Cpr E 489: Computer Networking and Data Communications
Lab Experiment #9 – CloudLab Experiment: TCP Congestion Control
(Total Points: 100)

Objective

Using CloudLab to evaluate a TCP congestion protocol by collecting, visualizing, and analyzing data.

Pre-Lab

Before the lab starts, you may follow the instructions below to prepare you CloudLab experiment.

Lab Expectations

Work through the lab and let the TA know if you have any questions. After the lab, write up a lab report and be sure to:

- Attend the lab. **(5 points)**
- Summarize what you learned in a few paragraphs. **(25 points)**
- Include your answers to all exercises with screenshots when asked. **(70 points)**

Procedure

Prepare Your Experiment

1) If you haven't already, login to Cloudlab at: https://www.cloudlab.us/login.php
2) Select **Experiments** and **Start Experiment**.
3) Select **Change profile**, search for **cpre489-tcpcongestion**, and select it.
4) Click **Select Profile** and then **Next**.
5) Use your net-id for the name of the experiment and select a cluster with a green dot next to it. Then select **Next** and then **Finish**.
6) Wait for your resources to be ready. This may take several minutes. If you receive an email regarding the image of your nodes being outdated, ignore it.
7) Log into **client** and **server** nodes via SSH. Use the same technique you used in Lab 4.

Exercise 1: Generate Data

1. On the **client**, load the tcp_probe kernel module, and tell it to monitor traffic to/from TCP port 5001:
```
sudo modprobe tcp_probe port=5001 full=1
sudo chmod 444 /proc/net/tcpprobe
```
2. On the **server**, run
```
iperf -s
```
3. On the **client**, run
```
dd if=/proc/net/tcpprobe ibs=128 obs=128 | tee /tmp/tcpprobe.dat
```
4. Open another SSH session to the **client** and run
```
iperf -t 60 -c server -P 3
```
5. Wait for iperf to complete on the **client**. It will take about a minute. In the window where the TCP probe is running, you should see a line of output for each TCP packet. Take screenshots of the probe and iperf output for the running results. **(10 points)**
6. The output of the TCP probe will be saved in /tmp/tcpprobe.dat on the **client**. Exit all SSH sessions and use the following scp command to transfer this file to your own machine for processing. Substitute your username or net ID for **username** or **netid**, the node's host name for **hostname** or **host**, and the SSH port number for **portnum**.
```
scp -i <private_key> -P <port> netid@hostname:file_location dest_location
```

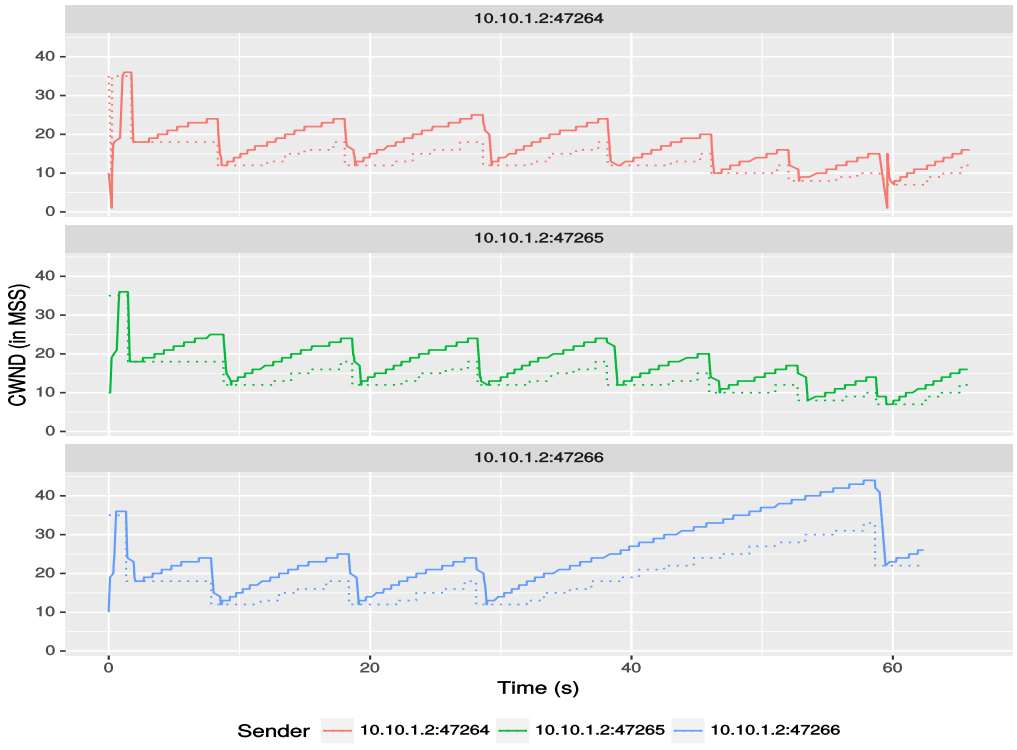
The TCP probe module records a line of output every time a packet is sent, if either the destination or source port number in the TCP packet header is 5001 (since we loaded it with the port=5001 option). Each line of output will include the following fields, in order:

Field	Explanation
Time	Time (in seconds) since beginning of probe output
Source	Source address and port of the packet, as IP:port
Destination	Destination address and port of the packet, as IP:port
Bytes	Bytes in packet
Next	Next send sequence number, in hex format
Unacknowledged	Smallest sequence number of packets sent but unacknowledged, in hex format
cwnd	Size of send congestion window for this connection (in MSS)
ssthresh	Slow-start threshold for this connection (in MSS)
Send window	Send window size (in MSS) – set to the minimum of send CWND and receive window size
Smoothed RTT	Smoothed estimated RTT for this connection (in ms)
Receive window	Receiver window size (in MSS), received in the last ACK. This limit prevents the receiver buffer from overflowing, i.e., prevents the sender from sending at a rate that is faster than the receiver can process the data.

Exercise 2: Data Analysis

Create a plot of the congestion window size and slow start threshold for each TCP flow over the duration of the experiment, similar to the figure below. (10 points)

There should be three graphs: one for each of the three iperf connections, indicated by the source port number (the IP Addresses will be the same).



Annotate your plot, to show the following: (20 points)

- Periods of **Slow Start**
- Periods of **Congestion Avoidance**
- Instances where 3 duplicate ACKs were received (which will trigger **Fast Recovery**)
- Instances of **Timeout**

Using your plot and/or experiment data, **explain how the behavior of TCP is different in the Slow Start and Congestion Avoidance phases. (10 points)**

Also, using your plot, **explain what happens to both the congestion window and the slow start threshold when 3 duplicate ACKs are received. (10 points)**

Exercise 3: Clean Up Your Work

1) Terminate your experiments and take a screenshot of your empty experiment list after completing the lab. Include a screenshot in your lab report. **(10 points)**

Tips

- After 16 hours, your resources will automatically be terminated. If you wish to extend their reservation you must **Extend** the resources. This button is located next to **Terminate**.
- It is **recommended** to complete this lab on your own lab account so that your SSH keys will be on your student X drive. Using 489labuser will leave your keys on the lab computer unless extra steps are taken.
- Refer back to Lab 4 if you've forgotten how to do certain actions such as starting and termination an experiment.
- You may observe ssthresh sizes that are abnormally large (e.g., the maximum 32-bit integer value) during the beginning of transmission. Omitting these values or replacing them with interpolated values is okay for the purposes of this lab.