the rate at which the Transmitter (Sender/Uploader) uploaded the file. Similarly, you will also print at the receiver the rate at which the file was received. We will call the transmission rate and receiving rate as Tx Rate and Rx Rate respectively. Tx rate is the amount of data (in Bits) transmitted divided by the time taken to read and send the complete file in chunks of *Packet Size* bytes each. Similarly, the Rx rate is defined as the total file size received (in bits) divided by the time taken to receive the file over the socket and write it to the disk. For example, if a file was uploaded from embankment to euston, the format for printing this information is:

*At Tx end:*

Tx: embankment -> euston, File Size: x Bytes, Time Taken: y seconds, Tx Rate: z bits/second

*At Rx end:*

Rx: embankment -> euston, File Size: a Bytes, Time Taken: b seconds, Rx Rate: c bits/second

**NOTE:** You should read the file in chunks of *packet size-byte* buffers and send those buffers using the send socket call, instead of reading the whole file at once. You can use UNIX utility function *gettimeofday* to know the time taken for receiving and sending the file at the two ends. Make sure to appropriately call this function in your program to account only for the time taken for uploading (reading and sending) and downloading (receiving and writing) the file. After printing this information, flush the standard output using *fflush*, to immediately print this information.

**NOTE:** UPLOAD command on the server should display an error message. No files should be uploaded to the server. Any such attempt should also display suitable error messages.

## 11. DOWNLOAD <connection id 1> <file1> <connection id 2> <file2> <connection id 3> <file3>

This command will download a file from each host specified in the command. Please note that the total number of hosts can be 1, 2 or 3. The hosts will be part of the list of hosts displayed with the LIST command.

E.g., if a command DOWNLOAD 2 file1 3 file2 4 file3 is entered for a process running on underground, then this process will request file1 from embankment, file2 from highgate and file3 euston. All these files are to be sent parallelly using TCP connections. The local machine will automatically accept the file and save it in the same directory where your program is under the original name. When the download is complete this process will display a message indicating so. Also, the remote machine will display a message in its user interface indicating that a file (e.g. a.txt, b.txt or c.txt) has been downloaded along with the hostname of the host from which the file was downloaded. Upon completion, a success message is displayed. If the download fails for some reason, an error message should be displayed. When a download is occurring, a message should be displayed on the local machine. If the download fails for some reason, an error message should be displayed on the remote machine.

Similar to the UPLOAD command, at the end of each successful download you will print Rx rate at which the Receiver downloaded those files and the Tx rates at which each Sender sent those files.

**NOTE:** Both notifications and data should use TCP connections. Make sure the clients send their files in parallel even though they cannot start sending files exactly at the same time.

**NOTE:** DOWNLOAD command on the server should display an error message. No files should be downloaded from the server. Any such attempt should also display suitable error messages.

**12. STATISTICS** Each client should maintain the following statistics about each of the clients displayed with the LIST command: number of uploads to that client, average upload speed (in bits/sec), number of downloads from that client, average download speed (in bits/sec). The server should also maintain the same statistics for all registered clients. Note that server does not perform any upload/download operations. It just collects the statistics from all clients and stores them locally.

When the command STATISTICS is executed on the *server*, the server should contact each client in the Server-IP-List, get updated statistics, and display all of them in the format shown in the example below:

*Upload refers to transfer of data from Hostname 1 to Hostname 2.*

*Download refers to transfer of data from Hostname 2 to Hostname 1.*

Hostname 1	Hostname 2	Total Uploads	Average upload speed (bps)	Total Downloads	Average download speed (bps)
embankment.cse.buffalo.edu	highgate.cse.buffalo.edu	5	563459295	11	248614521
euston.cse.buffalo.edu	embankment.cse.buffalo.edu	3	467234508	2	963466478
...	...	...	...	...	...

The output will contain all pairs of hosts that have at least one upload OR download operation executed between them. You do NOT need to show entries where both number of uploads and downloads equals zero.

When the command STATISTICS is executed on a *client*, the client should display the statistics it maintains locally. An example for the output format is shown below:

On *highgate.cse.buffalo.edu*, output might look like:

Hostname	Total Uploads	Average upload speed (bps)	Total Downloads	Average download speed (bps)
embankment.cse.buffalo.edu	5	563459295	11	248614521
euston.cse.buffalo.edu	3	467234508	2	963466478
underground.cse.buffalo.edu	2	134567098	0	0

The output will contain all the other peers/clients that have at least one upload OR download operation with this host. You do NOT need to show the clients that this client has never connected to before.

### 3.4 Before you begin coding...

In all likelihood, you will have a whole lot of questions about the assignment. Students before you (in previous versions of CSE 489/589) had too. We have collected the most common ones out of those as well as the most common pitfalls that students make while coding, which otherwise are easily avoidable, and put them together as FAQs. We strongly suggest that, after reading this handout, you go through the FAQs at <http://goo.gl/Wo9mpn>. In case you still have questions, the course blog is the place to go.

## 4. Analyze

Make sure you test your program for different values of file sizes between 1000 Bytes and 10 MBytes, and then for sizes {50, 70, 100, 150, 200} MBytes. You should also test your program for different packet sizes (or the size of the buffer you read from the file and send at a time using the send socket call), ranging from 100 Bytes to 1400 Bytes. These two parameters will be referred to as *File Size* and *Packet Size*. You can generate files of different sizes using the UNIX utility *dd*. For example, to generate a file of size 512 bytes, use the command:

```
dd if=/dev/zero of=test_file_to_create count=1
```

Here count=1 refers to 1 block of 512 bytes.

**NOTE:** Please delete these test files once you have tested your application and do not include any of these in your submission.

### 4.1 Data Rates vs. File Size

Run your application for different values of *File Size* between 1000 Bytes and 10 MBytes, and then for sizes {50, 70, 100, 150, 200} MBytes. Observe the Tx Rate and Rx Rates. Keep the *Packet Size* to be constant at 1000 Bytes and do a single file transfer at any time for these measurements.

Write down your observations. What variations did you expect for data rates by changing the file size and why? Do they agree with your measurements; if not, why? Remember to analyze the entire system, which includes not only the network, but also the Tx and Rx ends.

## 4.2 Data Rates vs. Packet Size

Run your application for different *Packet Sizes* (ranging from 100 Bytes to 1400 Bytes, by increasing in steps of 200 Bytes), and observe the Tx Rate and Rx Rates. Keep the file size constant at 200 MBytes and do a single file transfer at any time for these measurements. Write down your observations. What variations did you expect for data rates by changing the packet size and why? Do they agree with your measurements; if not then why? Remember to analyze the entire system, which includes not only the network, but also the Tx and Rx ends.

## 4.3 Data Rates vs. Load Variations

Run your application on different machines, and start multiple file transfers over the network at the same time. Vary the load over the network, by varying the number of simultaneous file transfers from 1 through 3, i.e., {1,2,3}. Keep the File Size constant at 70 Mbytes and Packet Size at 1000 Bytes for all transfers.

Write down your observations. What variations did you expect for data rates by changing the load and why? Do they agree with your measurements; if not then why? Remember to analyze the entire system, which includes not only the network, but also the Tx and Rx ends.

## 4.4 Install iperf and Measure Network Bandwidth

Iperf is a tool for measuring network performance, especially the maximum TCP/UDP bandwidth available. For more information about the tool, refer to its homepage.

Install iperf :

1. On a CSE student server (e.g., dokken) download iperf source, by using this command:  
wget <http://sourceforge.net/projects/iperf/files/iperf-2.0.5.tar.gz>
2. Untar the source and examine its README.
3. Execute ./configure
4. make (Do not go for the make install step)
5. To run iperf between two machines say dokken (server) and embankment (client), run the iperf binary as follows.(You may add TCP port number which is not showed in this example):

On the server:

```
dokken {~/iperf-2.0.5/src} > ./iperf -s
```

Then on the client:

```
embankment {~/iperf-2.0.5/src} > ./iperf -c timberlake.cse.buffalo.edu
```

**NOTE:** To measure the available bandwidth, you run iperf on one machine which acts as a server and another which acts as a client. The client sends packets (TCP) to the server as fast as it can, and measures the network bandwidth. For more information regarding this, refer to iperf help.

Analysis: Observe the available bandwidth which iperf outputs for 1 client and then increase the number of clients from 1 through 3, by running the iperf on other client machines also as you did on embankment above.

Compare the results (available bandwidth) of iperf for a single client and for multiple clients (load variations) with the results obtained from your File Sharing Application (section 4.3). Justify why do/don't they conform to each other. Briefly record all your analysis and observations for sections 4.1, 4.2, 4.3 and 4.4 in a file called Analysis\_Assignment1.txt or Analysis\_Assignment1.pdf and turn in with your implementation.

## 5. Submission and Grading

### 5.1 What to Submit

Your submission should contain a tar file – Name it as <your ubit\_name>.tar:

- All source files including Makefile. The Makefile should be named as Makefile and NOT any other name. Further Makefile should generate a *single* executable named *assignment1*. *DON'T submit separate programs for client and server.*
- The source containing the main() function should be named as <ubit\_name>\_assignment1.c/<ubit\_name>\_assignment1.cpp  
For example, dimitrio\_assignment1.c/dimitrio\_assignment1.cpp
- Your analysis for sections 4.1, 4.2, 4.3 and 4.4 in a file named Analysis\_Assignment1.txt/pdf. The analysis document will reside in the same directory as the Makefile.  
(Usage of graphs for your analysis is highly recommended.).

### 5.2 Starter Template/Module

We have often observed that many students fail to adhere to the submission instructions and/or naming conventions described above. This results in loss of points from the total grade of the assignment. To remedy this, we have prepared a template that can take care of most of such requirements for you and provide you with a good starting point to begin coding. To get the template and instructions on using it, visit <http://goo.gl/cn9QLq>

### 5.3 How to submit

Use the submission command submit\_cse589 to submit the tar file.

### 5.4 Grading Criteria

- In general, we care about:
  - Correctness of output.
  - Appropriate error-handling.
  - Your analysis.
  - Organization and documentation of your code.

Refer to PA1\_grading\_guidelines.pdf for a more detailed breakdown of the grading criteria.



### 5.5 Important Key Points:

- *All commands are case-insensitive.*
- *Error Handling is very important – Appropriate messages should be displayed when something goes bad.*
- *DON'T ASSUME. If you have any doubts in project description ask the TAs.*
- *Please follow the naming conventions mentioned in the submission guidelines. We will only evaluate the last received submission named as per the guidelines.*
- *Submission deadline is hard. No extensions. Any submission after 23:59:59 of September 26<sup>th</sup> 2014 EDT will be considered as late submission.*
- *Please do not submit any binaries, object or test files.*