5G Fixed Wireless vs LEO vs Cable Home Internet Performance Comparison

Andy Lacy, Rebecca Wetzel, Michael Reynolds, and Peter Sevcik

NetForecast®

NetForecast Report NFR5148

Sept. 2023

EXECUTIVE SUMMARY

At long last, the previously limited menu of internet connection options for the home is expanding to include 5G fixed wireless and low earth orbit (LEO) satellite services. This is welcome news, especially in underserved areas. To help households make informed decisions about which available connection option is best for them, NetForecast set out to test and compare performance across a representative collection of fixed wireless, LEO satellite, and cable network providers.

Fifty-five participants in 29 states hosted NetForecast QMap® test probes to measure the performance of two fixed wireless internet services (T-Mobile 5G Home Internet and Verizon 5G Home Internet), one LEO satellite internet service (Starlink—the only available residential LEO service provider), and two cable internet services (Charter Spectrum and Comcast Xfinity) from December 2022 through May 2023. NetForecast measured latency, effective bandwidth, and packet loss. With 10 or more probes per service provider testing around the clock, we completed more than six million latency tests and nearly a half million effective bandwidth tests during the test period.

Latency is the elapsed transit time from user device to server and back (reported as round-trip time in milliseconds—ms). Latency performance results summarized in Figure 1 show that the fixed wireless providers delivered median latencies of 81.4 ms, compared to 93.5 for the LEO provider, and 56.8 for the cable providers.

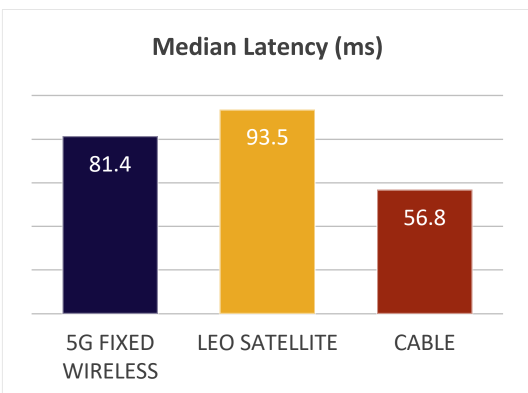

Figure 1 – Median Latency by Network Type

For most networked applications, latencies under 100 ms result in an acceptable user experience, although lower latency is best for latency-sensitive applications such as online gaming.

Effective bandwidth is the rate at which information is received by a single user using a single TCP connection over HTTP in Megabits per second (Mbps). Effective bandwidth is not the same as a speed test which measures the provisioned bandwidth from the ISP.

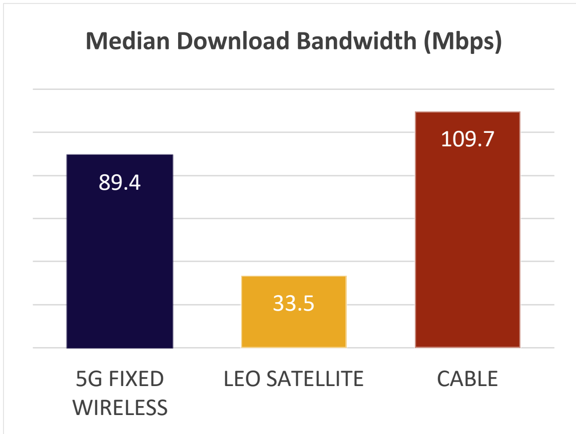

Figure 2 - Median Effective Download Bandwidth by Network Type

Figure 2 shows that the fixed wireless providers delivered 89.4 Mbps median effective download bandwidth to individual users for a 50 MB file transfer, while the LEO provider delivered 33.5 Mbps, while the cable providers delivered 109.7 Mbps. Effective bandwidth of 30 Mbps should deliver an acceptable user experience for most applications, thus these results should satisfy the performance needs for most user applications.

Although less critical than latency and effective bandwidth, NetForecast also measured packet loss—a count of data packets lost in transit (reported as percentage packet loss). Results showed that in aggregate, average packet loss was under one percent for all connection types tested. Packet loss of less than one percent is generally able to deliver an acceptable user experience for most applications.

TEST METHODOLOGY AND MEASUREMENTS

For this study, NetForecast ran automatic, continuous, active tests using our QMap internet user experience measurement application installed on test probes connected to each household's ISP-provided customer premises equipment ("CPE") via an ethernet cable. The tests measured latency, effective bandwidth, and packet loss. Measurement data from the tests was automatically uploaded to the QMap cloud platform for aggregation, analysis, and report generation. NetForecast tested the following services:

Service Provider	Service Tested
T-Mobile	5G fixed wireless home internet
Verizon	5G fixed wireless home internet
Starlink	LEO satellite home internet
Charter	Spectrum cable home internet
Comcast	Xfinity cable home internet

The primary user expectation is for an "application service" to respond soon after the user makes some form of entry (clicked, typed, spoken, etc.). An application service operates on a server responding over the internet to an application operating on a user's device. Responsiveness is important to users, and when a user describes an experience as "slow" they are referring to the aggregate effect of the following metrics (listed in order of importance): latency, loss, and bandwidth.

Latency Measurements

NetForecast measured network latency continuously throughout each day to reflect the true user experience over time (also referred to as observed latency). Latency is the elapsed time between when a data packet leaves a user's device, arrives at a destination server, and a response packet returns from that server to the user's device. This elapsed time is referred to as round trip time (RTT), and it is measured in milliseconds. Tests were automatically run from the QMap probes in volunteers' home using the ping utility, to servers located in Virginia, Ohio, Oregon, and San Francisco.

Every application service incorporates many round-trip events. For example, a web page is "built" by the browser following a script of HTTP Gets that are replied to with some content to be displayed. A typical web page requires dozens of such events.

Packet Loss Measurements

NetForecast also measured packet loss, which is a measure of data packets that fail to arrive at their destination. The results were reported as the percentage of packets lost relative to packets sent. Lost packets are very costly to overall response time.

The application on the device must first wait for the first RTT, then it must wait for either end to realize that a loss occurred, and then again for a second RTT. Beyond application performance, packet loss represents unproductive traffic on the wire and can aggravate poor bandwidth conditions.

Bandwidth Measurements

NetForecast measured effective bandwidth, the rate of information received by a single user, which reflects the experience of individual users within a household. Using HTTP, NetForecast transferred payloads of 200 KB, 1 MB, and 50 MB, which represent typical payload transfers over the internet for activities such as web browsing. Results were reported in megabits per second.

The QMap effective bandwidth measurement is unlike traditional speed tests such as Ookla's Speedtest because QMap tests are performed continuously throughout the day every day, whereas other approaches rely on user-initiated tests when a user thinks the internet is slow. ISPs often advertise bandwidth as "speed," thus promoting a narrative that subscribers should buy higher bandwidth services to improve application responsiveness. While this was true when bandwidth delivered was measured in single digits, above 30 Mbps the benefits of higher bandwidth are marginal at best.

RESULTS

This section presents the overall latency, packet loss, and effective bandwidth results for T-Mobile Home Internet and Verizon 5G Home Internet services, Starlink's LEO home internet service, and residential cable internet services from Charter and Comcast. Testing took place from December 2022 through May of 2023.

Latency Results

How quickly an online application responds affects a user's satisfaction and productivity. The combined impact of network latency and packet loss on a user's quality of experience (QoE) is at least as important— and in many cases more important— than bandwidth. High latency and loss slow application response times.

Latency performance results in Figure 3 show cable ISPs delivered the lowest median latencies—near 50 ms, compared to between 70 and 80 ms for the fixed wireless providers, and nearly 90 ms for the LEO satellite provider.

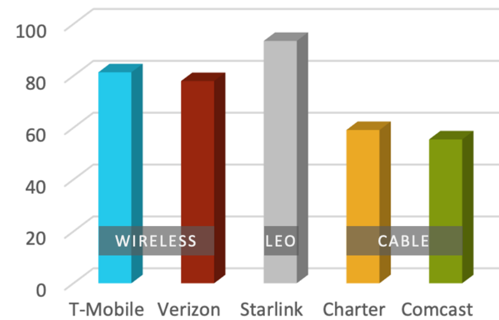

Figure 3 - Median Latency by ISP

The data in Figure 4 show the value below which 99 percent of the data falls—a value that reflects performance variability and is often considered a more accurate metric than the median because it takes outliers into account. The 99th percentile values for Charter, Comcast, Verizon, and Starlink indicate consistent latency, while T-Mobile data shows highly variable latency. The 99th percentile latency values for Charter, Comcast, Verizon, and Starlink are about twice their median values, while the 99th percentile value for T-Mobile is more than four times that of its median.

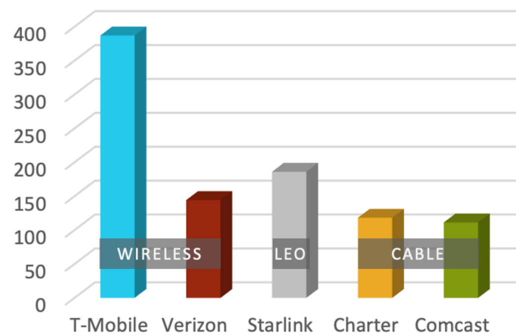

Figure 4 - Latency 99th Percentile by ISP

Comparative latency measurement counts by service provider in Figure 5 show T-Mobile's Home Internet service has the highest count of latency test results longer than 120 ms. In fact, although not shown here, T-Mobile's latency counts did not trail off until 600 ms and did not merge to near zero until past four seconds!

In contrast, Verizon's 5G Home Internet service latency distribution tracked closely with those of the cable ISP services, with almost all latency results under 120 ms—and almost no results greater than 300 ms. Starlink showed a significant number of latency test results in the 400 to 600 ms range, but trailed off to near zero after that, thus outperforming T-Mobile.

It is worth noting that Charter, Starlink, and Verizon exhibit two pronounced peaks. This is due to East Coast/West Coast latency, with the left peak representing lower latency for same-coast traffic, and the right representing higher latency from traffic traversing longer coast-to-coast distances.

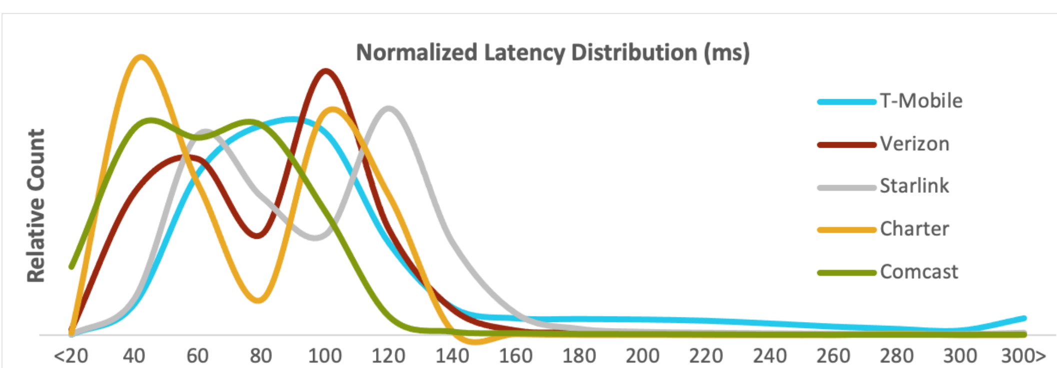

Figure 5 – Normalized Latency Distribution by ISP

Figures 6 and 7 below show how latency varied among ISPs based on time of day. We divided the day into three broad household activity categories: "sleeping"—from midnight to 6am; "working"—from 6am to 5pm; and "playing"—from 5pm to midnight.

All values were time stamped in local times for each probe location. Figure 6 shows a small difference in median latency based on time of day for T-Mobile and Starlink, while the other three providers exhibit almost no difference in latency based on time of day.

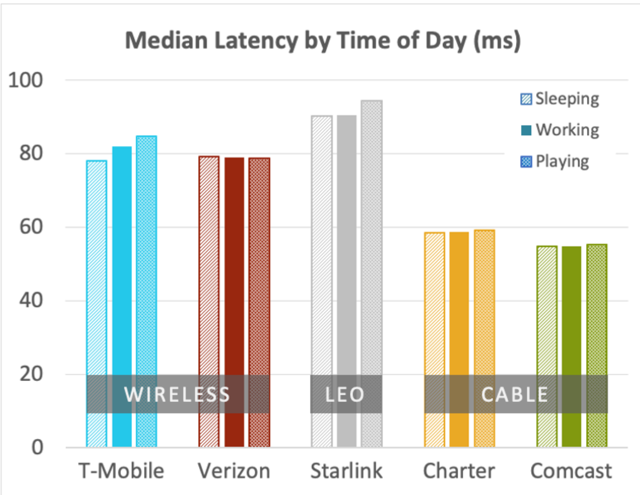

Figure 6 – Median Latency by ISP & Time of Day

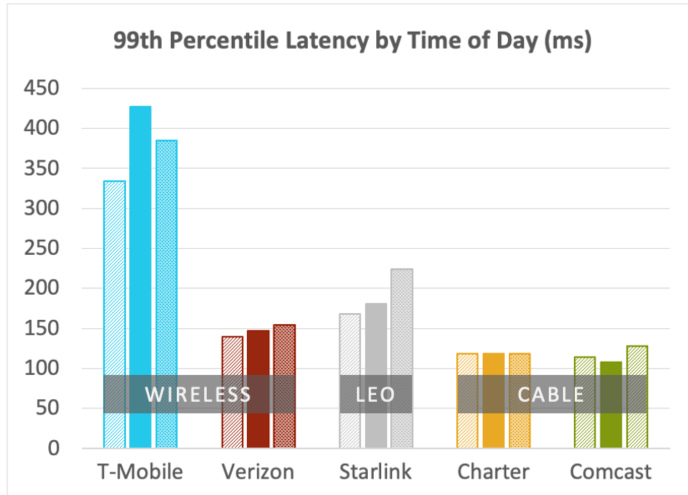

Figure 7 – Latency 99th Percentile by ISP & Time of Day

In contrast, the 99th percentile latency data show a sizeable increase in latency for T-Mobile during the 6am to 5pm "working" time compared to other times of day, and there is a noticeable increase in Starlink latency during the evening "playing" hours from 5pm to midnight.

Packet Loss

Packet loss results shown in Figure 8 were surprisingly high for T-Mobile Home Internet, with approximately 5% packet loss. The high packet loss may have had a regional component, as high packet loss was seen in four of 14 locations. Starlink also exhibited high packet loss, with over one-half percent loss. In contrast, Comcast, Verizon, and Charter showed extremely low packet loss.

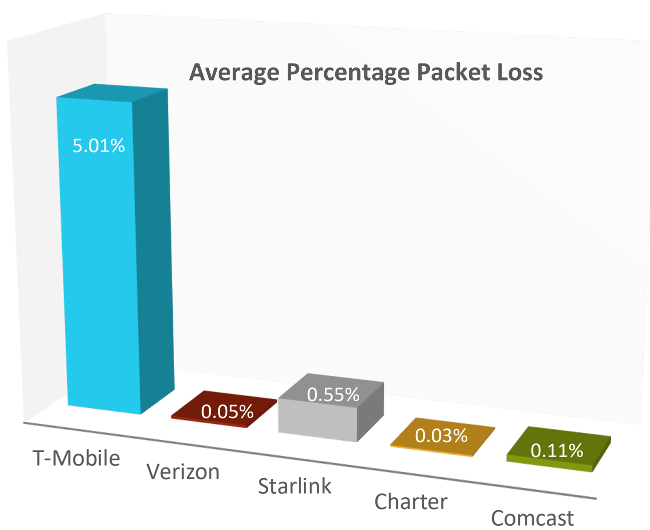

Figure 8 – Average Percentage Packet Loss

Bandwidth Results

The effective bandwidth results by provider and payload size in Figure 9 show Comcast with the best overall median effective bandwidth. As with latency, Starlink was the poorest performer of the five providers, with less than a third the effective bandwidth of Comcast for the 50 MB payload.

T-Mobile Home Internet and Verizon 5G Home Internet fixed wireless services exhibited almost identical median bandwidth, with slightly more than two thirds the performance of Comcast for the 50 MB payload, but they both outperformed Charter.

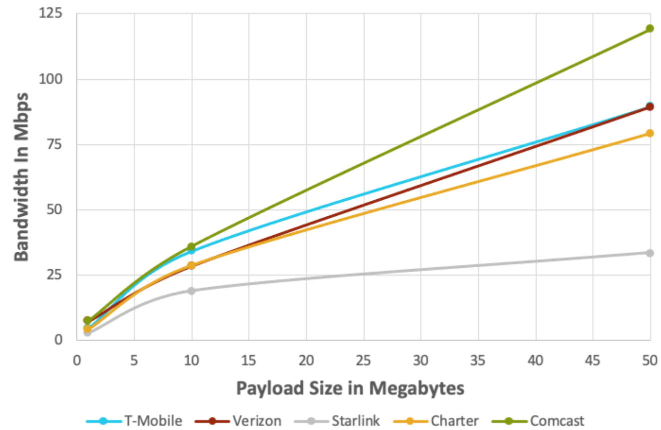

Figure 9 - Median Effective Bandwidth by Provider

The 99th percentile results for effective bandwidth in Figure 10 show the Mbps value where 99% of the transfers delivered that bandwidth or greater. For example, for the 50 MB payload size, 99% of transfers for Verizon delivered at least 29.2 Mbps, showing it to provide the most consistent performance.

Comcast and Charter showed almost identical bandwidth variability, with 99th percentile values notably lower than Verizon. T-Mobile and Starlink showed similar bandwidth variability for the 99th percentile, at about one fifth that of Verizon for the 50 MB payload.

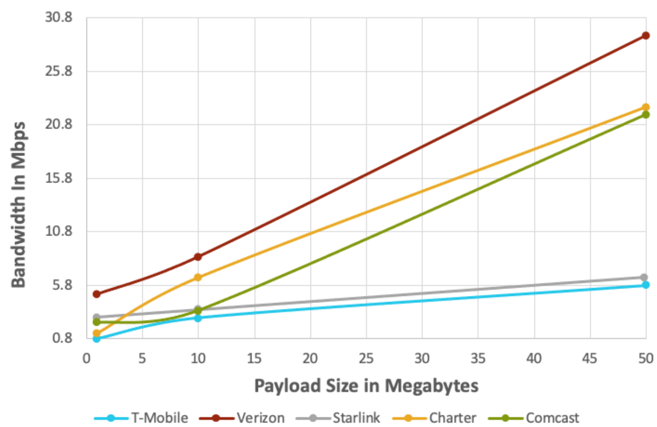

Figure 10 - Effective Bandwidth 99th Percentile by ISP

CONCLUSIONS

Based on the NetForecast performance test results in this study, fixed wireless and LEO services should deliver acceptable user experiences most of the time for most user applications. Cable services, which formed the performance benchmark for the study, routinely deliver a high-quality, more consistent experience—but for households in underserved areas, and those looking for alternatives, LEO and 5G fixed wireless are viable choices.

Verizon's 5G Home Internet service performed surprisingly well compared to cable for effective bandwidth and packet loss, while T-Mobile's Home Internet service fell short in all performance categories. Not only did T-Mobile exhibit the worst performance for latency, effective bandwidth, and packet loss, it rivalled Starlink for last place in 99th percentile performance, indicating service inconsistency. Starlink had the longest latency and the worst effective bandwidth of the services tested, although for packet loss, it bested T-Mobile.

ABOUT THE AUTHORS

Andrew Lacy

Andy Lacy is NetForecast's Chief Data Scientist. Responsible for developing NetForecast deep analytics that uncover trends and anomalies in large datasets gathered by NetForecast tools or by client infrastructure. He developed key network metrics that account for subtle application and protocol behavior.

He is a certified Scrum Master with a commitment to continuous improvement, test-driven development.

Rebecca Wetzel

Rebecca Wetzel is the President of NetForecast, and an internet industry veteran. She helped realize the commercialization of the internet in its early days, and worked to design and market some of its first value-added services.

She has spent much of her career launching and guiding network technology startups and working as an internet industry analyst.

Mike Reynolds

Mike Reynolds is a veteran project manager and business analyst, with further expertise in software development and data science, and designer of popular trading card games based on The Lord of the Rings and Star Wars.

His prior technical project experience was in casino gaming, STEM journal website development, and point-of-care testing data management.

Peter Sevcik

Peter Sevcik is the Founder of NetForecast and is a leading network performance expert. An internet pioneer, Peter was among the first to measure and develop internet performance improvement techniques. He helped design more than 100 corporate and commercial networks.

In addition, Peter invented the Apdex performance reporting methodology, and has co-patented application response-time prediction and network congestion management algorithms.