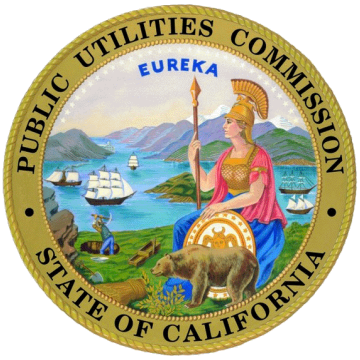
Analysis of Mobile Broadband Performance in California



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Abstract

This report details our project for CSUMB's Spring 2018 CST 499 Capstone class. Since 2012, the California Public Utilities Commission (CPUC) has gathered mobile performance data in 6 month intervals across 2000 locations in California. This data pertains to TCP and UDP performance of the four major carriers (AT&T, Sprint, T-Mobile, and Verizon). This is a continuation of previous research by Yashkaran Singh which analyzed TCP upload and download speeds and round-trip time (RTT). For this project, we focused on UDP jitter and loss and whether there was a correlation between TCP and UDP metrics. Based on our research, we have concluded that there is a correlation between jitter, loss, and download/upload speeds in California.

1. Introduction

For the past 6 years, the CPUC has gathered data related to the mobile performance of AT&T, Sprint, T-Mobile, and Verizon across 2000 locations in California. This data has been gathered in 6 month intervals, called rounds, using CPUC's own performance analysis tool called CalSPEED. Drivers are sent across the state and run the application on phones and tablets at each location multiple times.

Although previous analysis has been done on this dataset with regards to TCP download/upload speeds and RTT, this was only done for the western server. We performed the same TCP analysis on the eastern server, along with analyzing UDP jitter and loss for both servers. Our first goal was to rank the mobile carriers by their UDP performance, similar to the previous analysis done for TCP. Following that, we wanted to have a complete picture of both TCP and UDP metrics to determine if there was a correlation between the protocols. Essentially, we wanted to find out whether quality TCP performance also meant quality UDP performance.

Dataset

We analyzed four different rounds of data collected by the CPUC from 2012-2017 (Round 1, 5, 10, and 12). Each of these datasets contained between 15,000-18,000 records and 56-123 data items. The range of the columns is due to more data being collected in later rounds. We had an adequate number of rows to analyze, and we trimmed down the columns to only the relevant ones: cell phone provider, RTT, upload speed, download speed, jitter, and loss. During the analysis, we sorted the data, averaged the values for each percentage, and then plotted the average values. Due to this process, the graphs display a cumulative distribution.

Prior to analyzing the data, we made the decision to clean the data by replacing “NA” and “No effective service” values with the average value of the column. As the column values are sorted from lowest to highest, this allows the graph to have a smooth curve and be easily understandable. However, the exception to this is in regards to the jitter graphs where those values are replaced with “INF”. This allows one to visualize the point where data past a certain point becomes unavailable, which has the added benefit of showing the percentage of coverage for each carrier.

2. Mobile Carriers’ Average UDP Jitter and Loss

Jitter is the time delay between packet arrival. This is not to be confused with latency. For example, if a client is constantly receiving a packet every 50ms after the last, but then the next packet arrives 300ms after, the jitter would be 250ms in that instance. Jitter can be thought of as latency spikes, and lower jitter means better network performance. Conversely, higher jitter means worse network performance.

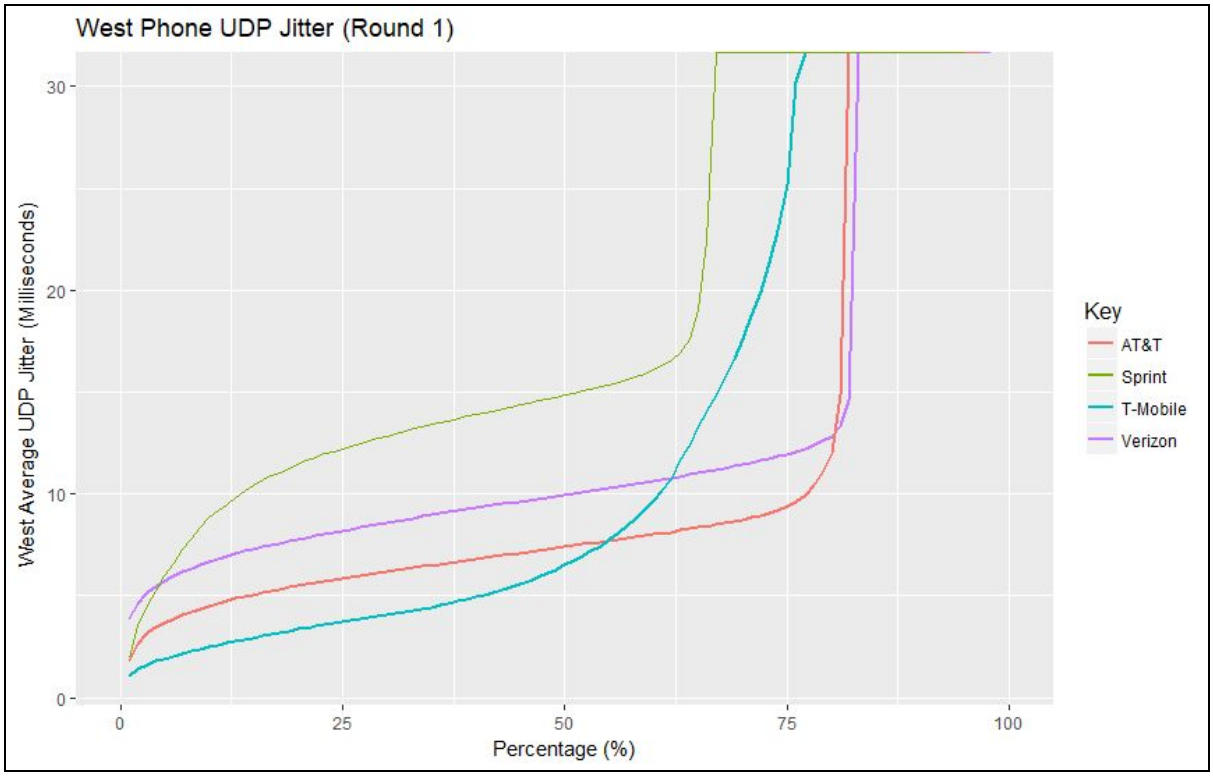

Figure 2.1: West round 1 jitter data collected in Spring 2012

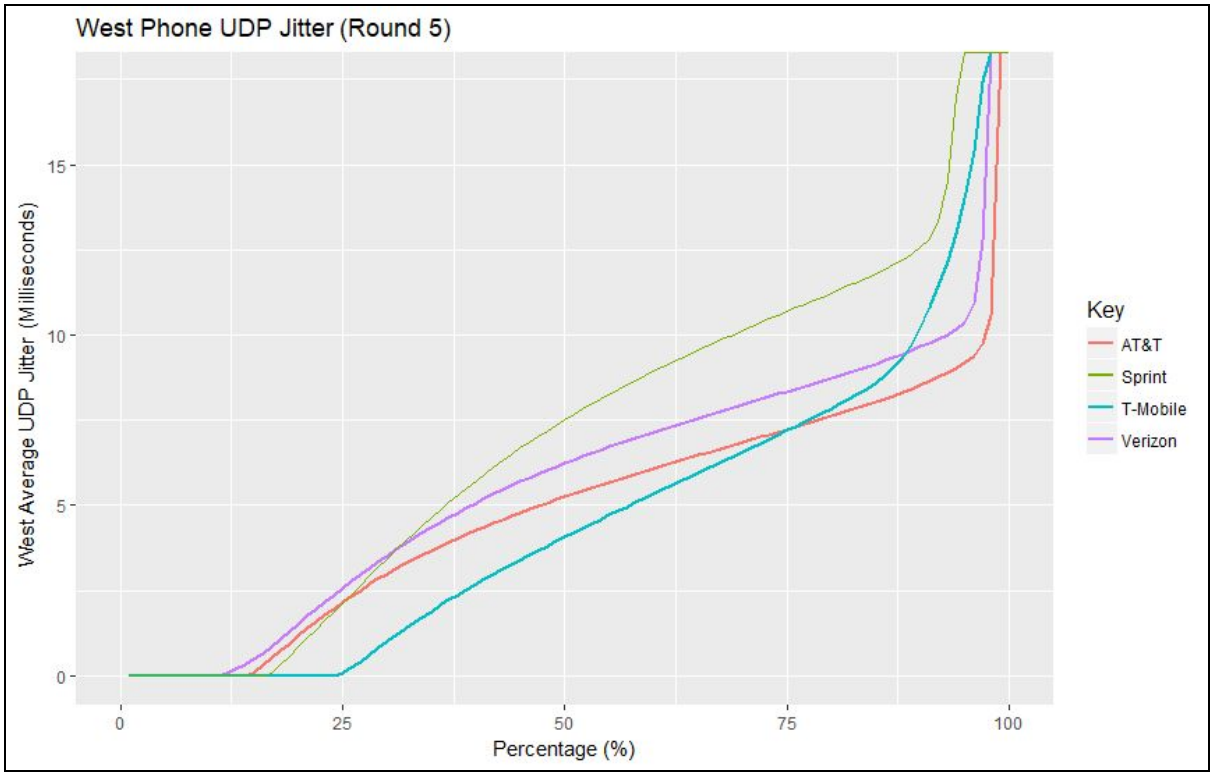

Figure 2.2: West round 5 jitter data collected in Spring 2014

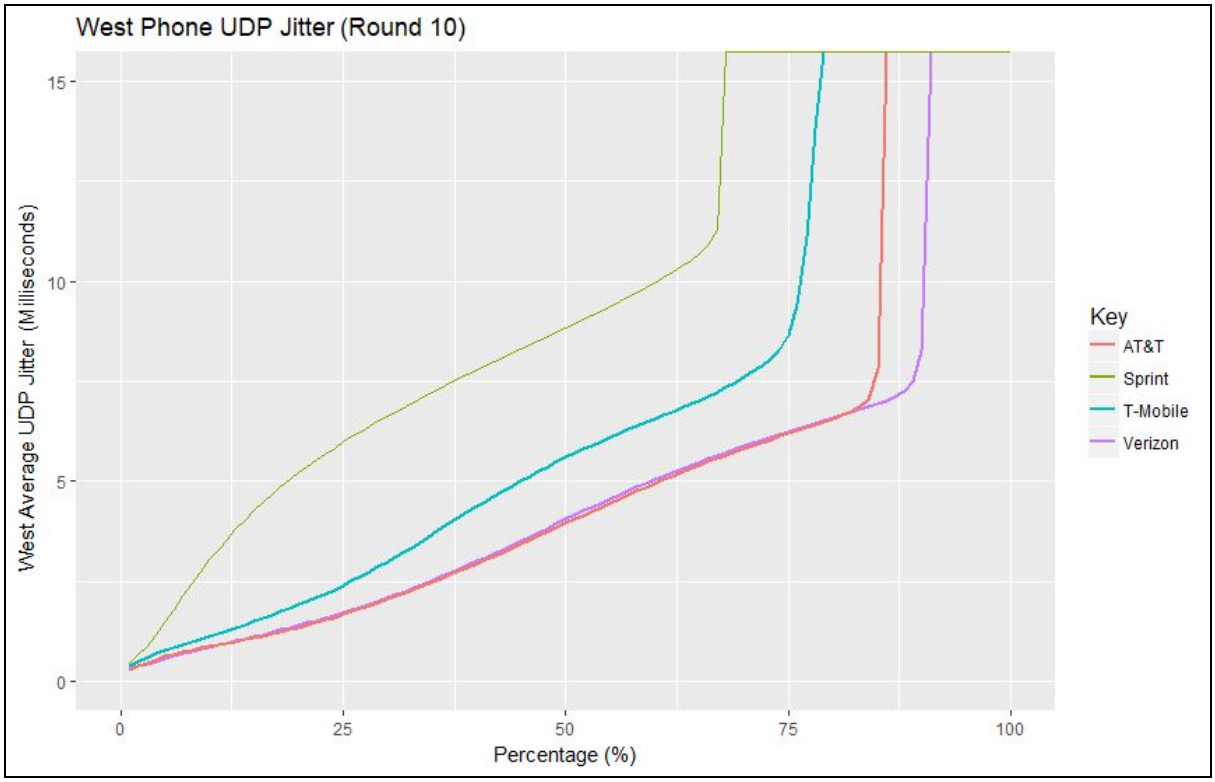

Figure 2.3: West round 10 jitter data collected in Fall 2016

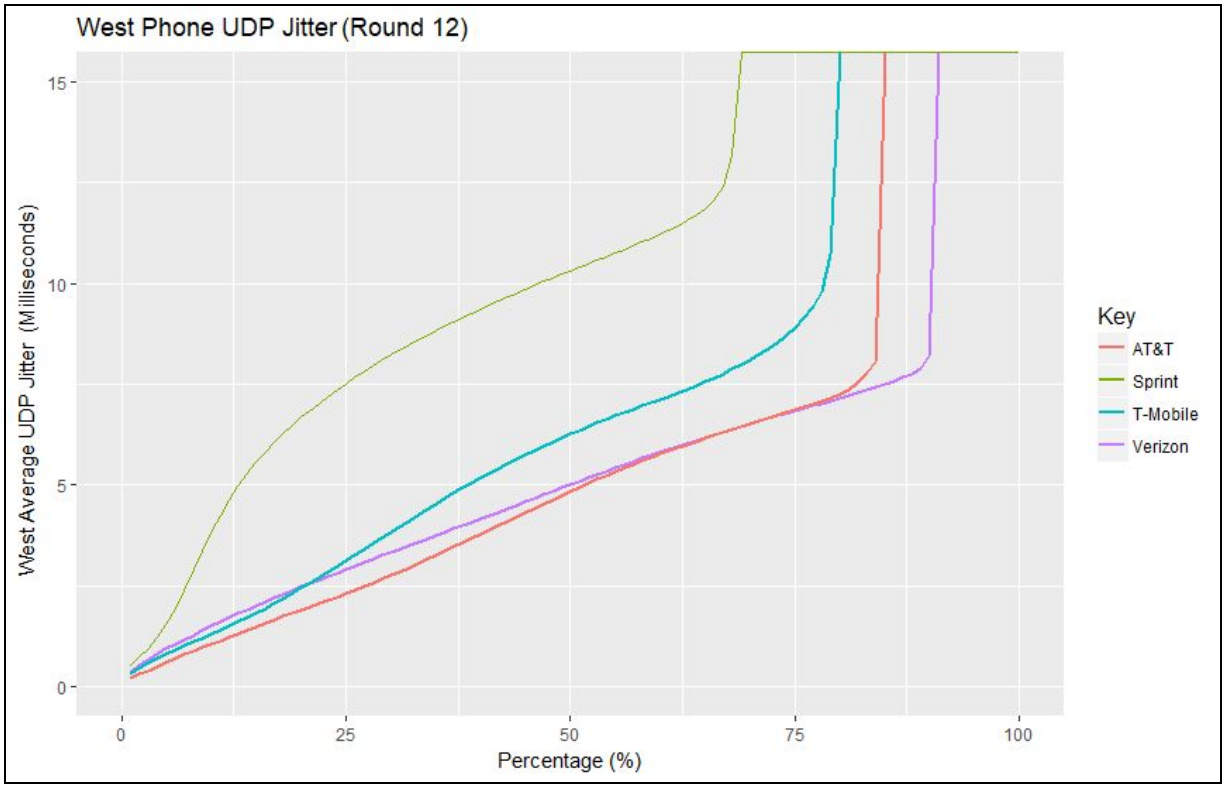

Figure 2.4: West round 12 jitter data collected in Fall 2017

Figures 2.1-2.4 above show the average jitter of each major carrier to the west server as a cumulative distribution for each round analyzed. For example, the value shown at the 25 percent mark shows the average of the lowest 25 percent of the data. Based on the above data, Sprint consistently had the highest jitter and the least amount of coverage (based on the point the values go to infinity) in California of the four major carriers from 2012-2017. An interesting trend to note is that T-Mobile had the lowest average jitter for the majority of the data in round 1 and 5, although AT&T and Verizon performed better when ~80 percent of the data is accounted for. In round 10 and 12, T-Mobile consistently has the second highest jitter. In the earlier rounds AT&T had the lowest jitter, but in recent years AT&T and Verizon are tied for least jitter. The average jitter to the east CPUC server shows the same trends, and those graphs can be found in the appendix as A.1-A.4.

Datagram loss refers to how many packets are sent from the host but are not received by the client. With TCP these packets are retransmitted, but with UDP the data stream continues and ignores any dropped packets. Loss is measured as the percentage of packets that are dropped, and a lower percentage of loss correlates to better performance.

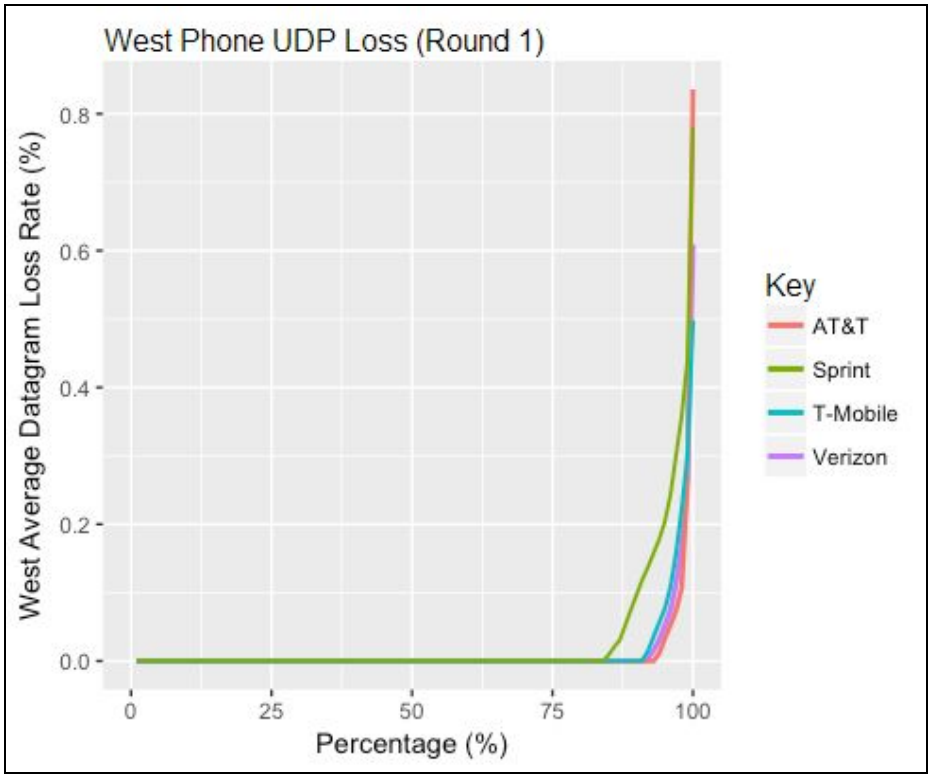

Figure 2.5: West round 1 loss data collected in Spring 2012

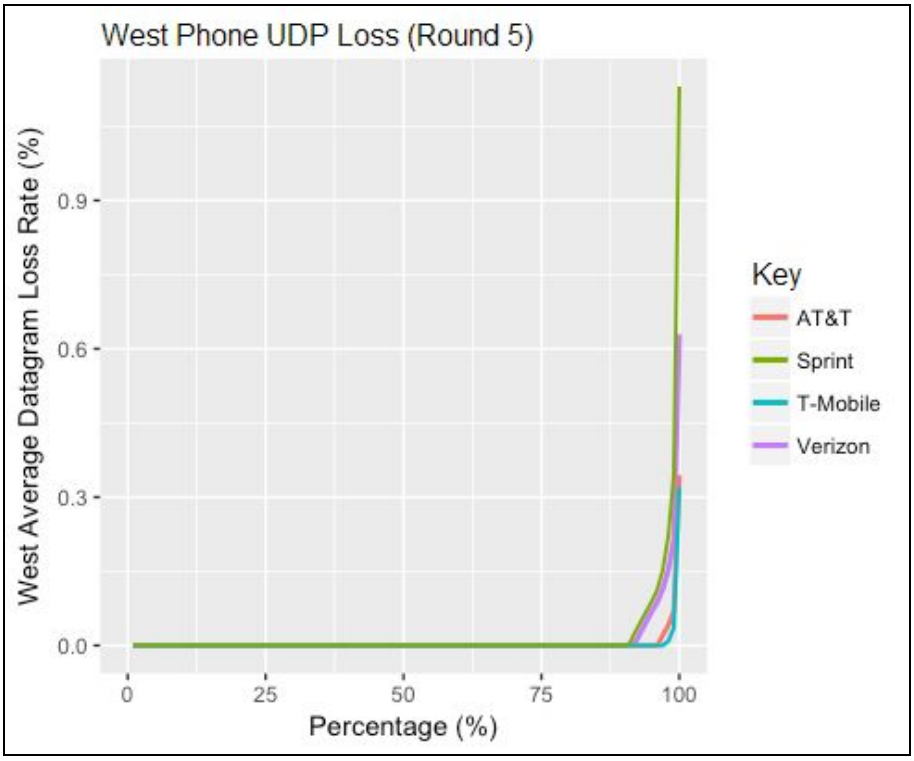

Figure 2.6: West round 5 loss data collected in Spring 2014

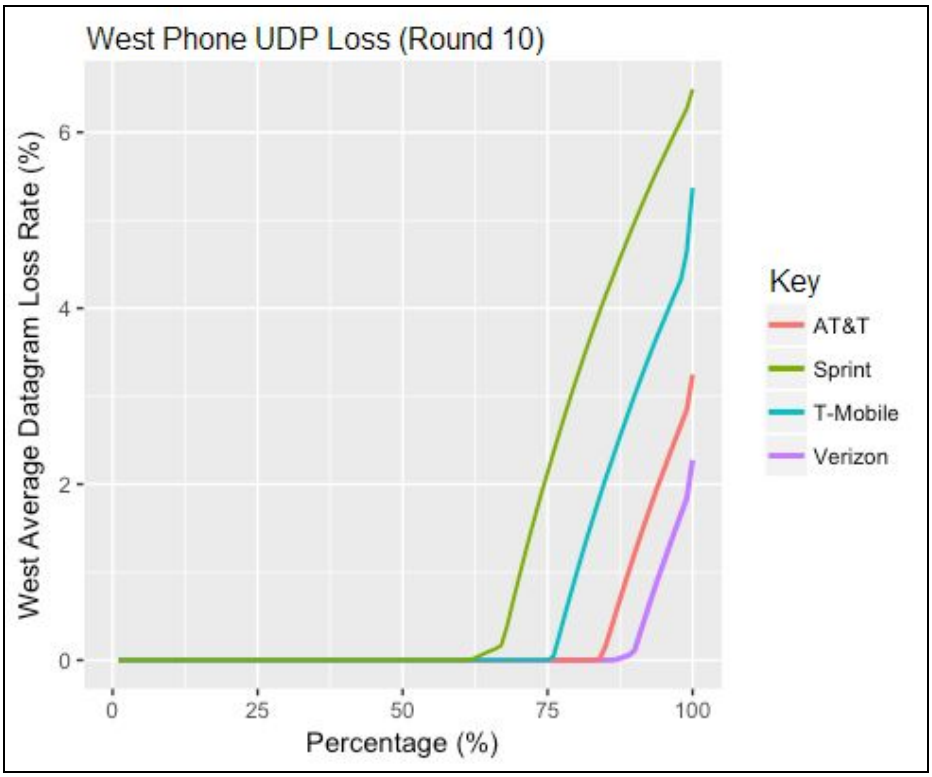

Figure 2.7: West round 10 jitter data collected in Fall 2016

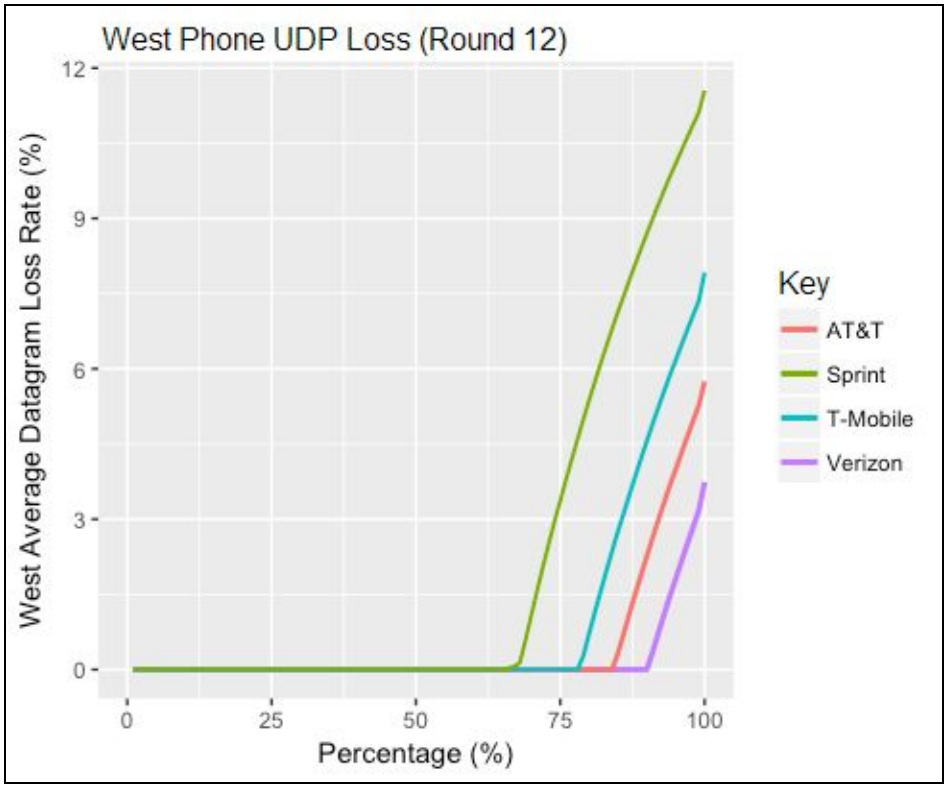

Figure 2.8: West round 12 jitter data collected in Fall 2017

Figures 2.5-2.8 above show the average datagram loss of each major carrier to the west server as a cumulative distribution for each round analyzed. Based on the graphs above, all carriers performed similarly in rounds 1 and 5 with no loss for ~80 percent of the data. The loss that did occur beyond that was also minimal, with less than one percent of the packets being dropped. Despite this equality early on, rounds 10 and 12 data fall in line with the jitter results. Verizon suffered the least datagram loss, followed by AT&T, T-Mobile, and then Sprint. There is also an unusual trend with the data; as the rounds progress, overall performance actually decreases and more loss occurs. The cause for this change is unknown, and would require further research. The average datagram loss to the east CPUC server also shows the same trends, and those graphs can be found in the appendix as A.5-A.8.

3. Mobile Carriers' Average East RTT and Download/Upload Speeds

As a continuation of the previous semester's research, we analyzed round-trip time and download and upload speeds to the east CPUC server. Round-trip time refers to how long it takes a packet to be sent from the host to the client, plus how long it takes for the packet acknowledging the initial packet to be sent from the client to the host.

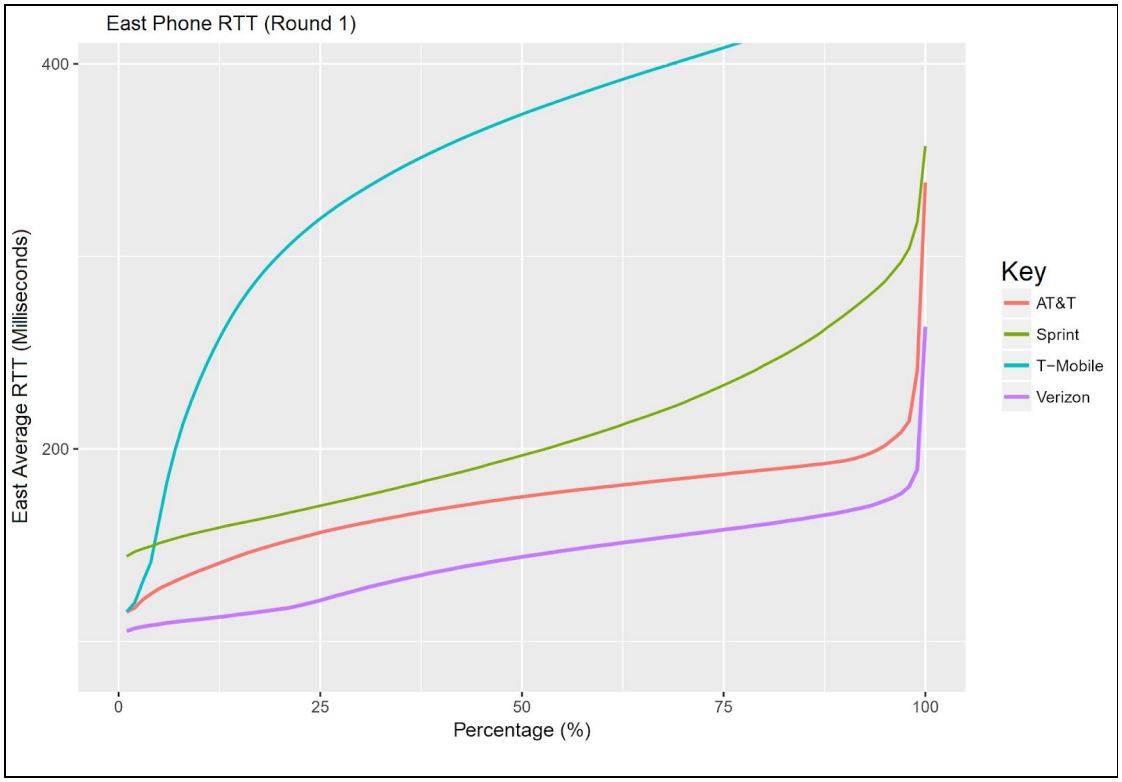

Figure 3.1: East round 1 RTT data collected in Spring 2012

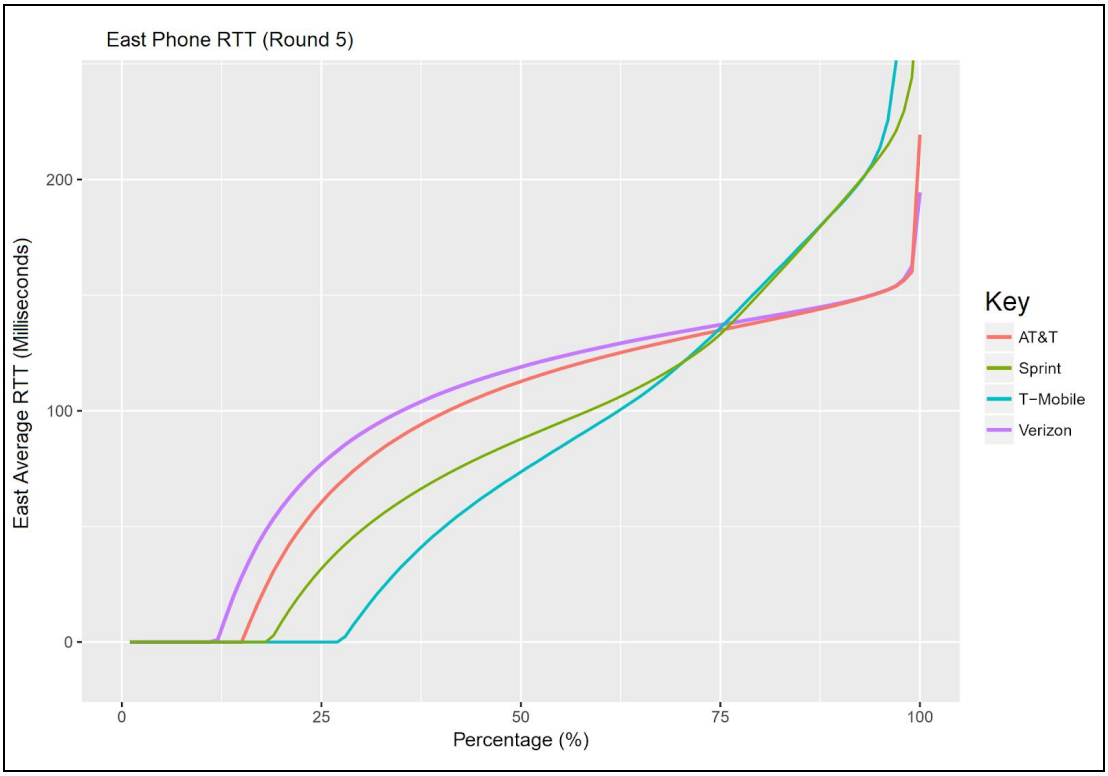

Figure 3.2: East round 5 RTT data collected in Spring 2014

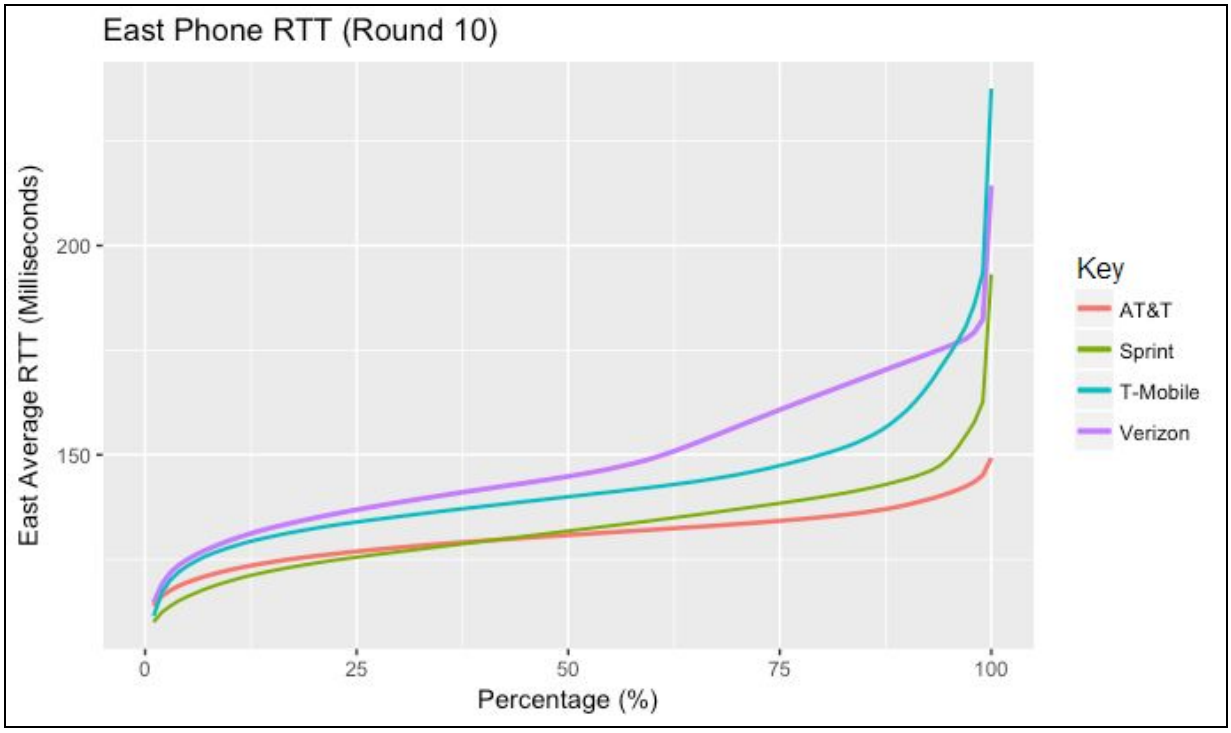

Figure 3.3: East round 10 RTT data collected in Fall 2016

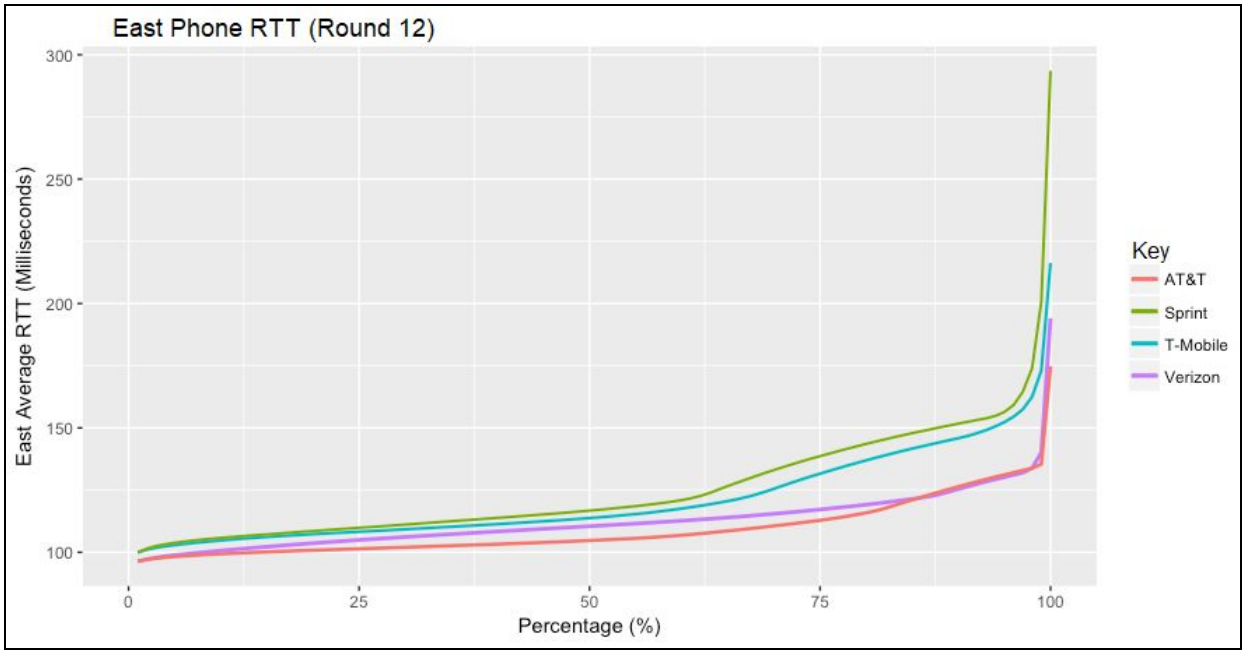

Figure 3.4: East round 12 RTT data collected in Fall 2017

Figures 3.1-3.4 above show the average RTT of each major carrier to the east server as a cumulative distribution for each round analyzed. Based on the graphs above, RTT has become more consistent through the rounds, with most devices performing at the same level in round 12.

Ranking the carriers by RTT is inconclusive, as the differences are small in recent rounds. This data also matches the west RTT data analyzed in the previous report, with performance increasing over the rounds.

Download and upload speed refer to the rate at which bits of data are transferred between client and host. For this metric, higher numbers indicate greater performance. The download and upload speeds below are measured in Kilobits per second (Kbps).

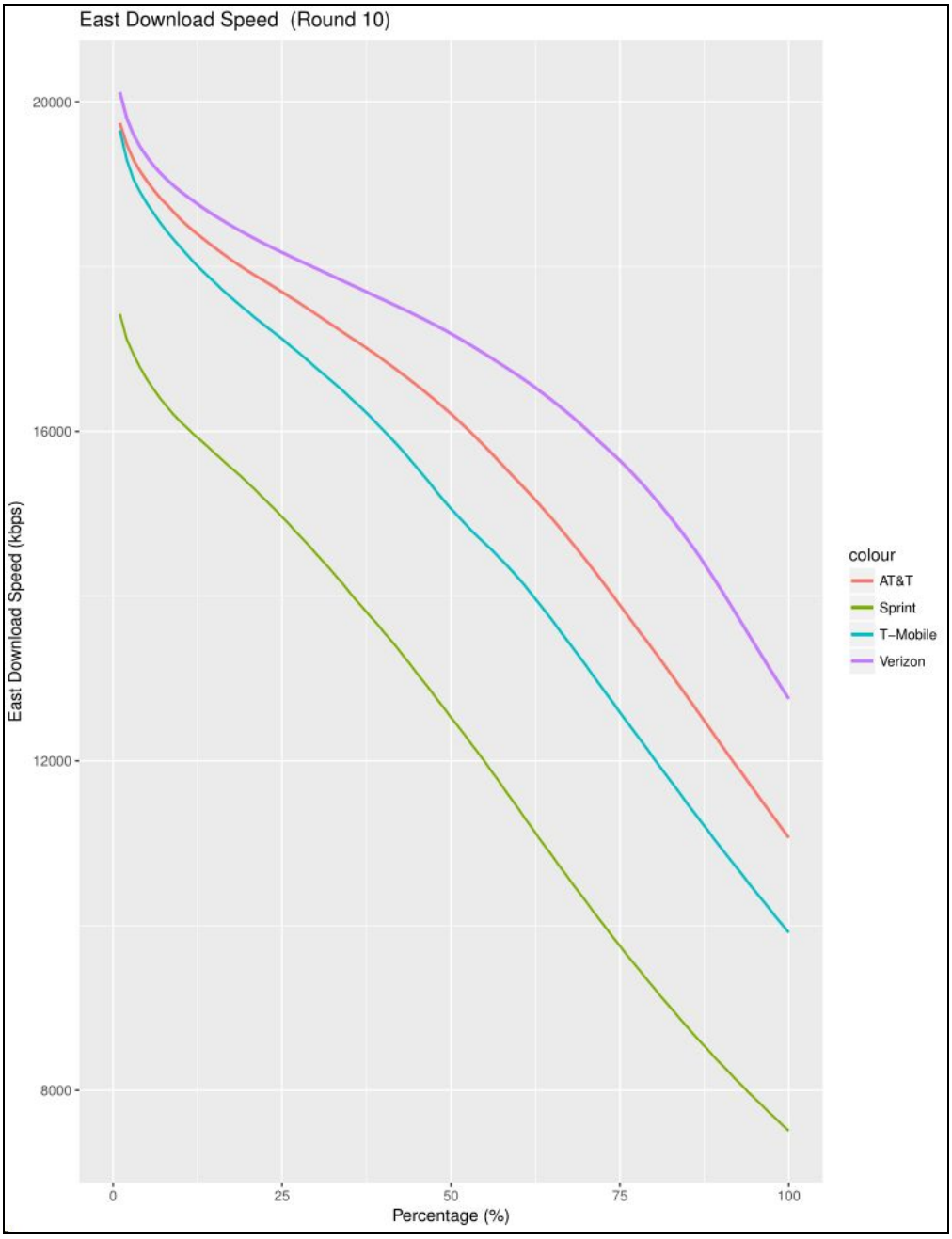

Figure 3.5: East round 10 download speed data collected in Fall 2016

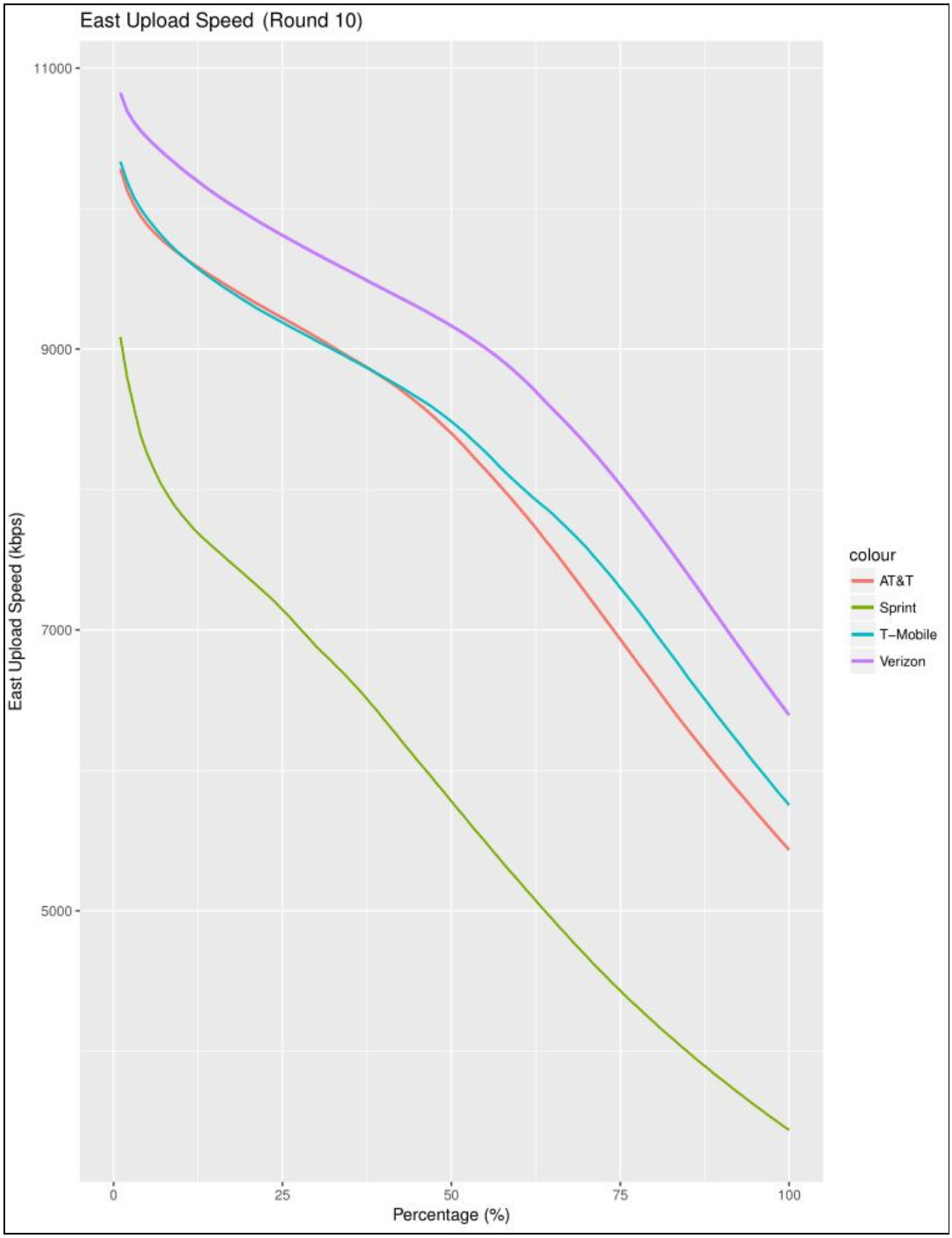

Figure 3.6: East round 10 upload speed data collected in Fall 2016

Figures 3.5 and 3.6 above show the average download and upload speeds to CPUC's east server as a cumulative distribution for round 10. The carrier performance between rounds is similar and follows the same trend as detailed in the previous report, so only these two rounds are shown. One observation to make is that these download and upload speeds are consistent

with datagram loss and jitter. Verizon has the highest speeds, AT&T and T-Mobile compete for the middle spots, and Sprint is at the bottom. This suggests there is a possible correlation between these three metrics.

4. Performance Trend of Each Carrier

The individual performance of each carrier for rounds 1, 5, 10, and 12 was also analyzed. These results can be seen in Figures 4.1-4.4 for west data, and B.1-B.4 for east data. This was done using jitter as the metric, and every carrier has improved since round 1. One thing to note is that although round 10 and round 12 performance are very similar, jitter actually tended to be lower in round 10, which is not expected. One reason for this could be that more people in California are using mobile networks, but current cell towers are functioning well enough to not justify upgrading infrastructure yet. The same trend was also observed for datagram loss.

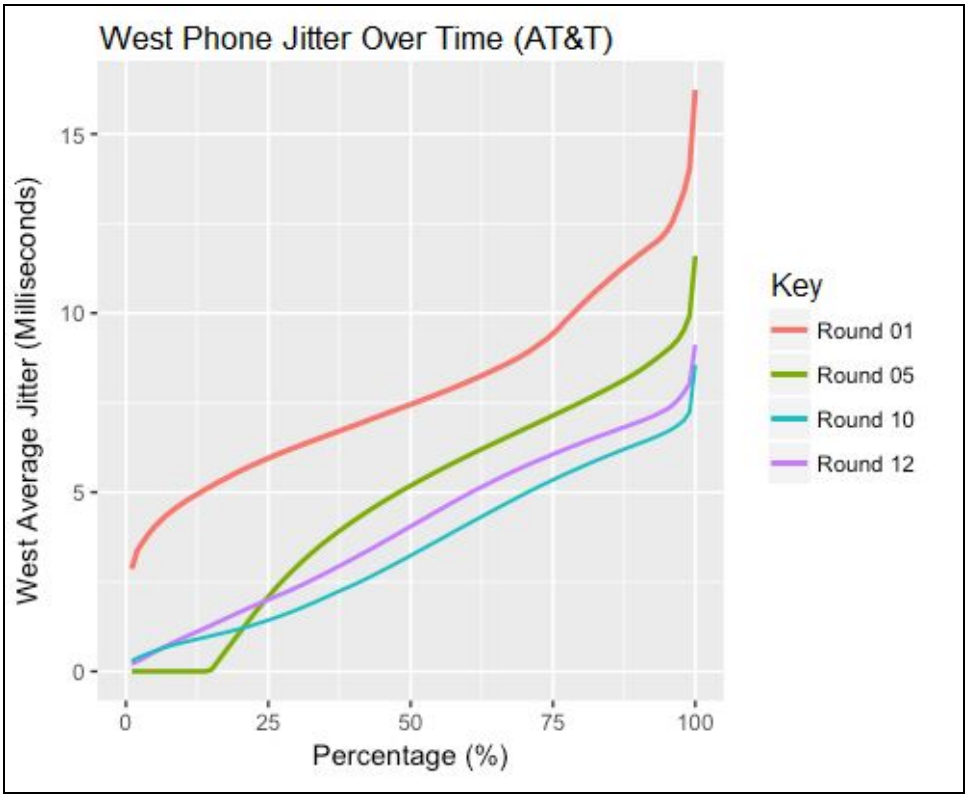

Figure 4.1: West jitter over time for AT&T

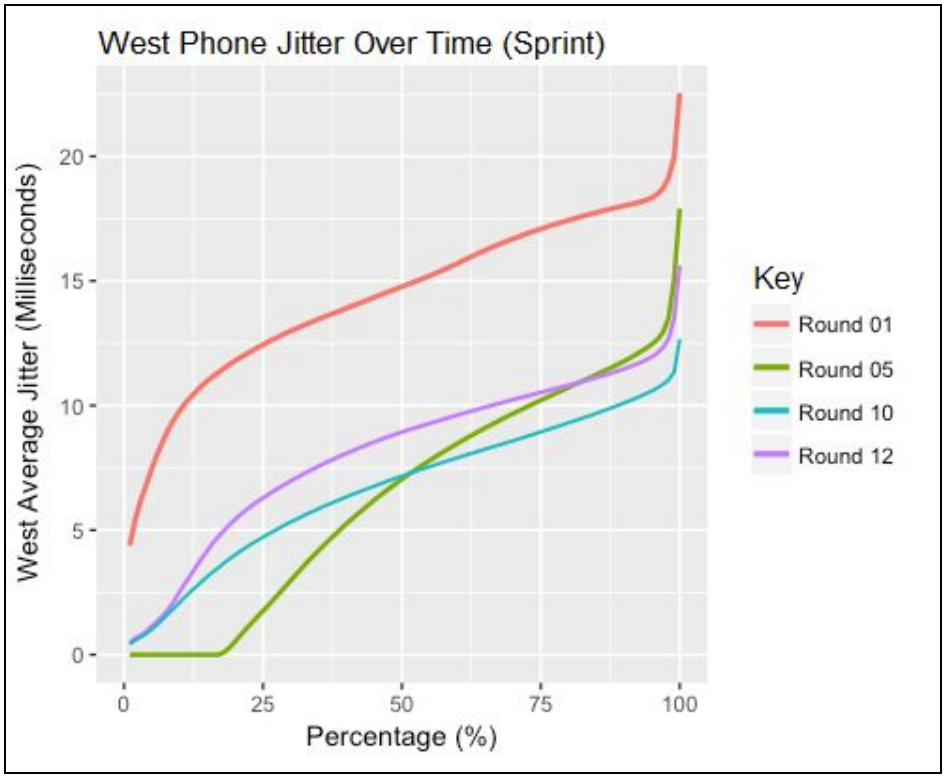

Figure 4.2: West jitter over time for Sprint

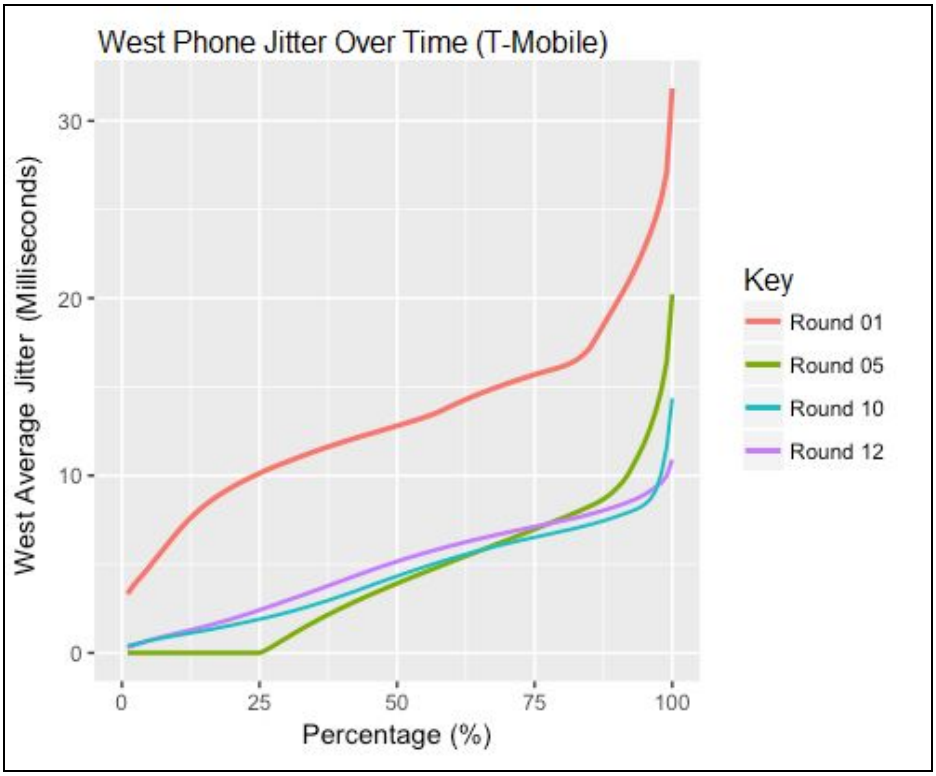

Figure 4.3: West jitter over time for T-Mobile

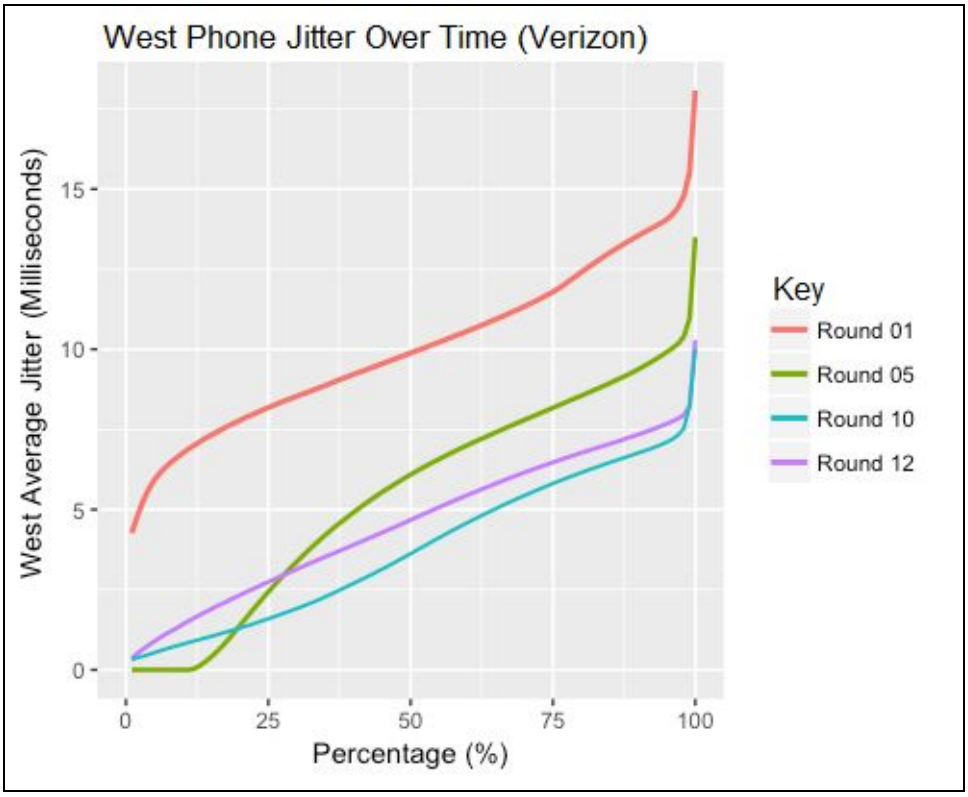

Figure 4.4: West jitter over time for Verizon

5. Conclusion

Based on the above information, we have concluded that there is a correlation between jitter, loss, and download/upload speeds in California. Verizon typically had the lowest jitter and loss while having the highest download/upload speeds, which equates to the best performance. Verizon was followed by AT&T, T-Mobile, and Sprint respectively. Round-trip time across the datasets was much less consistent and thus the carriers could not be ranked.

In terms of further research, there is more that could be done. This report examined numerous metrics over four rounds, but there will soon be thirteen rounds of data. It can be hypothesized that these trends hold true over the entirety of the data, but it is not certain. Additionally, each of the 2000 locations tested is also categorized by a type (Tribal, Rural, and Non-Rural); it is worth investigating whether the general trends hold true for each location type.

Appendix A: East Phone Average UDP Jitter and Loss

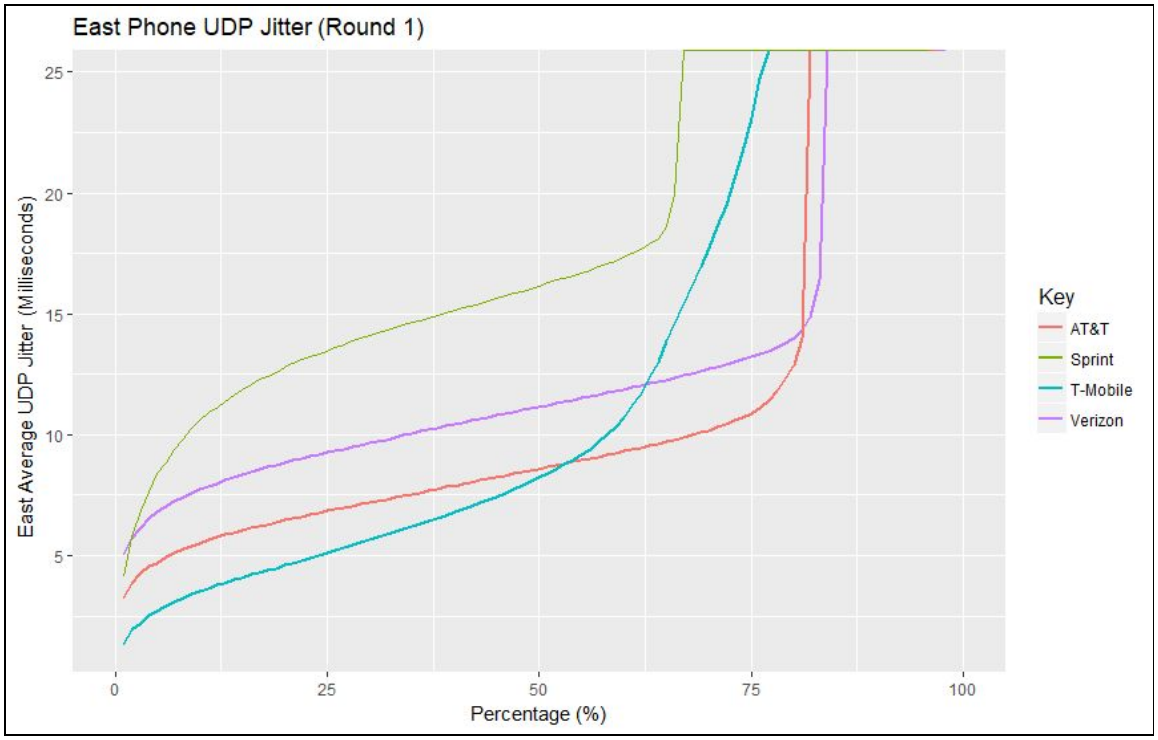

Figure A.1: East round 1 jitter data collected in Spring 2012

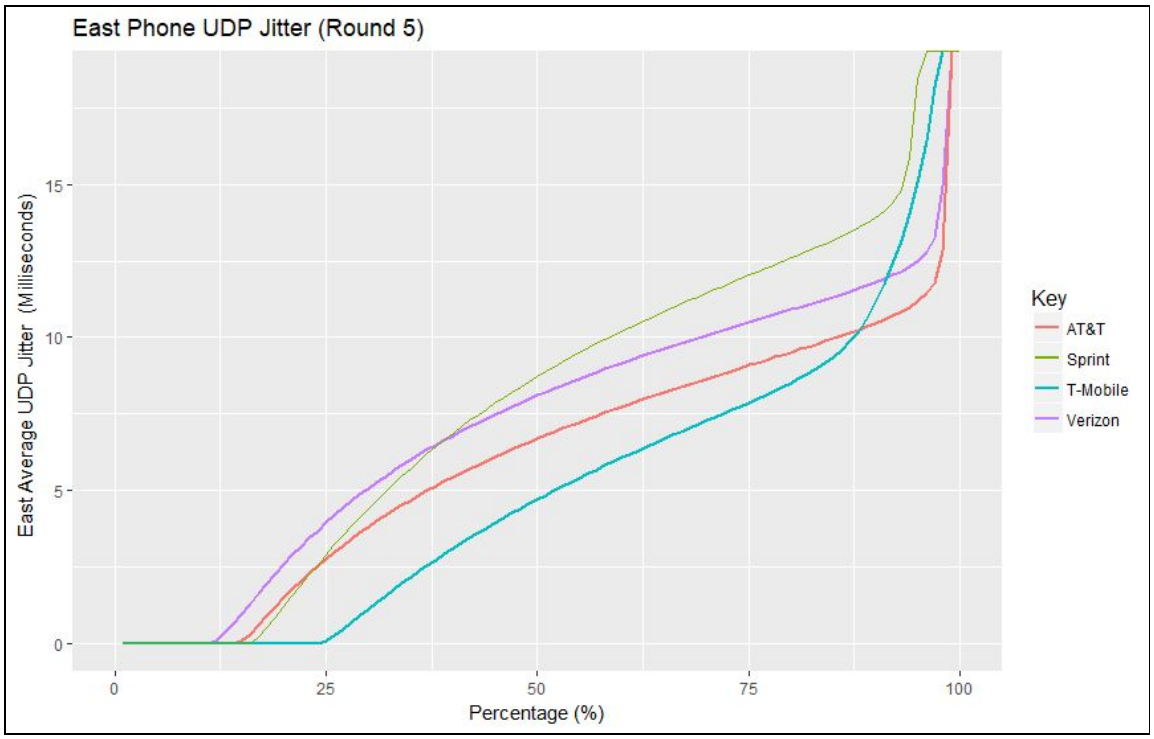

Figure A.2: East round 5 jitter data collected in Spring 2014

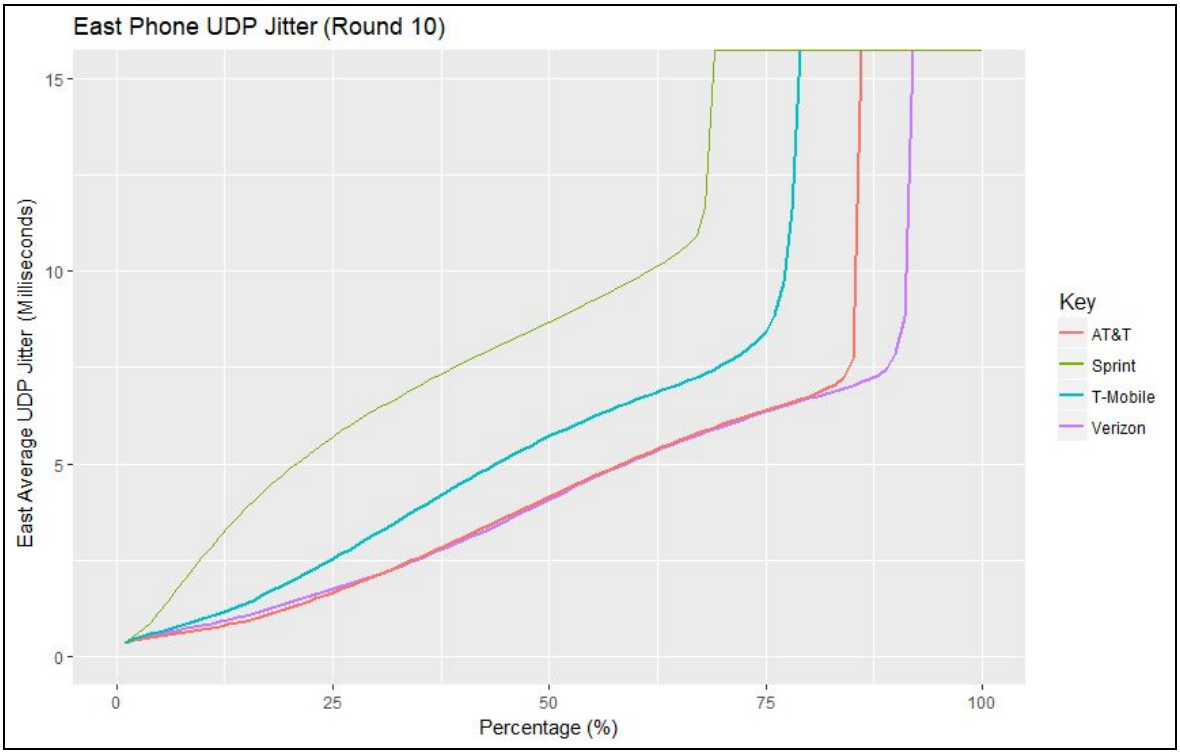

Figure A.3: East round 10 jitter data collected in Fall 2016

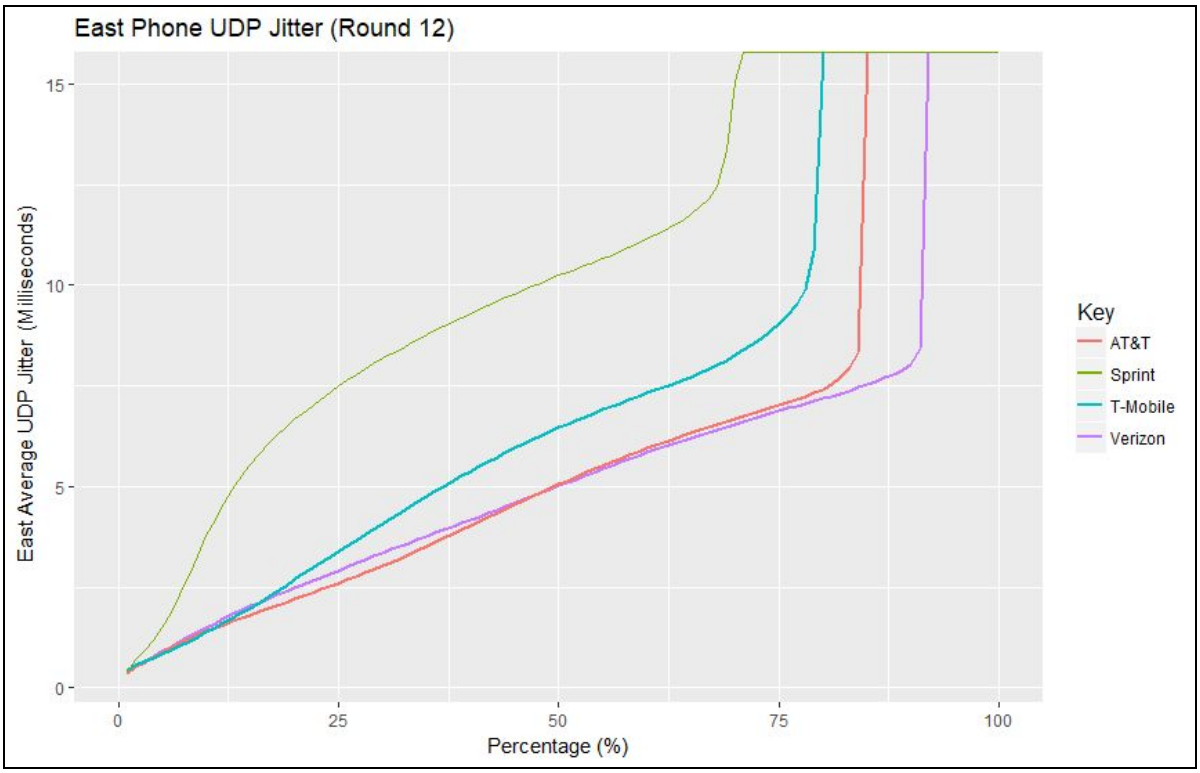

Figure A.4: East round 12 jitter data collected in Fall 2017

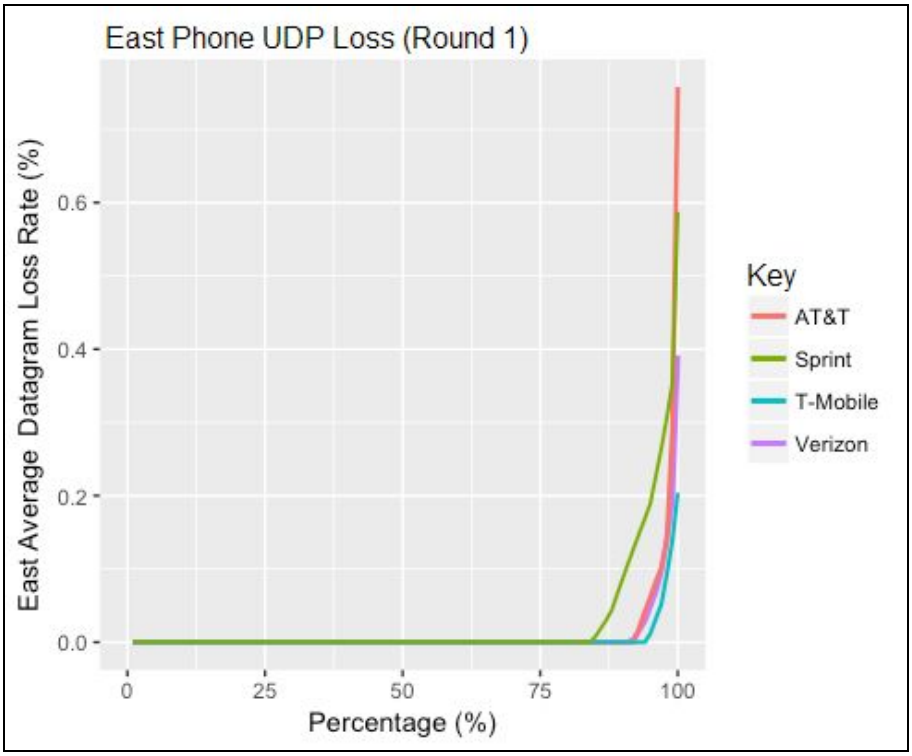

Figure A.5: East round 1 loss data collected in Spring 2012

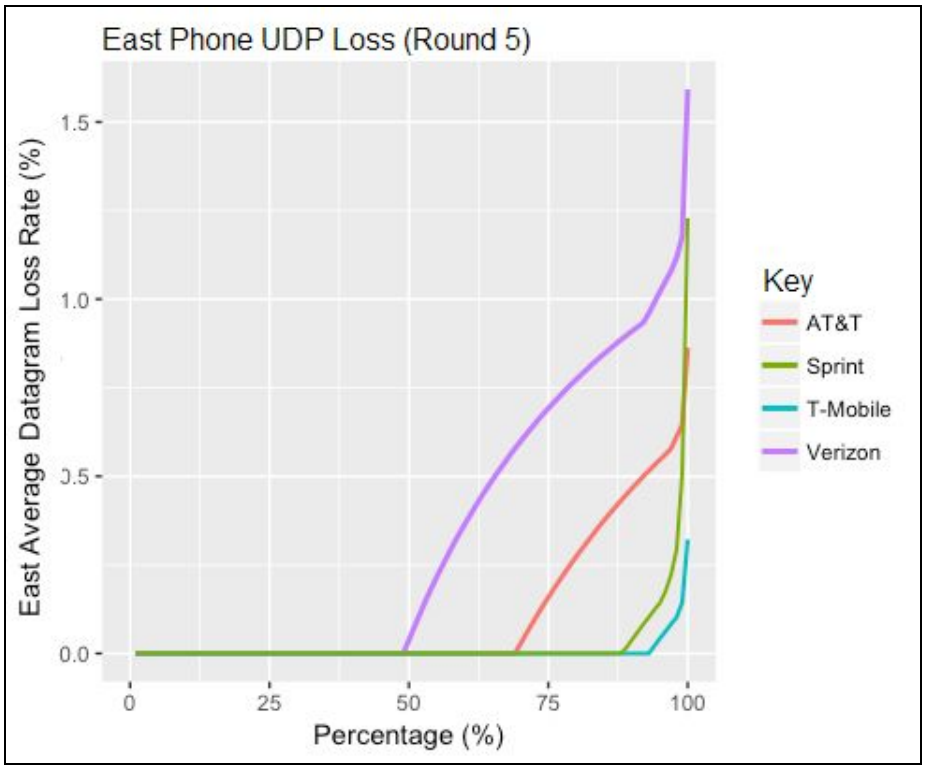

Figure A.6: East round 5 loss data collected in Spring 2014

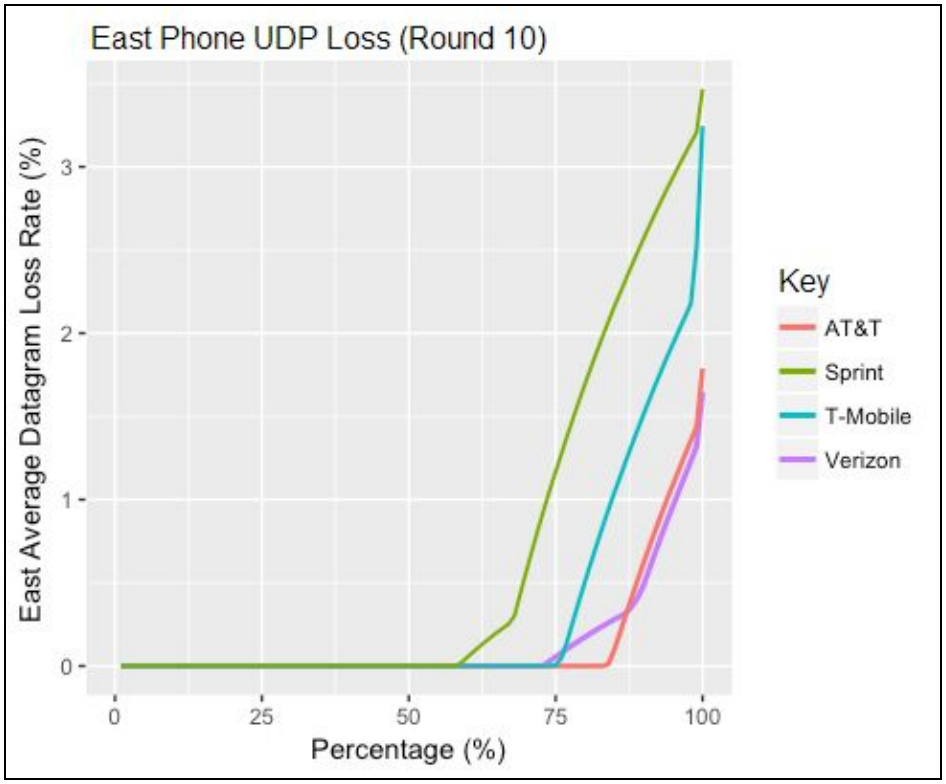

Figure A.7: East round 10 loss data collected in Fall 2016

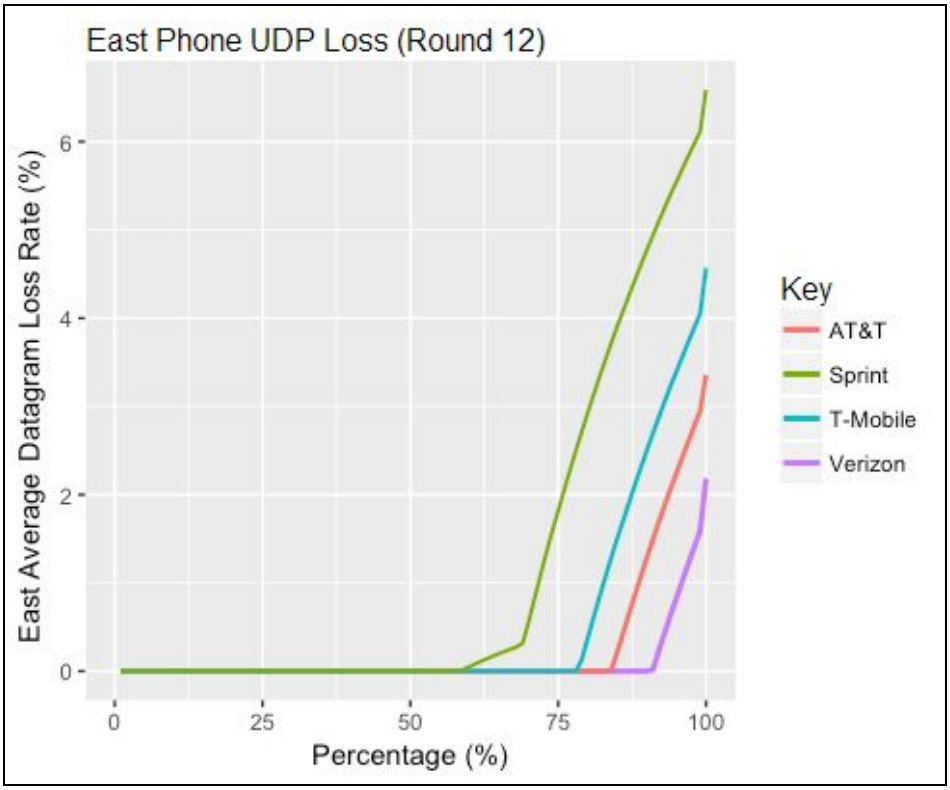

Figure A.8: East round 12 loss data collected in Fall 2017

Appendix B: East Phone Jitter Over Time

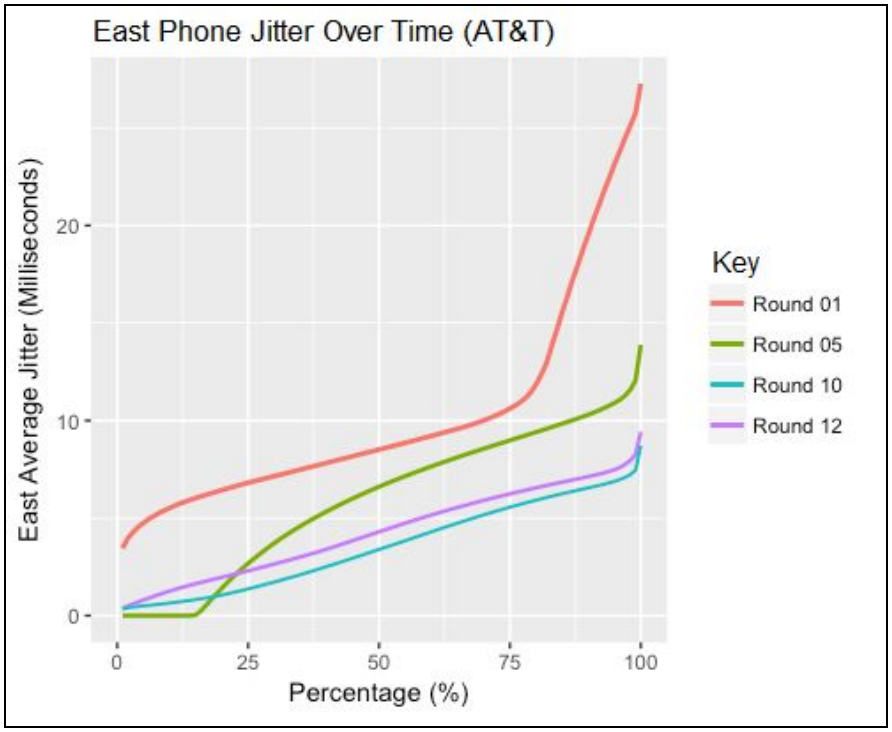

Figure B.1: East jitter over time for AT&T

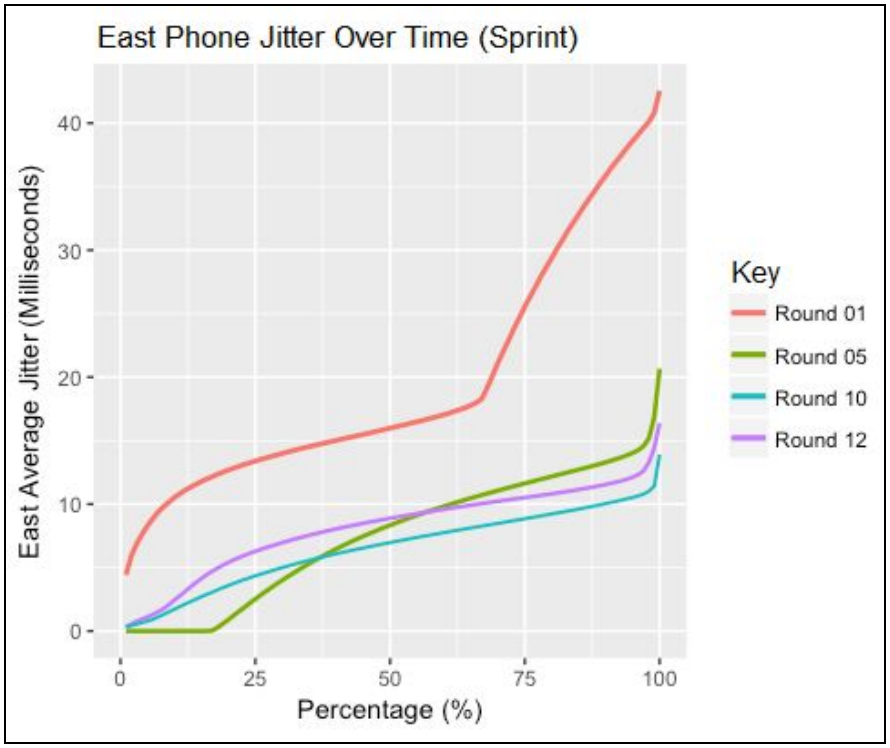

Figure B.2: East jitter over time for Sprint

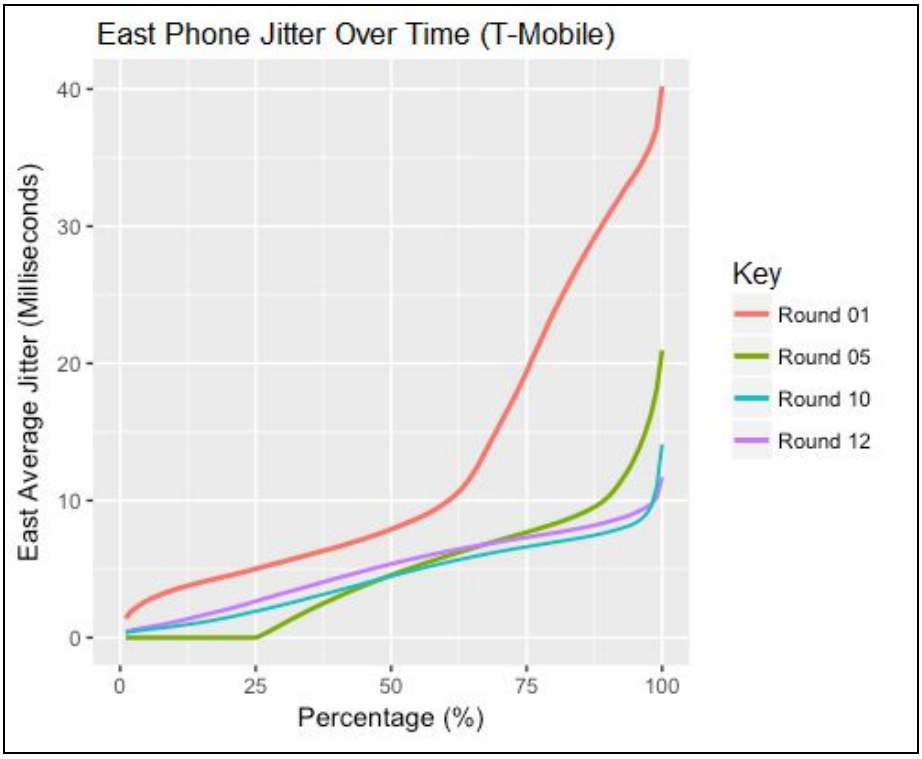

Figure B.3: East jitter over time for T-Mobile

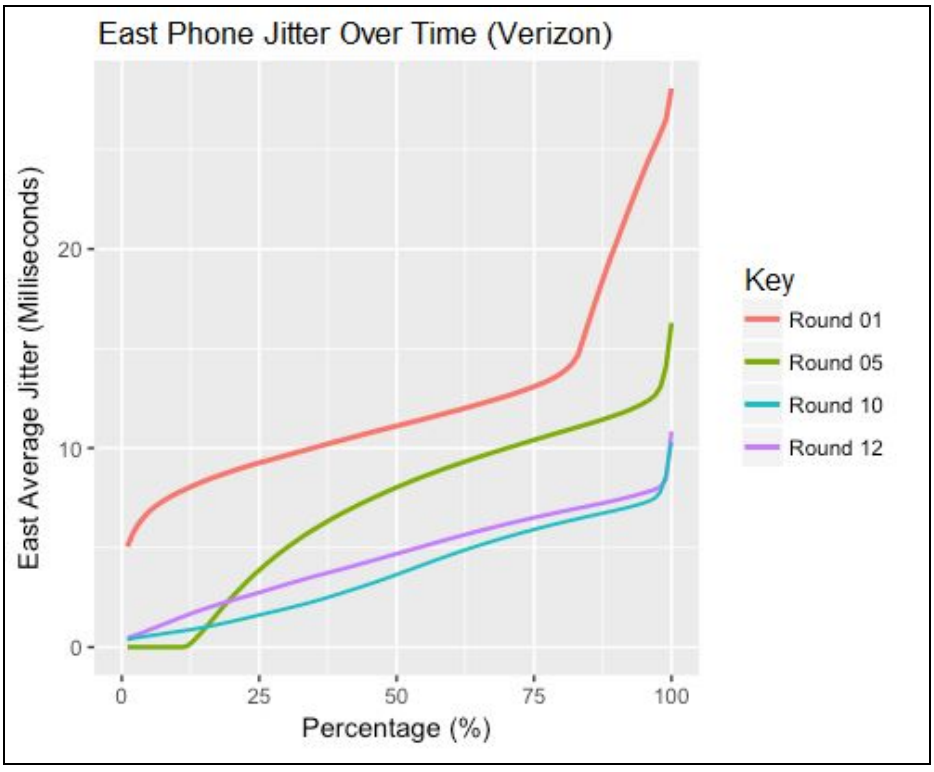

Figure B.4: East jitter over time for Verizon