Project Title:

Improving BBR for High-Latency, Low-Bandwidth Networks

Group Members:

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Project Overview:

This project is dedicated to investigating and improving the BBR (Bottleneck Bandwidth and Round-trip propagation time) congestion control algorithm for use in networks where high latency and low bandwidth are the norms—think satellite communications or certain 5G networks. Initially, we will replicate the original BBR algorithm and conduct thorough testing under various network conditions. We'll compare BBR's performance against well-known congestion control algorithms like TCP Reno and Cubic. Once we understand BBR's behavior, particularly its challenges in high-latency situations, we'll propose modifications to make it more robust in such environments.

Why This is an Important Problem:

While BBR has proven its strength in high-bandwidth, low-latency settings by achieving impressive throughput, it encounters difficulties in high-latency, low-bandwidth environments. In scenarios such as satellite or 5G networks, the algorithm's sensitivity to variations in round-trip time (RTT) can lead to inefficient use of available bandwidth and increased network jitter. By enhancing BBR for these conditions, we aim to achieve a more stable and efficient performance, ensuring reliable communications even when network conditions are less than ideal.

Methodology and Approach:

1. **Baseline Testing:**:
   We will begin by running tests to compare the performance of BBR against TCP Reno and Cubic. These tests will measure key metrics like throughput, latency, and packet loss, both in standard network settings and in high-latency environments (e.g., with a 600ms RTT).

2. **Modifying BBR for High Latency, Low Bandwidth Networks**:
   Based on our initial findings, we will modify the BBR algorithm to reduce its sensitivity to RTT variations. This will involve incorporating adaptive mechanisms such as smoothed RTT filtering and extended gain cycles. Our goal is to stabilize bandwidth estimation and pacing, ultimately leading to more consistent performance under high-latency conditions.

3. **Testing Modified BBR**:
   After implementing our modifications, we will rigorously test the revised version of BBR in simulated satellite or 5G network environments characterized by high RTT and low bandwidth. We will assess performance improvements by measuring throughput, delay, and fairness among competing flows, aiming for notable gains in throughput stability and latency reduction.

Related Work:

Our research is inspired by the work described in the paper "When to use and when not to use BBR: An empirical analysis and evaluation study" by Google researchers, which highlights both the strengths and limitations of BBR. Recognizing the need for improvements in high-latency, low-bandwidth networks, our project focuses on modifying the algorithm to overcome these specific challenges.

BBR: Congestion-Based Congestion Control: Measuring bottleneck bandwidth and round-trip propagation time: https://dl.acm.org/doi/10.1145/3012426.3022184

When to use and when not to use BBR: An empirical analysis and evaluation study: https://dl.acm.org/doi/pdf/10.1145/3012426.3022184

Platform:

We will utilize the ns-3 network simulator for our experiments. ns-3 offers a flexible environment where we can model various network conditions, including those with high latency and low bandwidth, to effectively compare the performance of BBR, TCP Reno, and Cubic.

Methodology/Approach:

- Implement BBR alongside other congestion control algorithms in ns-3.
- Simulate a network environment akin to satellite or 5G scenarios with high RTT and low bandwidth.
- Modify BBR’s congestion control mechanisms to better suit high-latency conditions.
- Evaluate and compare performance metrics such as throughput, latency, and fairness between the original and modified versions of BBR.