Project 3 - TCP Fast Open

(Based on a reproducing network research post)

Goal

The goal of this project is to learn about a specific change to TCP that reduces transfer latency. In the past lesson you learned about persistent TCP connections which enable a web browser to reuse a connection for multiple data requests. However, many HTTP requests occur over **new** TCP connections. For example, an image embedded in a web page may be located on a separate content server, or an ad is being loaded from a third party server, requiring a new TCP connection to be opened to obtain that image to properly display the webpage.

This insight led researchers at Google to investigate reducing the setup costs for a TCP connection. They developed TCP Fast Open (TFO) which permits sending data during the TCP handshake, ultimately reducing the load latency of a web resource by one round trip time (RTT). In this and the next two projects, you will dive into recent research in Computer Networks by replicating and extending the experimental results from a research paper in Mininet. In this project specifically, you will observe how TCP Fast Open improves HTTP transaction times for real websites.

The test setup provided uses a modified Chrome binary to download web pages from Mininet hosts acting as web servers. These hosts are hosting mirrored data pulled from real websites. The tests run for different latencies with TCP Fast Open disabled, and then enabled. TFO is a now a part of the Linux kernel, so it is built into our course VM.

NOTE: By default, the VM boots to a MPTCP enabled kernel, which will be used in Project 5. You will need to boot a different kernel for this project only.

To boot the other kernel:

1. Shut down your VM. You may need to completely power off your VM for this to work correctly.
2. Launch the VM, and click inside the VM window during the boot process.
3. Hold Shift during the boot screen. (On Mac, be sure to hold shift from the first image that appears or try holding down esc.)
4. The GRUB Menu should open. Select "Advanced Options for Ubuntu"
5. Select Ubuntu, with Linux 3.16.0-57 generic and hit enter.

Note: If you have made modifications to the VM (including disabling the second network adapter, working with shared folders, or SSH into the VM), your experiment may not work correctly. Attempt to work from a VM without modification. If that does not work, be sure to note any unexpected results in your analysis.
Note: Password for the VM is mininet.

It is advised to take snapshots of your VM and to reinstall the VM if you do not obtain good results (i.e., your graphs are just vertical bars).

Directions

1. Download the project code and modify permissions with "$ sudo chmod 777 -R . " within the project code directory if necessary.
2. Reference the assigned reading. We will be replicating the experimental results, as well as trying our own test cases. Additionally, the paper is a good reference for interpreting your results when answering the questions asked at the end of the experiment.
3. Familiarize yourself with the code that will run the experiment.

    a. `run.sh` - Shell script that runs the experiment under several different delay parameters with TFO disabled and enabled.

    b. `tfo.py` - Python script used to execute the simulation. Step through this file at a high level to understand how the experiment is run, and compare this to the methodology used in the original paper. You SHOULD NOT modify this file.

    c. `tfo-test/` - directory containing various scripts and executable code run on the hosts in the simulation.

d. `fetch.py` - script to automate downloading your own test data from the Internet.

e. `output-figures/` - directory for storing output performance graphs generated at the end of the experiment.

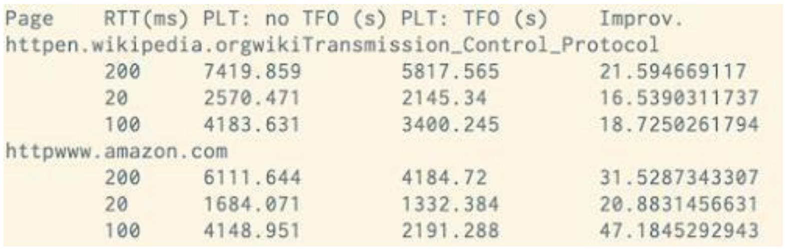
4. Run the experiment to replicate the paper by executing the following commands:

   a. `vnc4server` (The command may ask you to set a password, you can just use `mininet` for consistency. If you get an error with SIGINT, try changing SIGINT to INT in the script.)

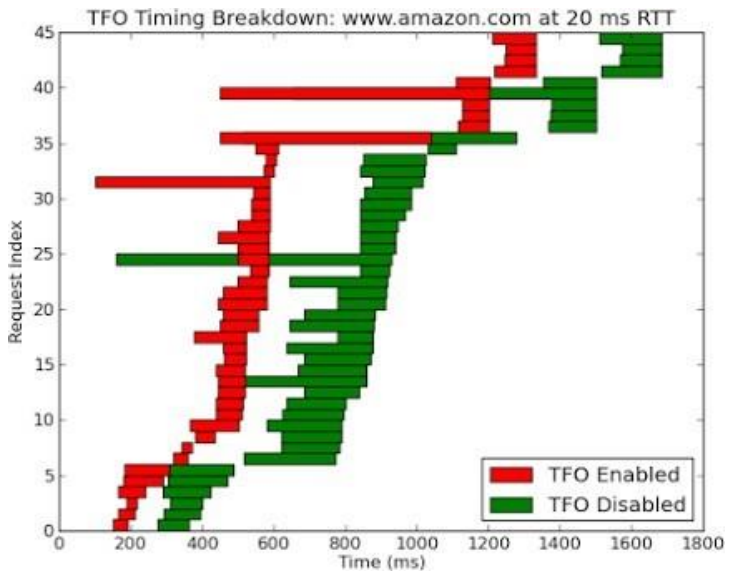
   b. `sudo ./run.sh`

5. The experiment takes some time to complete. When it's finished you should see results similar to the image below. Be sure to copy and paste this text into a text file named `observations.txt` for your final submission.

6. You can also view graphs of the results in the `output-figures` folder. On the graph, each request index represents one of the multiple requests to load the entire web page as the HTML references multiple objects on the page. For each request index, the bars represent the start and end time to download the page with TFO enabled and TFO disabled. In some cases, the red bar for TFO Enabled may overlap the timing for TFO Disabled.



```
Page    RTT(ms) PLT: no TFO (s) PLT: TFO (s)    Improv.
httpen.wikipedia.orgwikiTransmission_Control_Protocol
        200     7419.859        5817.565        21.594669117
        20      2570.471        2145.34         16.5390311737
        100     4183.631        3400.245        18.7250261794
httpwww.amazon.com
        200     6111.644        4184.72         31.5287343307
        20      1684.071        1332.384        20.8831456631
        100     4148.951        2191.288        47.1845292943
```



7. Next, you will run the experiment using your own set of websites. To do this, you'll need to

   create a `.pages` file with a list website URLS each on a single line similar to the

   `Paper.pages` file included with the project. For simplicity, name the file `myURLS.pages`. Be

   sure your file contains at least 3, but no more than 5 distinct URLs, from different domains

   (i.e. do not specify 5 different pages on gatech.edu).

   NOTE: The script has issues with Javascript heavy web pages, as well as `https`

   sites. Homepages for academic institutions like GT, blog posts, and newspaper websites

   work well as test sites. Also, if you shutdown the virtual machine in between runs of the

   experiment, be sure to restart VNC Server. **You are welcome to share sites that work with**

   the fetch script on Piazza with your classmates!

8. Next, run the `fetch.py` script to download the web pages: `./fetch.py --name myURLS`

9. You will also need to modify the `run.sh` script on lines 21 and 29 to reference
`myURLS.pages`.

10. Re-run the experiment and generate your experimental data: `sudo ./run.sh`

    If your experiment takes more than a few minutes, try simpler websites with less scripting. If

    your graphs look like two solid vertical bars, try shutting down your VM and running the project again, including booting from the other kernel. Make sure you are running vnc4server. You may need to restart vnc4server 3-4 times to get good results. Try different websites. Check the kernel: for instance: `uname -r` should give you an output of `3.16.0-57-generic`.

11. Finally, you will create a detailed yet concise (no longer than 2 pages with default font size, spacing and margins such as Arial size 10.5 font, 1.5 line spacing, 0.5" margins) report analyzing your results. Your analysis should include:
    a. A brief introduction of raw experimental data generated (copy the raw data from the console and explain it)
    b. Your analysis should answer the following questions for **each** URL you specified:
        i What effect does TFO have on the timing?
        ii How does the RTT value affect these results?
        iii Does the particular content available at this URL lend itself to performance enhancements provided by TFO?
        iv Were these results surprising in any way?
        v Include all graphs from the output-figures folder (images do not count toward your two page limit).

    c. Include a brief summary of your findings and state what conclusions you can draw based on the results of your experiment.

    d. Based on the reading and your experiment, in which of your website experiment scenarios do you see TCP Fast Open having the most performance gain over TCP? What about the worst?

12. Save your report as a PDF file named `Analysis.pdf`. Carefully format your report so the graders can easily identify that you have fully answered each question, including each sub-question under 11.b for every URL. For example, number each of your answers clearly. Double check that you have included all requested analysis, raw data, and graphs.

What to turn in

You will turn in the following files on Canvas: `Analysis.pdf` directly as a PDF, and the two files `observations.txt` and `myURLS.pages` zipped into a single file as follows:

For `observations.txt` and `myURLS.pages`, create a zip file named `gtlogin_p3.zip`. Substitute your GT login for gtlogin in the filename (example: smith7_p3.zip) and use the following command in the VM:

```
zip gtlogin_p3.zip observations.txt myURLS.pages
```

Turn in `Analysis.pdf` to the Canvas assignment named:

Project 3 - TCP Fast Open (.pdf submission)

Turn in `gtlogin_p3.zip` to the Canvas assignment named:

Project 3 - TCP Fast Open (.zip submission)

NOTE: It is fine if you resubmit and canvas appends a digit to the name of the zip file.

Note on Creating PDFs and Turnitin Plagiarism Check

We recommend you use Microsoft Word to generate the PDF you will turn in. We use Turnitin to check for plagiarism. Turnitin needs to be able to see a PDF file with selectable text. DO NOT create a PDF with all images -- you should be able to copy the text portion from your PDF and paste it into other applications. **Submitting a PDF made entirely of images may result in a 0 grade for the PDF.**

What you can (and cannot) share

Do **not** share the following files with your fellow students, on Piazza, or publicly:

1. `observations.txt`
2. `Analysis.pdf`

You **may**, and are highly encouraged to, share your interesting and or unique `.pages` files as well as the graphs of their performance. Are there sites out in the wild that TFO does not provide a significant increase in performance? Are there sites for which TFO had unexpectedly amazing results? Feel free to discuss with your fellow classmates on Piazza!

Grading

5 pts	Correct Submission	for turning in the correct files, with the correct names, and significant effort has been made towards completing the project per the instructions.
10 pts	Replicated Research	for correct experimental data produced in steps 5-7, located in `observations.txt`.
35 pts	Experimental Analysis	for your detailed, yet concise analysis of your results obtained in steps 8-11. Be sure to answer the questions specified and include the appropriate data/graphs in order to receive full credit.

Notes and Tips

1. Make sure your files all have the correct permissions: $ sudo chmod 777 -R .
2. If you get an error with SIGINT, try changing SIGINT to INT in the script
3. The script has issues with Javascript heavy web pages, as well as https sites. Try different websites.
4. If you shutdown the virtual machine in between runs of the experiment, be sure to restart VNC Server
5. Make sure you are running vnc4server. You may need to restart vnc4server 3-4 times to get good results.
6. If your graphs look like two solid vertical bars, try shutting down your VM and running the project again, including booting from the other kernel.
7. Check the kernel: for instance, `uname -r` should give you an output of `3.16.0-57-generic`.
8. The following change to line 99 of plot.py

    ```
    rects1 = plt.barh(np.arange(len(tfo_len)), tfo_len, height * 0.75,
    ```

    will make the tfo enabled plot line 3/4 of the size of the tfo disabled plot line. Feel free to dig into plot.py to make changes to the appearance of your graphs.