Analyzing Latency Variations Across Different Regions in the US

Ryan Lin (rhl72)

Professor Mark Allman

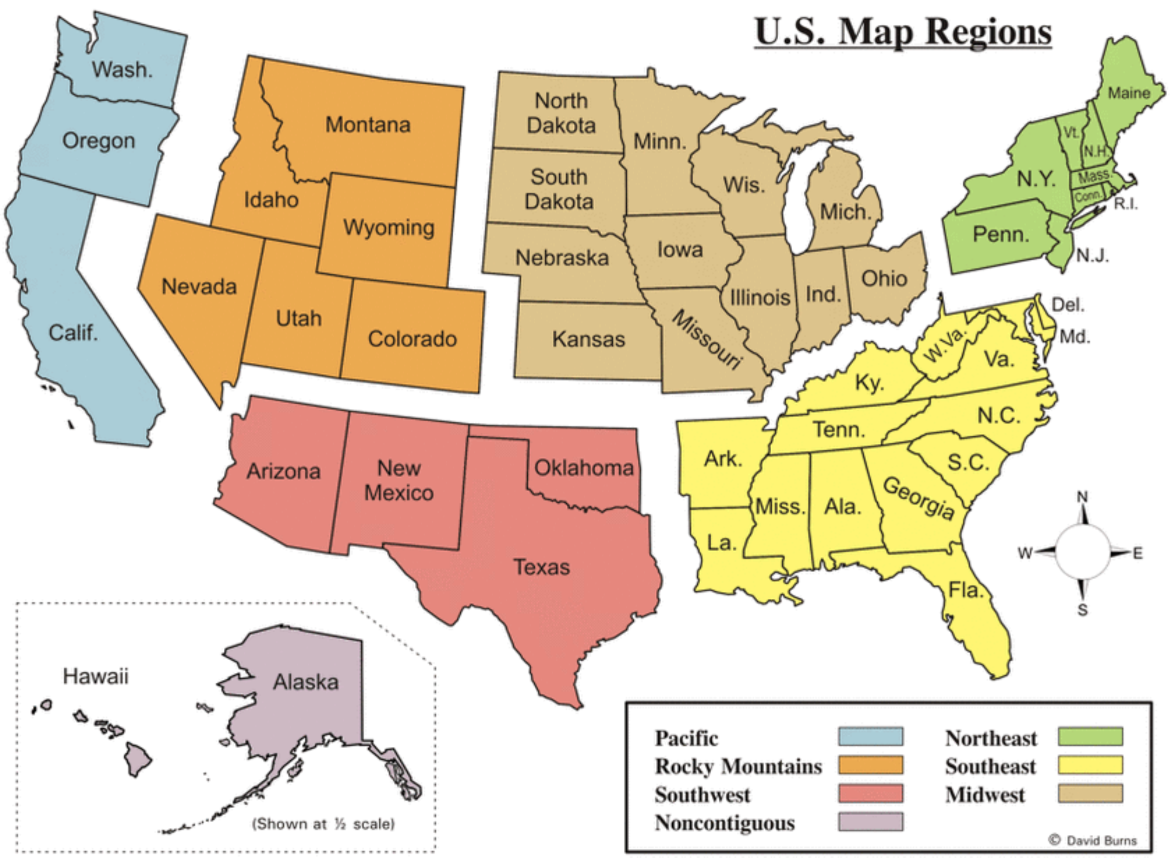
Computer Networks (CSDS 325)

12/5/2024

1 Introduction

Network latency is a critical factor affecting the performance of internet-based applications and services. It represents the time taken for data packets to travel from a source to a destination across a network. High latency can lead to slow web page loading times, lag in online gaming, and delays in real-time communications. Understanding latency variations across different regions can help internet service providers (ISPs), businesses, and policymakers improve network practices and enhance user experiences.

This project aims to analyze network latency variations across various **regions** within the United States. By measuring the round-trip times (RTTs) to servers located in different geographical areas, we seek to identify patterns and factors influencing latency, such as physical distance, network congestion, and regional infrastructure differences.



2 Procedure

2.1 Data Collection

In order to gather empirical data on latency variations, I implemented an automated data collection system that periodically measures key network performance metrics (packet loss, round-trip time, hop count) from multiple vantage points across the United States. The servers selected for measurement were all associated with universities in different U.S. regions. **Northeast**, **Midwest**, **South**, **West**, and **Mountain**. Five servers were chosen from each region, resulting in a total of 25 measurement targets. Using university servers as targets provides well-known, relatively stable endpoints and helps ensure that results are not overly influenced by transient hosts or weird services.

<u>Northeast</u>

- New York University - nyu.edu
- Harvard University - harvard.edu
- Massachusetts Institute of Technology - mit.edu
- Columbia University - columbia.edu
- Yale University - yale.edu

<u>Midwest</u>

- University of Chicago - uchicago.edu
- University of Michigan - umich.edu
- Northwestern University - northwestern.edu
- University of Illinois Urbana-Champaign - uiuc.edu
- Washington University in St. Louis - wustl.edu

<u>South</u>

- University of Texas at Austin - utexas.edu
- Duke University - duke.edu
- Vanderbilt University - vanderbilt.edu
- Rice University - rice.edu
- University of North Carolina at Chapel Hill - unc.edu

<u>West</u>

- Stanford University - stanford.edu
- University of California, Berkeley - berkeley.edu
- University of California, Los Angeles - ucla.edu
- California Institute of Technology - caltech.edu
- University of Southern California - usc.edu

<u>Mountain</u>

- University of Northern Colorado - unco.edu
- University of New Mexico - unm.edu
- University of Nevada, Las Vegas - unlv.edu
- Colorado College - colo.edu
- University of Utah - utah.edu

Measurement Tools and Commands:

- **ping**: Used to measure network latency and packet loss. Each measurement consisted of sending 10 ICMP echo requests and recording the minimum, average, and maximum RTT as well as the percentage of packets lost.
- **traceroute**: Used to determine the route that packets take through the network, providing insight into the path (sequence of routers) and the number of hops between the measurement machine and the target server.
- **dig**: Used to resolve the server's hostname into an IP address, ensuring that we always have a record of the IP address associated with each target at the time of measurement.

Automation and Scheduling:

A Python script was developed to do the data collection. This script periodically (every 5 minutes) executes ping, traceroute, and dig queries against the list of servers. After each round of measurements, the collected data (timestamp, region, server name, resolved IP, packet loss, RTT metrics, hop count, and traceroute path) was appended to a CSV file. Over the duration of 24 hours, this approach generated a large dataset capable of revealing patterns and trends in latency across different regions.

Data Format:

The resulting CSV file (named network_latency_data.csv) contains the following columns for each measurement:

- **Timestamp (UTC)**: The time at which the measurement was taken.
- **Region**: The geographic region (Northeast, Midwest, South, West, Mountain).
- **Server**: The hostname of the target server.
- **IP Address**: The resolved IP address of the server.
- **Packet Loss (%)**: The percentage of lost ICMP echo requests.
- **RTT Min (ms)**: The minimum round-trip time recorded.
- **RTT Avg (ms)**: The average round-trip time recorded.
- **RTT Max (ms)**: The maximum round-trip time recorded.
- **Hop Count**: The number of hops identified by traceroute.
- **Path**: The sequence of intermediate IP addresses from traceroute.

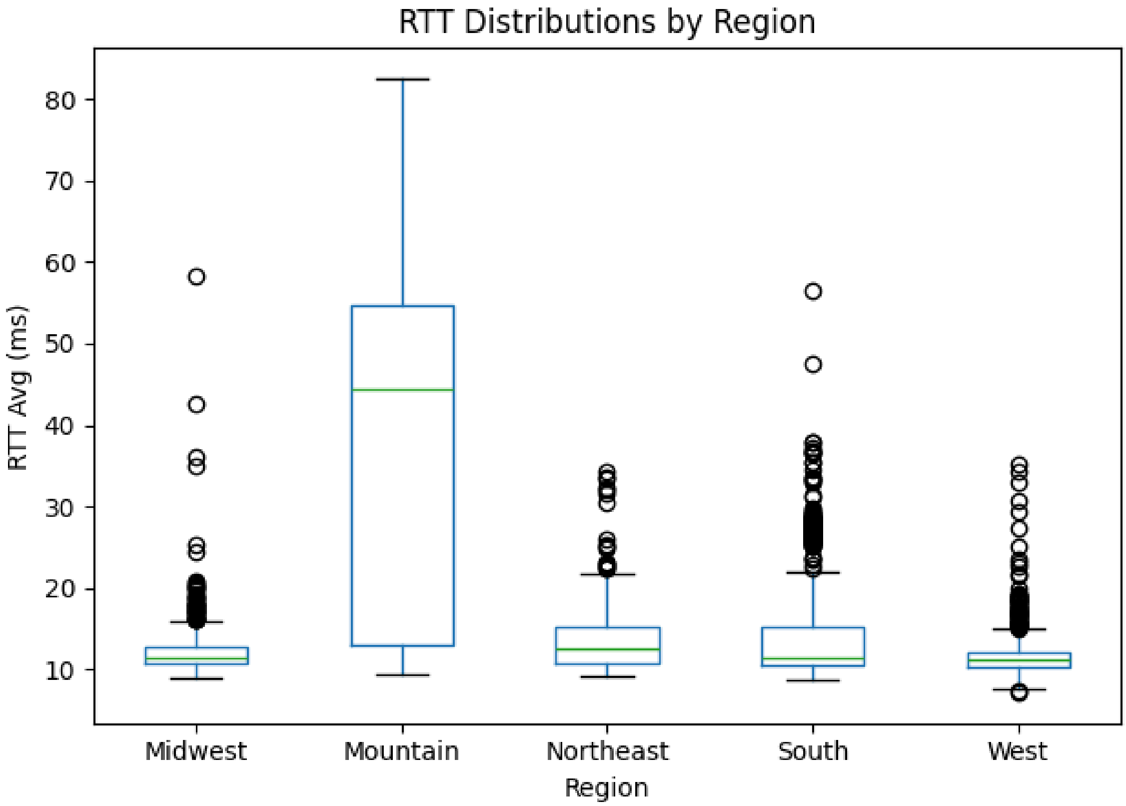
2.2 Data Analysis Methods

While the data collection process continuously generated a dataset containing latency metrics and routing information, the analysis of this data is yet to be completed. In the next phase, the procedure will involve parsing and processing of the CSV file to extract meaningful insights. This will involve:

- Cleaning and formatting the collected data.
- Aggregating statistics across time, regions, and servers.
- Visualizing latency distributions, hop counts, and packet loss rates.
- Comparing results between regions and examining potential temporal patterns.

3 Results

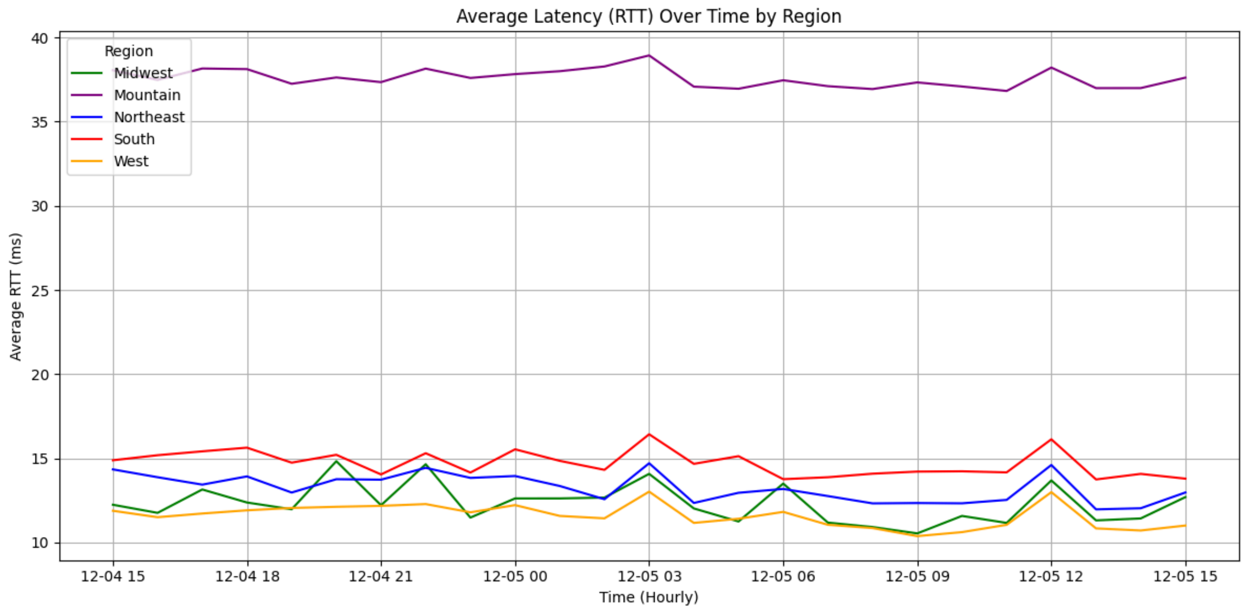
3.1 Round Trip Time Distribution by Region



This box plot shows the Round-Trip Time (RTT) distributions across five regions. The RTT average, measured in milliseconds (ms), is represented on the y-axis, while the x-axis lists the regions. Each box represents the interquartile range (IQR), showing the middle 50% of RTT values for each region, with a horizontal line inside each box indicating the median RTT. Whiskers extend to show the range of data within 1.5 times the IQR, and outliers beyond this range are represented as individual points.

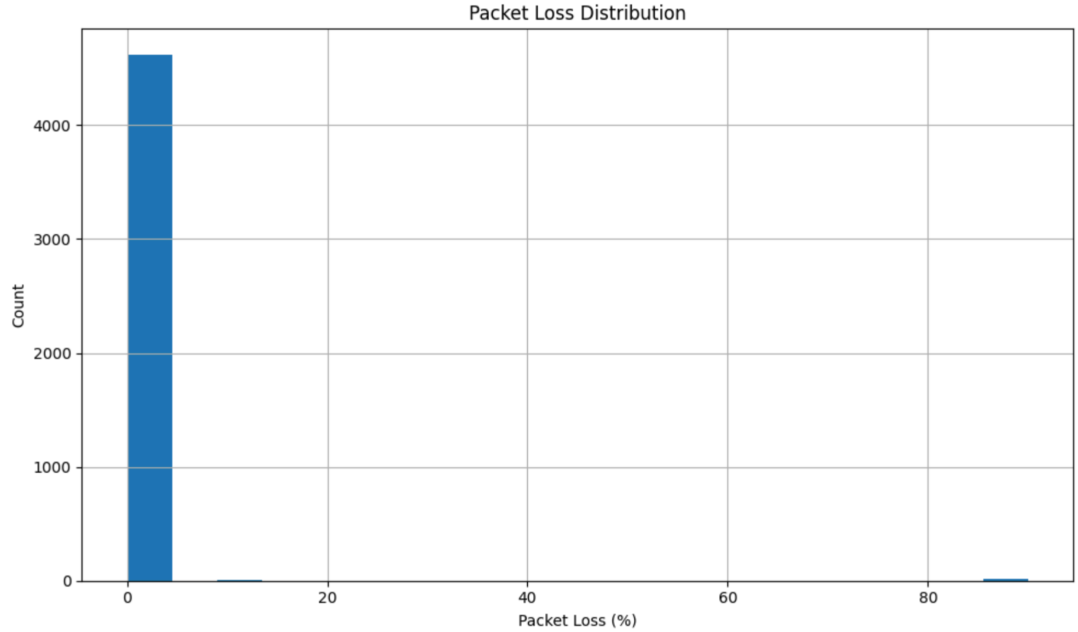
It looks like Mountain had the average RTT. It also had the highest interquartile range of RTT average values. The most consistent and lowest averages were notably Midwest, which makes sense since I am located here and West.

3.2 Average Region Latency time

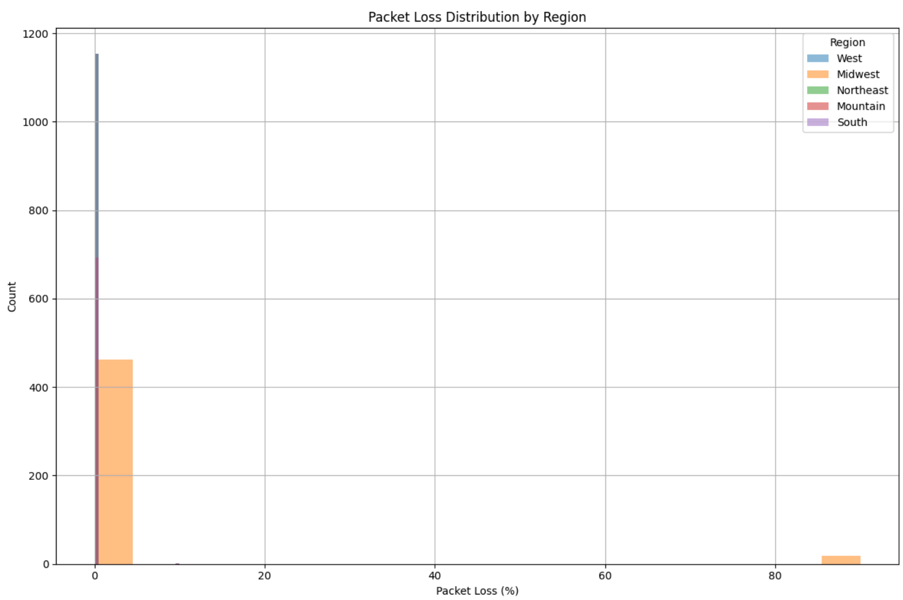


This is the average latency over time grouped by region. Interestingly, All the average latencies of all the regions followed a trend, derivative wise. There were slight deviations from this trend, most notably the Midwest pattern.

3.3 Packet Loss Distribution

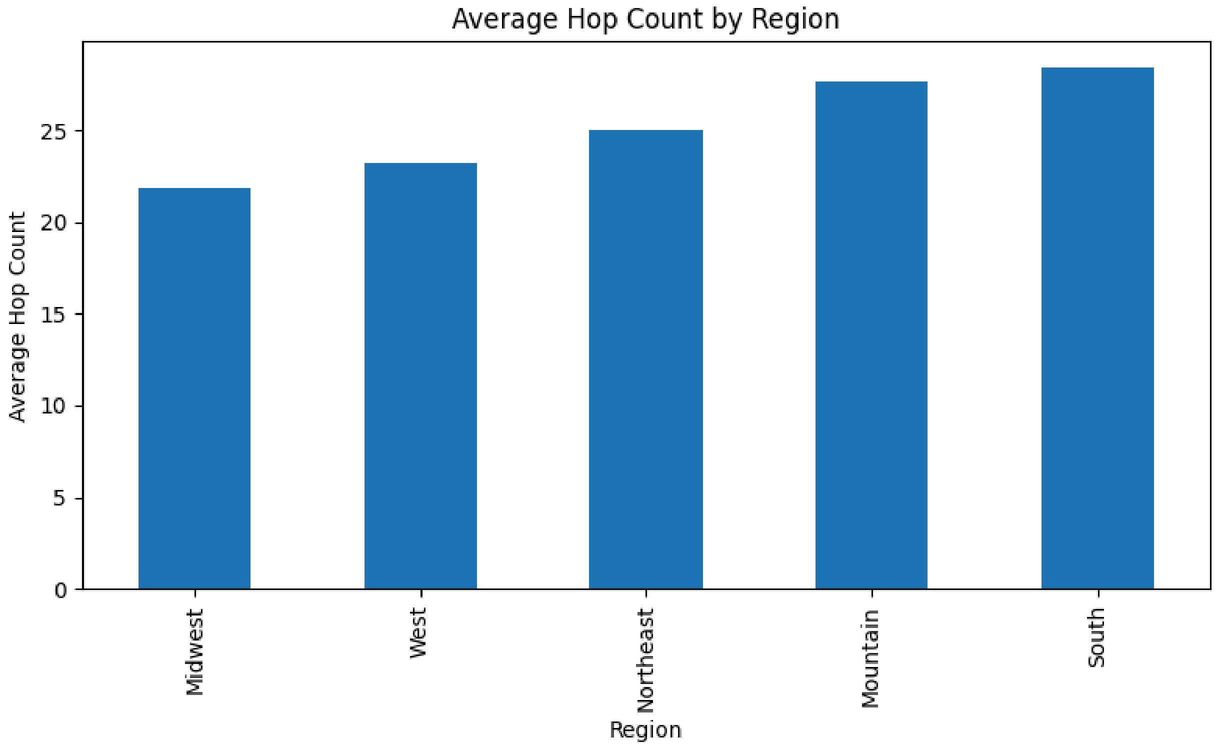


This graph shows the packet loss distribution of all pings. The graph displays that the majority of packets were not lost but there were some local maximums that are barely visible in the graph at around 10% and 90%.



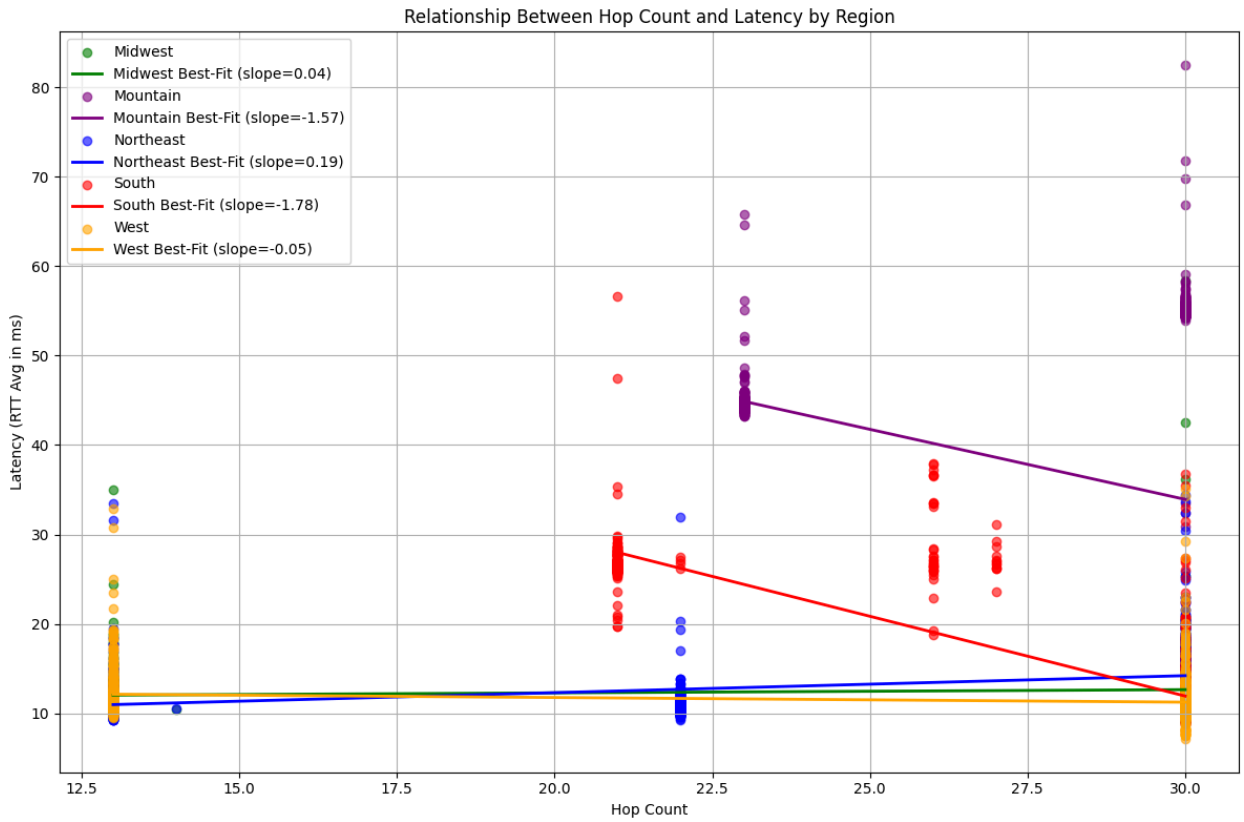
I grouped all of the regions by color and filtered out all the entries with no loss and it turns out that all of the entries with loss were from the midwest region which seemed very odd considering I am doing this in the MidWest.

3.4 Average Hop Count



This graph shows the average hop count for all of the regions. They all fall round the 20-27 range, but the ranking stands as Midwest, West, Northeast, Mountain, and South which does not indicate a direct relationship with distance and hop count.

3.5 Relationship Between Hop Count and Latency



This plots the relationship between latency and hop count by region along with a line of best fit to display the relationship between hopcount and latency. There are slight relationships between mountain and south regions where there is negative correlation, where an increase of hop counts is correlated with less latency. For the rest of the relationships they are positive, but very small indicating a weak correlation. It is also important to notice that there are numerous outliers that go against the relationships.