A Comparative Performance Study of Fixed Wireless Access Networks

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Abstract. In recent years, Fixed Wireless Access (FWA) has gained popularity as an alternative technology to conventional wireline infrastructure for providing high-speed broadband Internet access to residential consumers. These services have been widely marketed in the United States, and millions of homes have subscribed to them. Additionally, in the United States, more than $40 billion of funding has been allocated to improve connectivity in unserved and underserved areas—whether FWA can satisfy connectivity for such connectivity-poor areas is currently subject to a debate that hinges largely on how FWA performs relative to conventional wireline Internet access. Unfortunately, in spite of these high stakes, we have limited understanding about how FWA and wireline connectivity performance compare.

This paper explores Fixed Wireless Access performance in comparison to a wireline high-speed Internet provider using datasets from two independent deployments that performed continual active measurements from both types of networks. Our study reveals significant performance differences between FWA networks and the wireline network, such as evidence of bufferbloat when measuring latency under upstream load. We also find significant performance differences between the FWA networks themselves. Finally, we find that that FWA networks exhibit more temporal variations in performance than the wireline network. Our findings have significant importance for areas of improvement for FWA, as well as critical policy implications for consideration of FWA as a viable alternative to wireline connectivity for broadband funding in the United States.

1 Introduction

2 Methodology

We design our study to answer questions on the general performance of FWA networks relative to wireline networks. In this section, we describe the metrics we use to measure network performance and how we collect them. Then, we describe the two independent datasets employed: (1) the publicly available SamKnowns network performance dataset [2, 3] and a second dataset we collect deploying active measurements inside a number of households across different network operators. We refer to this second dataset as Active Measurements Dataset (AMD).

Ethical Considerations. During our measurement campaign, we took care to avoid collecting any sensitive information of the volunteers participating in

	SamKnowns				AMD			
Collection period	June 2023 – October 2023				June 2023 – October 2023			
Number of households	CCN	VZW	TMO	STL	CCN	VZW	TMO	STL
	0	0	0	0	13	3	4	4
Number of measurements	CCN	VZW	TMO	STL	CCN	VZW	TMO	STL
Down/Up throughput	0	0	0	0	22469	697	1243	1163
Latency	0	0	0	0	7842	619	1219	843

Table 1: Summary of the datasets.

the collection of one of the studied datasets. All experiments uniquely generate active measurements using public infrastructure, *e.g.*, speed test. Further, we did not collect any information on network activity generated in the households in the deployment.

2.1 Metrics

We study several common network performance metrics: download and upload speeds, latency, and latency under load. We describe each of these metrics below as well as the methodology used to collect them.

Download / upload speed tests. The first metric we collect is download and upload speeds as measured by multithreaded speedtests. Speedtest measurements have traditionally been used to identify the capacity of the bottleneck link between a client and a server, which is typically the last-mile access link.

Latency (unloaded). Next, we measure network latency during times when the network is *unloaded*—*i.e.*, the measurement platforms trigger measurements when the network is idle. By default, the SamKnows platform measures UDP latency by sending packets every 1.5 seconds (except when other tests are being conducted or when other traffic is detected).

Latency under upstream load. We measure network latency during periods when the network is busy. This test is often used to detect `bufferbloat` [1], as it is designed to measure queuing-related latency. The testing procedure includes creating an artificially high upstream load before triggering a latency test. If bufferbloat is present in the upstream direction, the latency measurement values will be inflated as the test traffic is subject to queue-related delays.

2.2 Dataset

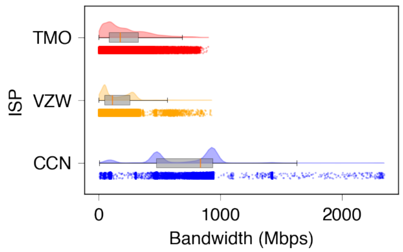
Datasets description

3 Results

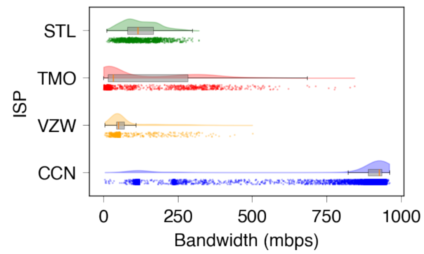
3.1 Bandwidth

We first measure upload and download speeds across both datasets using network speed tests. Figures 1a and 1b show download speeds, and Figures 1c and 1d display upload speed.

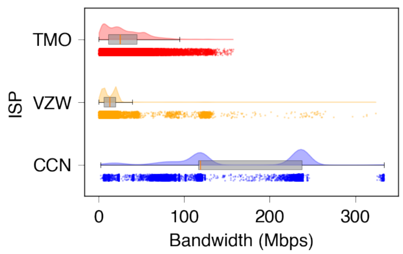
When analyzing download performance, we observe significant differences between the ISPs. First, as expected, the wireline Comcast (CCN in the figures) network reaches the highest download speeds. A closer look at Comcast reveals



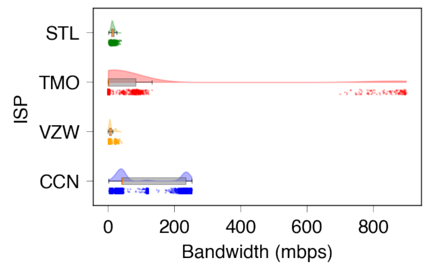
(a) Download SamKnows



(b) Download NetMicroscope



(c) Upload SamKnows



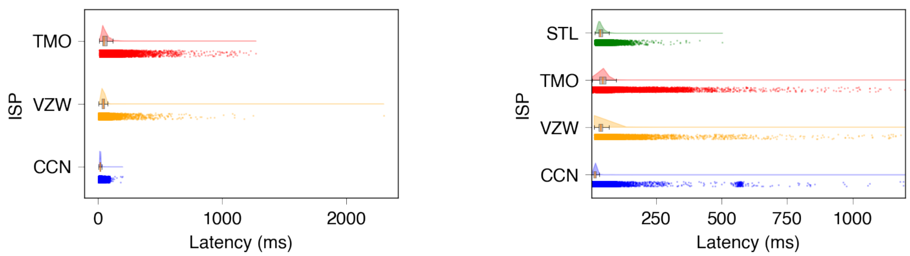
(d) Upload NetMicroscope

Fig. 1: Download and upload throughput measured with speed test measurements.

the underlying subscription packages that clients are subscribed to, with clusters of results roughly around 100 Mbps, and 500 Mbps, and 1 Gbps. Conversely, the fixed wireless access ISPs do not display such prominent groupings. Starlink offers the narrowest range of download speed performance, with a mean of roughly 100 Mbps. T-Mobile and Verizon, on the other hand, contain a much wider range of results.

In the SamKnows dataset, we do see a seemingly bimodal distribution for download speeds for Verizon, centering around roughly 20 Mbps and 200 Mbps. We posit that these results could be due to some clients being connected to 5G base stations while others may be connected via 4G LTE. However, as the access link properties are unavailable to the testing platforms, we are unable to confirm this assumption. We also observe a bimodal distribution for T-Mobile users in the NetMicroscope dataset. Again, this may be due to access link layer properties that we do not have access to.

Upload speedtests generally show similar results as the download tests, with expectedly lower overall performance as the majority of subscription packages for all of the ISPs measured are asymmetric. As with download speeds, we are able to easily see the different subscription tiers on the Comcast network, and the raw performance for the wireline network tends to surpass the FWA options. For SamKnows tests, we see that T-Mobile and Verizon upload speeds tend to be much lower than Comcast. Interestingly, we see a small number of very high speed upload measurements for T-Mobile on NetMicroscope. PRS: what do we think about this? What's happening here?



(a) SamKnows **(b)** NetMicroscope

Fig. 2: Latency without load.

3.2 Latency

We next inspect unloaded network latency. Recall from Section 2.1 that unloaded latency measurements are conducted when the network is otherwise idle. Figures 2a and 2b show the results over the course of the observation period.

As shown, in the SamKnows dataset we see that Comcast tends to have a narrow range of latency values, with a median of PRS: need value and a maximum of PRS: need value. Conversely, the FWA providers in the SamKnows dataset display a wider range of latency values, with maximums reaching up to PRS: value for T-Mobile, and PRS: value for Verizon. The NetMicroscope dataset (Figure 2b) shows slightly different results. While Comcast again has the smallest median latency (PRS: value), we observe a number of measurements above 500 ms on the wireline network. As in the SamKnows dataset, we again see that the FWA providers tend to experience a broader range of latencies. PRS: add medians, interquartile ranges, etc. to describe.

Interestingly, we again see that Starlink measurements fall in a more narrow range compared with T-Mobile and Verizon. We posit that this may be attributable to the nature of the access networks themselves. For example, cellular networks may be more susceptible to human movements in a given location—*e.g.*, a sports event or a concert that brings thousands of users into an area, causing congestion on the radio access layer. Conversely, it is relatively unlikely for a sudden influx of users to occur on the same Starlink infrastructure that a client connects to. These factors may factor into service provider selection moving forward, as it appears that LEO satellite connectivity may provide more predictable service. We explore temporal variations more deeply in Section 3.4.

3.3 Latency Under Load

3.4 Temporal

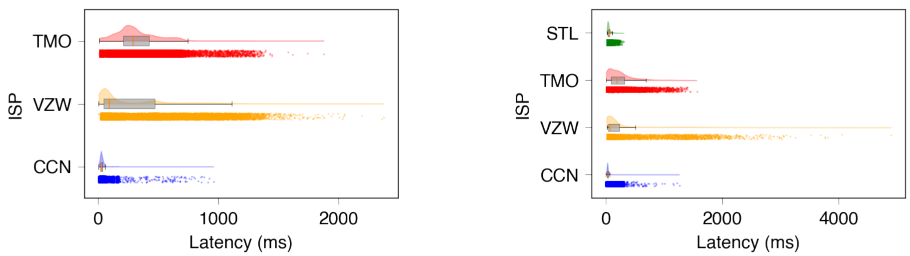
3.5 Discussion

4 Conclusion

Some conclusion

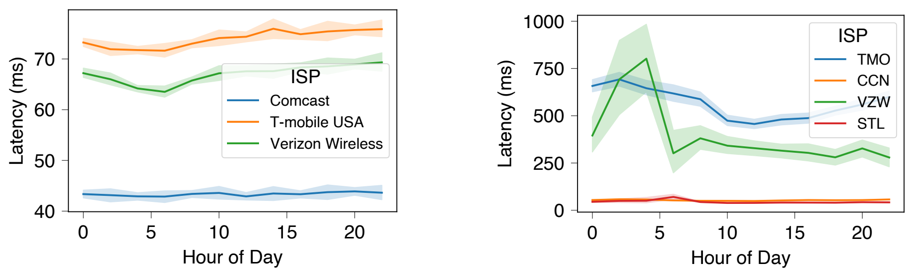
References

1. Gettys, J., Nichols, K.: Bufferbloat: Dark buffers in the internet. Commun. ACM **55**(1), 57–65 (Jan 2012)



(a) SamKnows **(b)** NetMicroscope

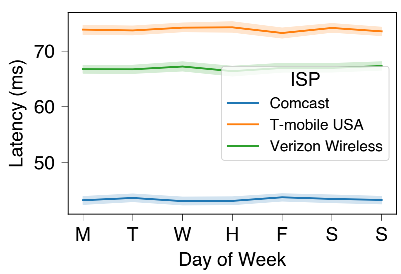
Fig. 3: Latency under load.



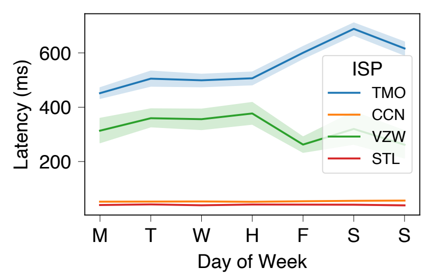
(a) SamKnows **(b)** NetMicroscope

Fig. 4: Latency under load across hours of the day.

2. SamKnows: SamKnows One (accessed October, 2023), `https://samknows.one`
3. SamKnows: Test Suit (accessed October, 2023), `https://www.samknows.com/tests`



(a) SamKnows



(b) NetMicroscope

Fig. 5: Latency under load across the days of the week.