Assignment 1: Sockets, Mininet, & Performance

CS640 Spring 2015

Due: Tuesday, February 10 at 11pm

Overview

Iperf is a common tool used to measure network bandwidth. You will write your own version of this tool in Java using sockets. You will then use your tools to measure the performance of virtual networks in Mininet and explain how link characteristics and multiplexing impact performance.

Learning Outcomes

After completing this programming assignment, students should be able to:

- Write applications that use sockets to transmit and receive data across a network
- Describe how latency and throughput can be measured
- Explain how latency and throughput are impacted by link characteristics and multiplexing

Clarifications

- The `Iperfer` server should shut down after it handles one connection from a client.

Part 1: Write Iperfer

For the first part of the assignment you will write your own version of `iperf` to measure network bandwidth. Your tool, called **`Iperfer`**, will send and receive TCP packets between a pair of hosts using sockets. When operating in *client mode*, `Iperfer` will send TCP packets to a specific host for a specified time window and track how much data was sent during that time frame; it will calculate and display the bandwidth based on how much data was sent in the elapsed time. When operating in *server mode*, `Iperfer` will receive TCP packets and track how much data was received during the lifetime of a connection; it will calculate and display the bandwidth based on how much data was received and how much time elapsed between received the first and last byte of data.

Client Mode

To operate `Iperfer` in client mode, it should be invoked as follows:

```
java Iperfer -c -h <server hostname> -p <server port> -t <time>
```

- ***`-c`*** indicates this is the iperf client which should generate data
- ***`server hostname`*** is the hostname or IP address of the iperf server which will consume data
- ***`server port`*** is the port on which the remote host is waiting to consume data; the port should be in the range 1024 < *`server port`* < 65535
- ***`time`*** is the duration in seconds for which data should be generated

You can use the presence of the **-c** option to determine `Iperfer` should operate in client mode.

If any arguments are missing or additional arguments are provided, you should print the following and exit:

```
  Error: missing or additional arguments
```

If the ***server port*** argument is less than 1024 or greater than 65535, you should print the following and exit:

```
  Error: port number must be in the range 1024 to 65535
```

When running as a client, `Iperfer` must establish a TCP connection with the server and send data as quickly as possible for *`time`* seconds. Data should be sent in chunks of 1000 bytes and the data should be all zeros. Keep a running total of the number of bytes sent.

After *`time`* seconds have passed, `Iperfer` must stop sending data and close the connection. `Iperfer` must print a one line summary that includes:

- The total number of bytes sent (in kilobytes)
- The rate at which traffic could be sent (in megabits per second (Mbps))

For example:

```
  sent=6543 KB rate=5.234 Mbps
```

You should assume 1 kilobyte (KB) = 1000 bytes (B) and 1 megabyte (MB) = 1000 KB. As always, 1 byte (B) = 8 bits (b).

Server Mode

To operate `Iperfer` in server mode, it should be invoked as follows:

```
java Iperfer -s -p <listen port>
```

- ***-s*** indicates this is the iperf server which should consume data
- ***listen port*** is the port on which the host is waiting to consume data; the port should be in the range 1024 < *`listen port`* < 65536

You can use the presence of the **-s** option to determine `Iperfer` should operate in client mode.

If arguments are missing or additional arguments are provided, you should print the following and exit:

```
  Error: missing or additional arguments
```

If the ***listen port*** argument is less than 1024 or greater than 65535, you should print the following and exit:

```
  Error: port number must be in the range 1024 to 65535
```

When running as a server, `Iperfer` must listen for TCP connections from a client and receive data as quickly as possible until the client closes the connection. Data should be read in chunks of 1000 bytes. Keep a running total of the number of bytes received.

After the client has closed the connection, `Iperfer` must print a one line summary that includes:

- The total number of bytes received (in kilobytes)
- The rate at which traffic could be read (in megabits per second (Mbps))

For example:

```
  received=6543 KB rate=4.758 Mbps
```

The `Iperfer` server should shut down after it handles one connection from a client.

Testing

You can test `Iperfer` on any machines you have access to. However, be aware the certain ports may be blocked by firewalls on end hosts or in the network, so you may not be able to test your program on all hosts or in all networks. You should be able to use two machines in the CS labs without any problems.

You can also test your tool using Mininet. Instructions are provided in Appendix A. You should complete Part 2 of this assignment before following the instructions in Appendix A.

You should receive the same number of bytes on the server as you sent from the client. However, the timing on the server may not perfectly match the timing on the client. Hence, the bandwidth reported by client and server may be slightly different; in general, they should not differ by more than 2 Mbps. Note, this behavior mirrors the behavior of the actual iperf tool.

Part 2: Mininet Tutorial

For the third part of the assignment, you will learn how to use Mininet to create virtual networks and run simple experiments. According to the Mininet website, *Mininet creates a realistic virtual network, running real kernel, switch and application code, on a single machine (VM or native), in seconds, with a single command.* We will use Mininet in programming assignments throughout the semester.

Running Mininet

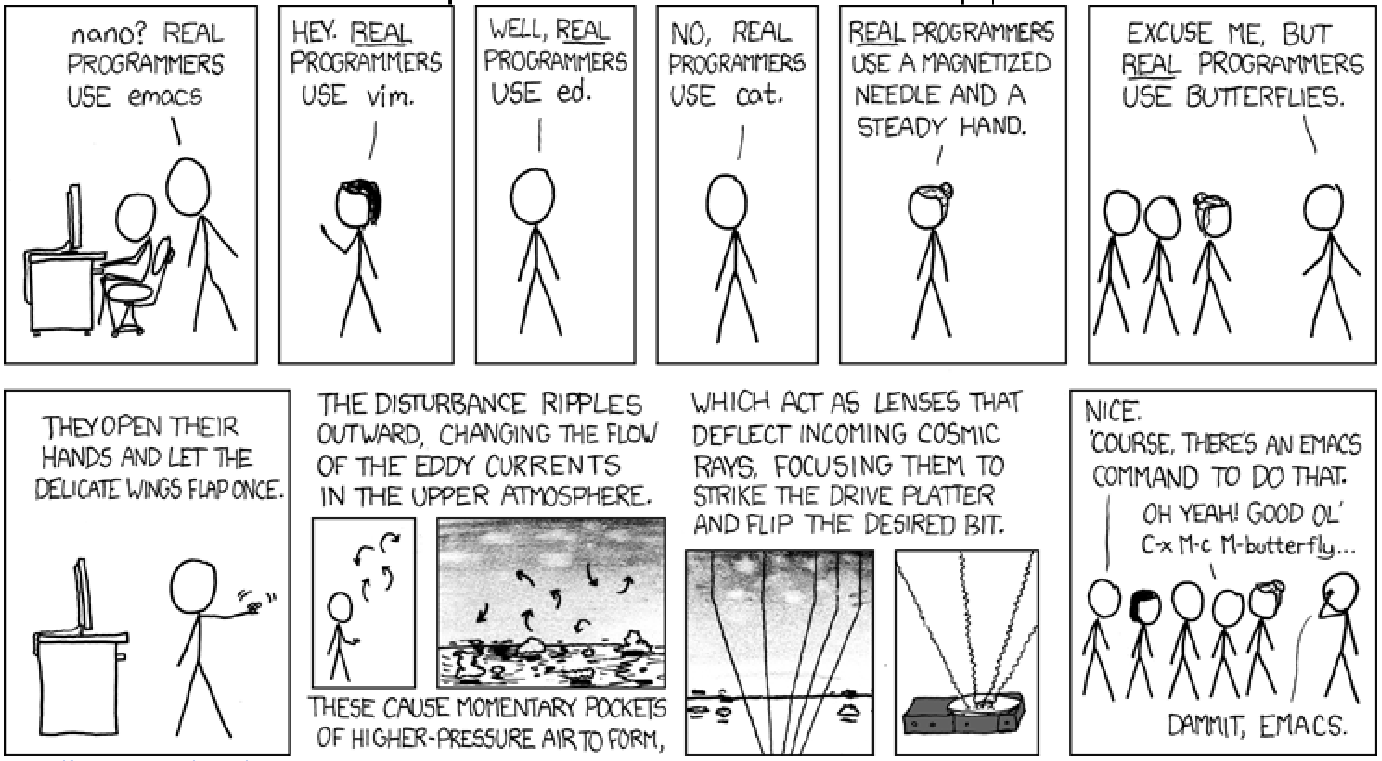
To run Mininet, you will need a virtual machine (VM) in the Instructional Virtual Lab. To be assigned a VM, visit http://sdn.cs.wisc.edu/mininet and login with your CS username and password. You must provide the CS username of your partner when you request a VM for your group.

You should use SSH, not the VMware remote console, to access your VM. When you connect via SSH, you should include the `-X` option to tunnel X11 (i.e., graphics) over SSH. For example:

```
  ssh -X ubuntu@mininet-99.cs.wisc.edu
```

You can only access your VM via SSH from within the CS network—i.e., from a machine in one of the instructional labs, an office machine (for grad students), a personal machine connected to the CS wireless network, or a personal machine with a VPN connection to the CS network. Also, you will need to have X11 installed on the machine from which you are connecting. X11 is installed by default on Linux machines in the CS department; on a personal machine, you can install Xming (Windows), Quartz (Mac OS), or a graphical environment (Linux) to get X11.

You should only need X11 to run xterms in Mininet. For editing files **now is the opportune time to learn a text editor that doesn't require a GUI!** Vim and emacs are the most popular.


nano? REAL PROGRAMMERS USE emacs
HEY. REAL PROGRAMMERS USE vim.
WELL, REAL PROGRAMMERS USE ed.
NO, REAL PROGRAMMERS USE cat.
REAL PROGRAMMERS USE A MAGNETIZED NEEDLE AND A STEADY HAND.
EXCUSE ME, BUT REAL PROGRAMMERS USE BUTTERFLIES.
THEY OPEN THEIR HANDS AND LET THE DELICATE WINGS FLAP ONCE.
THE DISTURBANCE RIPPLES OUTWARD, CHANGING THE FLOW OF THE EDDY CURRENTS IN THE UPPER ATMOSPHERE.
THESE CAUSE MOMENTARY POCKETS OF HIGHER-PRESSURE AIR TO FORM,
WHICH ACT AS LENSES THAT DEFLECT INCOMING COSMIC RAYS, FOCUSING THEM TO STRIKE THE DRIVE PLATTER AND FLIP THE DESIRED BIT.
NICE.
'COURSE, THERE'S AN EMACS COMMAND TO DO THAT.
OH YEAH! GOOD OL' C-x M-c M-butterfly...
DAMMIT, EMACS.
http://xkcd.com/378/

To transfer files to/from your VM you should use the `scp` (secure copy) command. See the `scp` man page, or find a tutorial online, for instructions on how to use scp. You could also use a revision control system, such as Git or Subversion, and checkout a copy of the repository in your VM.

Mininet Walkthrough

Once you have a Mininet VM, you should complete the following sections of the standard Mininet walkthrough:

- All of Part 1, except the section "Start Wireshark"
- The first four sections of Part 2—"Run a Regression Test", "Changing Topology Size and Type", "Link variations", and "Adjustable Verbosity"
- All of Part 3

At some points, the walkthrough will talk about software-defined networking (SDN) and OpenFlow. We will discuss these during the second half of the semester, so you do not need to understand what they mean right now; you just need to know how to run and interact with Mininet.

To change the background color of xterm windows to make them more readable, run the following command in your Mininet VM (in a regular shell, not while Mininet is running):

```
 echo "XTerm*Foreground: black" > ~mininet/XTerm
```

You do not need to submit anything for this part of the assignment.

Part 3: Measurements in Mininet

For the last part of the assignment you will use the tool you wrote (`Iperfer`) and the standard latency measurement tool `ping`, to measure the bandwidth and latency in a virtual network in Mininet. You must include the output from some of your experiments and the answers to the questions below in your submission. Your answers to the questions should be put in a file called `answers.txt`.

Read the `ping` man page to learn how to use `ping`.

You must install Java in your Mininet VM before you can run `Iperfer`. You can install Java by running the following commands:

```
 sudo apt-get update
 sudo apt-get install openjdk-7-jdk
```

A python script to run Mininet with the topology described below is located at: http://cs.wisc.edu/~agember/cs640/s15/files/assign1.tgz. To download the script in your Mininet VM, run:

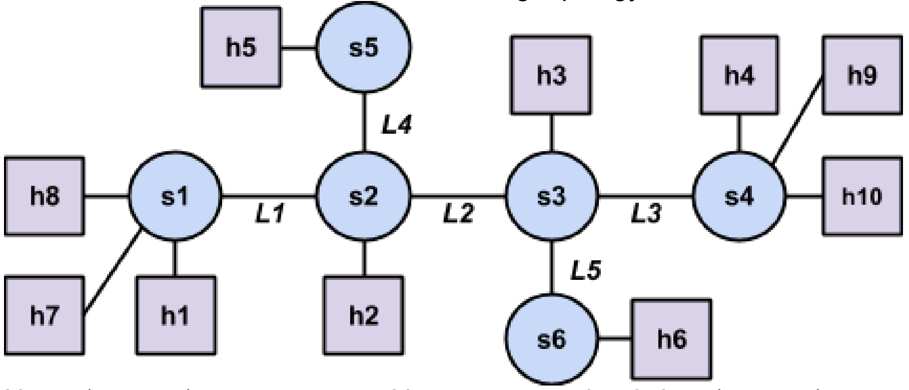
```
  wget http://cs.wisc.edu/~agember/cs640/s15/files/assign1.tgz
 tar xzvf assign1.tgz
```

Q1: Link Latency and Throughput

To run Mininet with the provided topology, run the Python script `assign1_topo.py` using sudo:

```
  sudo python assign1_topo.py
```

This will create a network with the following topology:



Hosts (`h1` - `h6`) are represented by squares and switches (`s1` - `s6`) are represented by circles; the names in the diagram match the names of hosts and switches in Mininet. The hosts are assigned IP addresses `10.0.0.1` through `10.0.0.10`; the last number in the IP address matches the host number. When running `ping` and `Iperfer` in Mininet, you **must use IP addresses**, not hostnames.

First, you should measure the RTT and bandwidth of each of the five individual links between switches (`L1` - `L5`). You should run `ping` with 20 packets and store the output of the measurement on each link in a file called `latency_L#.txt`, replacing `#` with the link number from the topology diagram above. You should run `Iperfer` for 20 seconds and store the output of the measurement on each link in a file called `throughput_L#.txt`, replacing `#` with the link number from the topology diagram above.

Q2: Path Latency and Throughput

Now, assume h1 wants to communicate with h4. What is the expected latency and throughput of the path between the hosts? Put your prediction in your `answers.txt` file.

Measure the latency and throughput between `h1` and `h4` using `ping` and `Iperfer`. It does not matter which host is the client and which is the server. Use the same parameters as above (20 packets / 20 seconds) and store the output in files called `latency_Q2.txt` and `throughput_Q2.txt`. Put the average RTT and measured throughput in your `answers.txt` file and explain the results. If your prediction was wrong, explain why.

Q3: Effects of Multiplexing

Next, assume multiple hosts connected to `s1` want to simultaneously talk to hosts connected to `s4`. What is the expected latency and throughput when two pairs of hosts are communicating simultaneously? Three pairs? Put your predictions in your `answers.txt` file.

Use `ping` and `Iperfer` to measure the latency and throughput when there are two pairs of hosts communicating simultaneously; it does not matter which pairs of hosts are communicating as long as one is connected to `s1` and one is connected to `s4` . Use the same parameters as above. You do not need to submit the raw output, but you should put the average RTT and measured throughput for each pair in your `answers.txt` file and explain the results. If your prediction was wrong, explain why.

Repeat for three pairs of hosts communicating simultaneously.

Q4: Effects of Latency

Lastly, assume `h1` wants to communicate with `h4` at the same time `h5` wants to communicate with `h6`. What is the expected latency and throughput for each pair? Put your prediction in your `answers.txt` file.

Use `ping` and `Iperfer` to conduct measurements, storing the output in files called `latency_h1-h4.txt`, `latency_h5-h6.txt`, `throughput_h1-h4.txt`, and `throughput h5-h6.txt`. Put the average RTT and measured throughput in your `answers.txt` file and explain the results. If your prediction was wrong, explain why.

Submission Instructions

You must submit:

- The source code for `Iperfer`—all Java source files for `Iperfer` should be in a folder called `iperfer`; the folder should include a Makefile that compiles the Java source
- Your measurement results and answers to the questions from Part 3—all results and a text file called `answers.txt` should be in a folder called `measurement`
- A `README` file with the names and CS usernames of both group members

You must submit a single tar file containing the above. To create the tar file, run the following command, replacing username1 and username2 with the CS username of each group member:

```
  tar czvf username1_username2.tgz iperfer measurement README
```

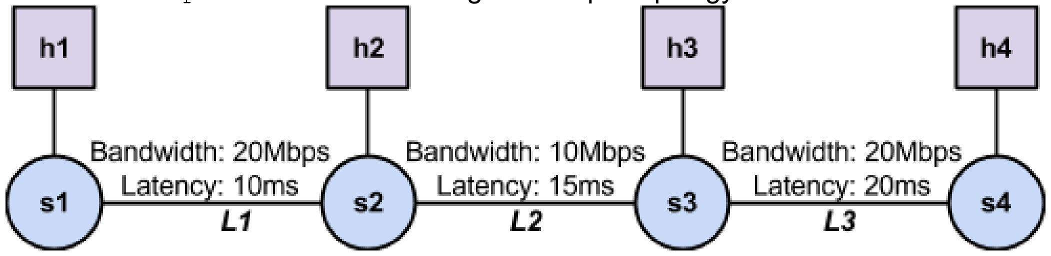
Upload the tar file to the *Assignment 1* dropbox on Learn @ UW. Please submit only one tar file per group.

Appendix A: Testing Iperfer in Mininet

You must install Java in your Mininet VM before you can run `Iperfer`. You can install Java by running the following commands:

```
 sudo apt-get update
 sudo apt-get install openjdk-7-jdk
```

You can test `Iperfer` in Mininet using the sample topology shown below.



A python scripts to run Mininet with this topology described below is located at: http://cs.wisc.edu/~agember/cs640/s15/files/assign1.tgz. To download the scripts in your Mininet VM, run:

```
  wget http://cs.wisc.edu/~agember/cs640/s15/files/assign1.tgz
 tar xzvf assign1.tgz
```

To run Mininet with the provided topology, run the Python script `assign1_test.py` using sudo:

```
  sudo python assign1_test.py
```