CS 3251: Computer Networking I (Section A and B) **Fall 2023**

Programming Assignment 2

Handed Out: 10/31/2023 *Due: 11/28/2023*

1 Introduction

In this assignment, you will implement your own congestion control algorithm. Specifically, you will implement the congestion avoidance component of TCP Vegas. The goal of the assignment is to help you understand how congestion control algorithms are implemented and tuned. Thus, we do not expect you to write a lot of code as this implementation builds upon the existing UDT4 codebase [1].

TCP Vegas is a delay-based CC algorithm that attempts to estimate the congestion in the network based on sample RTTs and uses this to adjust the Congestion Window (`CWND`) before a loss event happens. Start by reviewing the Vegas paper, mainly the Abstract and Techniques(Section 3.2). You will be implementing section 3.2 only.

This implementation, as evident in the provided template, utilizes UDT's Configurable Congestion Control (CCC) class.

We expect you to implement a fully functioning algorithm that keeps queues short and achieves high utilization. Your grade will be based on the performance of your implementation.

2 Instructions

2.1 Implementing the Congestion Control Algorithm

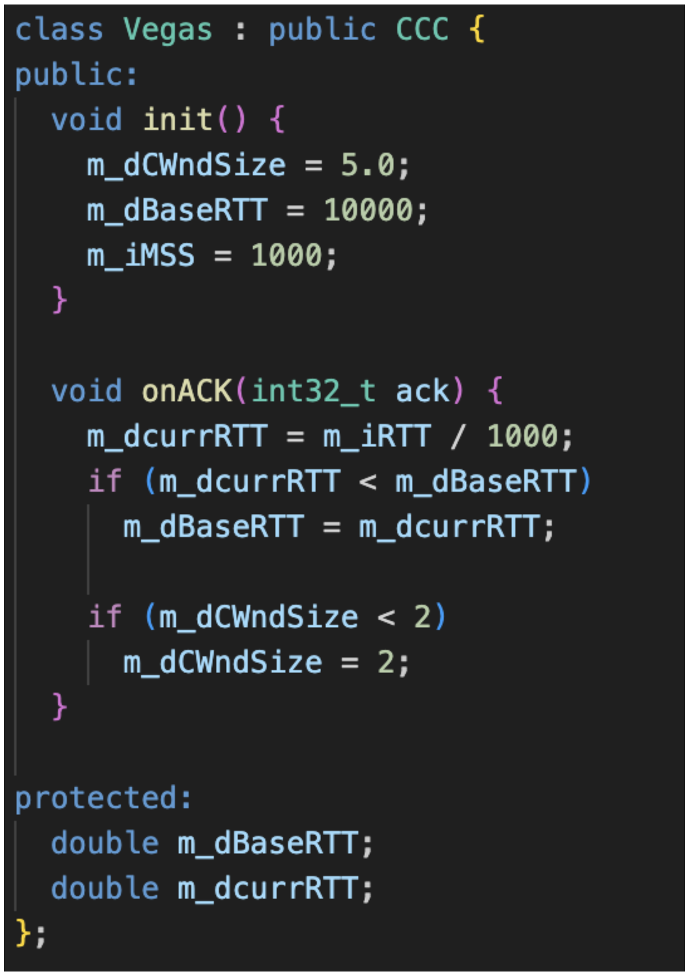
You will implement your algorithm in the `Vegas` class of the `src/cc.h` file, which inherits from the `CCC` class. We have provided a template implementation in the `src/cc.h` file. Read over the comments in the file and complete your implementation in the marked sections.

- You must implement the Vegas algorithm in the onACK() function of the Vegas class. The code structure is shown in Figure 1.
- The `CCC` class already has member variables that are populated by UDT to measure the RTT (`CCC::m\_iRTT`). You can set CWND simply by assigning a value to `Vegas::m_dCWndSize`.
- In the provided skeleton, we already initialized some variable for you. Please do not change our initialization. Further, the skeleton code ensures that CWND never drops

[1] The instruction team's reference implementation is less than ten lines of code. Yours should be similar.

below 2.

- You will need to declare variables for you implementation of Vegas (alpha, beta, etc.) in the `protected` section of the `Vegas` class and initialize them in the marked section of the `Vegas::init()` function.
- Please don't change the initial values we set for predefinfed variables.



```
class Vegas : public CCC {
public:
  void init() {
    m_dCWndSize = 5.0;
    m_dBaseRTT = 10000;
    m_iMSS = 1000;
  }

  void onACK(int32_t ack) {
    m_dcurrRTT = m_iRTT / 1000;
    if (m_dcurrRTT < m_dBaseRTT)
      m_dBaseRTT = m_dcurrRTT;

    if (m_dCWndSize < 2)
      m_dCWndSize = 2;
  }

protected:
  double m_dBaseRTT;
  double m_dcurrRTT;
};
```

Figure 1: Vegas Class Structure

Your `onACK()` function handles when an acknowledgment packet is received. Implement your Vegas logic inside this function and update the `m_dCWndSize` variable to change the congestion window size.

The `src/cc.h` file provides detailed documentation about the implementation you must complete, which can be summarized into the following steps:

- Calculate the expected throughput. This is the ratio between `CWND` and `baseRTT`, where `CWND` is the size of the current congestion window.
- Calculate the actual throughput (aka actual sending rate). This is calculated per RTT,

i.e, every time an ACK is received. The details of the calculations are at the end of Section 3.2 in the TCP Vegas paper.

- Calculate the difference between the expected throughput and the actual throughput. Then, adjust the window size `m_dCWndSize` accordingly. In particular, if the difference is smaller than alpha, increase `CWND` by a small linear factor, LinearIncreaseFactor * `CWND`. If it is greater than beta, reduce it by the same amount. Otherwise, do not change the window.

You implementation will be evaluated based on its ability to achieve good throughput while keeping the RTT short and stable. We will use the standard deviation of the RTT over the period of a short experiment. A low standard deviation for the RTT reflect a relatively stable queue length.

You are not required to implement slow start. Thus, our evaluation of your algorithm provides a few seconds for your algorithm to slowly probe the available bandwidth in the network. Also, we don't require you implementation to react to loss. Thus, all our tests will include a bottlneck with very large (virtually infinite) buffer.

In our experience, the amount of code needed to implement the logic above is less 30 lines of code, including variable definitions and initialization. We expect it this part to be the easier component of the assignment. The main task is identifying appropriate Alpha, Beta, and LinearIncreaseFactor values based on window size.

Feel free to use the autograder to experiment with different values until you find the correct configuration that passes our test cases.

2.2 Building and Running Experiments

Use the Gradescope Autograder to check if your implementation meets the project requirements. Pay attention to how the window size changes in the "Client Process Output" on Gradescope. If it stays the same or changes too quickly, you might need to tweak the values of Alpha and Beta. The Linear Increase Factor controls how fast the window size adjusts, so you can adjust it to get the right standard deviation.

If you prefer, we have provided a Dev Container environment and the associated Makefiles for compiling and debugging your implementation locally. While it is arguably more convenient, you do not need a fully functional local development environment to complete this assignment – editing the "cc.h" file and testing your implementation with the Autograder should be sufficient in most cases. The bulk of this assignment should be tuning the Vegas parameters instead of implementation.

1. Install Visual Studio Code from code.visualstudio.com
2. Install Docker or Podman for your system. See the instructions on docs.docker.com
3. Install the "Remote Development" extension pack. If you are using Podman, follow the instructions here to configure the remote container extension.

4. Decompress the project archive and open the folder in Visual Studio Code. If you prefer Podman over Docker, read and modify the ".devcontainer/devcontainer.json" in the project folder accordingly.
5. VSCode should prompt you to re-open the project in a container. If not, use the keyboard shortcut Ctrl + Shift + P (Cmd + Shift + P on macOS) to open the command palette. Type and click "Dev Containers: Rebuild and Reopen in Container".
6. VSCode should set up the development environment as specified in the provided ".devcontainer/devcontainer.json" file. You may need to wait a few minutes for VSCode to install the required extensions inside the container.

3 Deliverable

Please submit your `src/cc.h` file to Gradescope. No other deliverables are necessary.

4 Helpful Resources

1. `https://www.cs.emory.edu/~cheung/Courses/558/Syllabus/02-transport/vegas.html`
2. `https://udt.sourceforge.io/udt4/doc/ccc.htm`
3. `https://www.geeksforgeeks.org/basic-concept-of-tcp-vegas/`

5 Submission Guidelines and Rubric

5.1 Guidelines

- Upload the only the `cc.h` file in the `src/` folder to Gradescope.
- We do not limit the number of your submissions. But do keep in mind that the autograder will likely be congested closer to the deadline.

5.2 Rubric

We will create three different network conditions to test your algorithm. Each setting has a different Bandwidth Delay Product, to ensure that no static configuration of the window works for all of them. In particular, we will use the following scenarios:

- one-way delay of 200.00 ms, and bandwidth rate of 1Mbps
- one-way delay of 200.00 ms, and bandwidth rate of 10Mbps
- one-way delay of 300.00 ms, and bandwidth rate of 10Mbps

Your submission will be graded as follows (total 100 points):

- Compilation (4 points).
- Test case 1 (32 points total):
  - STD DEV $<$ 5ms (8 points)
    - Throughput $>$ 0.2Mbps (8 points, contingent on having an STD DEV of less than 5ms)
    - Throughput $>$ 0.4Mbps (16 points, contingent on having an STD DEV of less than 5ms))
  - Note that you will lose all points of the test case if STD DEV $>$ 5ms
- Test case 2 (32 points total):
  - STD DEV $<$ 10ms (8 points)
    - Throughput $>$ 2Mbps (8 points, contingent on having an STD DEV of less than 10ms)
    - Throughput $>$ 3Mbps (16 points, contingent on having an STD DEV of less than 10ms))
  - Note that you will lose all points of the test case if STD DEV $>$ 10ms
- Test case 3 (32 points total):
  - STD DEV $<$ 30ms (8 points)
    - Throughput $>$ 2Mbps (8 points, contingent on having an STD DEV of less than 30ms)
    - Throughput $>$ 3Mbps (16 points, contingent on having an STD DEV of less than 30ms))
  - Note that you will lose all points of the test case if STD DEV $>$ 30ms

6 Logistics

1. **Start early! :)**
2. Try to make use of existing threads set up by TAs to post questions, helps keep things organized
3. Your question may already be answered: try to go through existing questions before posting new ones.