Satellite Broadband Remains Inferior to Wireline Broadband

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VANTAGEPNT.com 605-995-1777
2211 N Minnesota Street Mitchell SD 57301

Contents

1 Executive Summary

Not all broadband services are created equal. The usefulness of a broadband service is determined by how well online applications work or whether they work at all. The quality of the broadband connection can be measured by certain "standards" which include speed, latency, monthly capacity, reliability and scalability. When a broadband service does not meet the minimum requirements of one or more of these standards, the customer will have a lower quality broadband experience. In 2013, Vantage Point Solutions (VPS) performed a detailed analysis of broadband services provided over satellites titled, "Analysis of Satellite-Based Telecommunications and Broadband Services."[1] This whitepaper demonstrated that satellite-based broadband services did not meet the then-minimum standards for a high-quality broadband connection. This updated analysis also shows that even with the new satellite platforms, satellite-based broadband has been unable to keep pace with the rapidly increasing customer demands for speed and capacity, and future prospects for doing so remain highly questionable.

Providers are attempting to improve speed and capacity, but significant constraints remain. Spectrum is scarce and there are few opportunities for providers to acquire more, so "reusing" existing spectrum is the only practical means to increase speed and capacity. The same frequency spectrum can be "reused" two or more times by deploying additional, smaller spot beams directed at different geographical locations within the satellite's footprint. These satellite advances are explained in more detail and will be shown to be evolutionary advances, not revolutionary. Following is a brief review of the five key broadband performance standards and the capabilities of the current and planned geostationary broadband satellites.

- **Speed** – Increasing the number of spot beams has allowed a broadband satellite to have between 200 and 300 Gbps of total capacity. This capacity is shared by all satellite users in their spot beam. Oversubscription of spot beams, which happens regularly, results in customers not achieving their advertised speeds. Capacity-intensive applications such as distance learning, healthcare, entertainment, video chat and conferencing can quickly exhaust the satellite capacity at relatively low subscriber counts.
- **Latency** – The new satellites still operate in a geostationary orbit 22,000 miles above the equator. Because technology must still obey the laws of physics and signals cannot travel faster than the speed of light, satellite broadband service continues to be plagued by high latency. With average latencies over 600 ms,[2] satellite broadband service is far from meeting the Federal Communications Commission (FCC) standard of a 100 ms round trip, and is more than 20 times that of the *average* landline broadband service. This aspect of satellite broadband service significantly degrades or makes unusable many real-time applications, such as voice, emergency notifications, health services and virtual private networks.

[1] Analysis of Satellite-Based Telecommunications and Broadband Services, Vantage Point Solutions, Nov. 2013. (https://ecfsapi.fcc.gov/file/7520956711.pdf) ("VPS 2013 satellite whitepaper")

[2] 2016 Measuring Broadband America Fixed Broadband Report, FCC, Dec. 1, 2016, p. 21. (http://data.fcc.gov/download/measuring-broadband-america/2016/2016-Fixed-Measuring-Broadband-America-Report.pdf)

- **Capacity** –Because the capacity on satellites is severely limited, providers often place extremely low capacity thresholds on their broadband customers to control usage. Only 60,000 subscribers, which is less than 0.06% of the nation's current broadband subscribers, using 25 Mbps service will exhaust the capacity on ViaSat's most recent satellite. Therefore, even after the launch of new satellites, satellite providers need to carefully manage customers' data usage. All the current data plans offered by Hughes Network Services (Hughes) and ViaSat, have capacity thresholds that are substantially less than the average customer's usage.[3] In fact, none of the current satellite broadband plans currently meet the FCC's minimum 160 GB capacity standard for Connect America Fund (CAF) eligibility.[4]

- **Reliability** – Satellite communications become unreliable under certain environmental conditions that regularly occur.[5] Frequencies utilized by satellite systems are susceptible to outages during rain, ice or snow conditions. In addition, twice-a-year sun outages occur for many days in a row and each can last 15 minutes or longer. Terrestrial blockage is also an issue for customers in northern states because the likelihood of an object obscuring the direct view of a satellite increases as the subscriber's distance from the equator increases. Terrestrial blockage, periodic solar outages and weather interference are all reliability issues that continue to persist, even with the new satellite platforms. As customers increasingly rely on broadband for critical services, such as eHealth, satellite-based services are not able to meet the necessary reliability requirements.

- **Economical and Scalable** – Customer broadband demands in terms of both speed and capacity increase at a faster rate than available satellite capacity, even after considering technology advances. Increasing broadband capacity often requires that new geostationary satellites be launched — an endeavor that takes years and costs millions of dollars.

This whitepaper will show that satellite broadband is still inferior to broadband services available from terrestrial broadband providers. Broadband funding using scarce public monies should be focused on investments that not only meet the current needs of broadband customers, but also will be able to easily adapt to customers' rapidly increasing speed and capacity demands. In the opinion of the authors of this whitepaper, satellite broadband does neither. There may always be some customers that subscribe to geostationary broadband satellite services, but it is almost always because they have no better alternative. Public funds should be directed to technologies that provide better quality broadband, are more scalable, and have longer useful lives.

[3] Different entities have measured a range of average broadband customer usage. The FCC reported average broadband usage at 160 GB per month, while a private research firm reported average usage to be 190 GB per month. Since both studies are based on data that is two years old, the average is likely much higher today.

[4] *Wireline Competition Bureau Announces Results of 2017 Urban Rate Survey for Fixed Voice and Broadband Services, Posting of Survey Data and Explanatory Notes, and Required Minimum Usage Allowance for ETCs Subject to Broadband Public Interest Obligations*, p. 3.

[5] Analysis of Satellite-Based Telecommunications and Broadband Services, pp. 11-14.

2 Current and Future Broadband Demands

All broadband providers have been investing in their networks to meet increased broadband demands. AT&T announced that its fiber service will expand to include 12.5 million locations across 67 markets by 2019.[6] Charter Communications (now known as Spectrum) is "moving toward a future where broadband speeds of up to 10 Gigabits per second are possible."[7] Verizon soon will be offering a 750 Mbps tier in its FIOS markets in New York City, New Jersey, Philadelphia and Boston.[8]

The need for high quality broadband is being driven by applications that have become commonplace.[9] These broadband applications include:

- Distance Learning
- Healthcare
- Video Chat and Video Conferencing
- Entertainment
- Cloud Computing

The quality of broadband services was characterized by five key metrics in a previous VPS whitepaper.[10] These metrics and the impact of substandard quality, summarized in Table 2-1, include high speed, low latency, high capacity, high reliability and economic scalability. A broadband service must have these characteristics to meet current and future consumer broadband demands.

[6] AT&T Fiber Expansion Continues with 50 New Communities Across 17 Markets, Telecompetitor, Mar. 24, 2017. (http://www.telecompetitor.com/att-fiber-expansion-continues-50-new-communities-across-17-markets/)

[7] Charter Eyes 10 Gbps Broadband, Multichannel News, Dec. 6, 2016. (http://www.multichannel.com/news/cable-operators/charter-eyes-10gbps-broadband/409489)

[8] Verizon Goes on the Offensive with Cable, Launches 750 Mbps Symmetrical Service, Telecompetitor, Jan. 12, 2017 (http://www.telecompetitor.com/verizon-goes-on-the-offensive-with-cable-launches-750-mbps-symmetrical-service)

[9] Evaluating 5G Wireless Technology as a Complement or Substitute for Wireline Broadband, Vantage Point Solutions, Feb. 2017, pp. 7-9. (https://ecfsapi.fcc.gov/file/1021310720678/02.13.17%20FCC%20Ex%20Parte-NTCA%20Letter%20Submitting%202017%20Technical%20Paper%2C%20WC%2010-90.pdf)

[10] Wireless Broadband is Not a Viable Substitute for Wireline Broadband, Vantage Point Solutions, Mar. 2015, p. 7. (https://ecfsapi.fcc.gov/file/60001039981.pdf)

Characteristic	Consumer Demand	Impact of Reduced Quality
High Speed	• In 2015, the median speed was 41 Mbps and has been increasing 28% annually.[11] At that rate, median speeds will be higher than 65 Mbps in 2017 and almost 250 Mbps in only 5 years. • 1 Gbps service is projected to be commonly available before 2020.[12] • Cisco estimates that the average United States household will have 12 broadband-connected devices in the near future, and broadband speeds will double between 2015 and 2020.[13]	• Households with slower broadband speeds will not be able to use broadband applications such as healthcare, distance education, entertainment and telecommuting.
Low Latency	• Latencies of between 12 and 58 ms are typical for terrestrial based providers, but greater than 600 ms for geostationary broadband satellites.[14] • The FCC requires round trip latency to be 100 ms or less on networks receiving support (e.g., Rural Broadband Experiments and CAF Phase II.)[15] • International Telecommunications Union (ITU) Recommendation G.114 specifies a maximum of 150 ms one-way latency for acceptable voice services. • Low latency is needed to support the increasing use of touch interfaces and the "Internet of Things." To ensure equipment manufacturers can meet these future broadband demands, new network equipment and technologies (including those overseen by international 5G wireless standard bodies[16]) are making significant investments designed to ensure lower latency.	• Higher latencies negatively impact the quality and user experience with highly interactive applications.[17] • Telemedicine and distance learning applications that require real-time video conferencing are becoming more widespread in rural areas.[18] High latency can significantly degrade or make these interactive applications unusable.

Table 2-1: High-Quality Broadband Characteristics ***(cont. on next page)***

[11] 2016 Measuring Broadband America, p. 15.

[12] Bringing the World Together, CAF 2 Modeling Fixed Wireless Capacity for CAF 2 Deployments, Adtran, Oct. 2015, p. 5. (https://ecfsapi.fcc.gov/file/60001331590.pdf)

[13] The Zettabyte Era – Trends and Analysis – Cisco, Jun. 2, 2016. (http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/vni-hyperconnectivity-wp.html)

[14] 2016 Measuring Broadband America, pp. 20-21.

[15] *In the Matter of Connect America Fund ETC Annual Reports and Certifications*, WC Docket No. 10-90 and 14-58, Report and Order and Order on Reconsideration, Released Mar. 2, 2017, p. 5. (https://apps.fcc.gov/edocs_public/attachmatch/FCC-17-12A1.pdf)

[16] 5G Wireless requires less than 4 ms of latency for the User Plan RF Interface, ITU Document 5/40-E 22, Minimum requirements related to technical performance for IMT-2020 radio interface(s), Feb. 2017, p. 6. (https://www.itu.int/md/R15-SG05-C-0040/en)

[17] 2016 Measuring Broadband America, p. 21.

[18] *In the Matter of Inquiry Concerning the Deployment of Advanced Telecommunication Capability to All Americans in a Reasonable and Timely Fashion, and Possible Steps to Accelerate Such Deployment Pursuant to Section 706 of the Telecommunications Act of 1996, as Amended by the Broadband Data Improvement Act*, GN Docket No. 14-126, 2015 Broadband Progress Report and Notice of Inquiry on Immediate Action to Accelerate Deployment, Released Feb 4, 2015, p. 22. (https://apps.fcc.gov/edocs_public/attachmatch/FCC-15-10A1.pdf)

Characteristic	Consumer Demand	Impact of Reduced Quality
High Capacity	• The FCC initially set a data usage limit of 150 GB per month as the minimum performance requirement for the receipt of CAF, with annual adjustments to reflect average usage of fixed broadband consumers.[19] The FCC's current data usage allowance is 160 GB per month.[20] • Average residential broadband usage in the United States, as measured by a private research firm, was 190 GB per month in 2015 and is growing rapidly.[21] • The findings of both the FCC and the private research firm are both two years old so broadband usage today is likely much higher.	• Most satellite customers subscribe to service plans that allow less than 30 GB per month of data usage. • Low data usage limits can be surpassed quickly when customers use common applications involving large file transfers, such as video-based applications or online back-ups.
High Reliability	• Public safety, healthcare, education and commerce increasingly rely on broadband for many of their critical services. • As the "Internet of Things" becomes more widespread, reliability will become more important.	• Lower reliability due to solar, terrestrial and environmental interference prevents satellite broadband from being utilized for critical eHealth or emergency-type services, as well as limits its use for education or commerce.
Economical and Scalable	• Networks must be scalable to meet rapidly increasing customer demand for both speed and capacity.	• Networks that are not scalable may become obsolete before the end of their economic lives, making it impossible for the provider to meet customers' broadband service needs without significant additional investment.

Table 2-1: High-Quality Broadband Characteristics (cont.)

[19] *In the Matter of Connect America Fund ETC Annual Reports and Certifications*, WC Docket No. 10-90 and 14-58, Report and Order and Order on Reconsideration, Released Mar. 2, 2017, p. 5. (https://apps.fcc.gov/edocs_public/attachmatch/FCC-17-12A1.pdf)

[20] *Wireline Competition Bureau Announces Results of 2017 Urban Rate Survey for Fixed Voice and Broadband Services, Posting of Survey Data and Explanatory Notes, and Required Minimum Usage Allowance for ETCs Subject to Broadband Public Interest Obligations*, WC Docket No. 10-90, Public Notice DA 17-167, Released Feb. 14, 2017, p.3. (https://apps.fcc.gov/edocs_public/attachmatch/DA-17-167A1.pdf)

[21] iGR: Average Monthly Broadband Usage is 190 Gigabytes Monthly Per Household, Telecompetitor, Sep. 26, 2016. (http://www.telecompetitor.com/igr-average-monthly-broadband-usage-is-190-gigabytes-monthly-per-household/)

3 Satellite Network and Technology

Satellite broadband services are currently delivered using geostationary satellites, although low earth orbit (LEO) satellites may be used in the future. The geostationary and LEO satellites each have different performance characteristics and unique limitations. These can be seen in Table 3-1.

Satellite Technology	Characteristics	Limitations and Impairments
Geostationary Orbit	• Satellites orbit at higher than 22,000 miles above the earth's equator. • Orbiting at the same speed as the earth rotates, satellites appear to be stationary above the earth so that ground station antenna can point to one orbital location in the sky. • Satellites are effective at broadcasting a signal to multiple locations simultaneously, such as is done for broadcast television. • Satellites are less effective with interactive applications when low latency is critical.	*High Latency* – The time to travel between the satellite and the antenna is approximately 20 times greater than landline broadband. *Terrestrial Blockage* – Especially in northern portions of the United States, a direct view of the satellite may be difficult to obtain. *Weather Interference* – Satellite frequencies are susceptible to weather degradation and outages. *Sun Interference* – During a several-day period in the spring and fall, the satellite alignment with the sun causes a loss of signal for 15 minutes or more per incident. *Spectrum Limitations* – Spectrum is a scarce resource so it must be reused to increase capacity.
Low Earth Orbit	• Satellites orbit only a few hundred miles above the earth. • Many satellites are required to provide continuous coverage. • Broadband LEO satellites have yet to be deployed, so some capabilities are speculative and actual satellite networks may not materialize as planned.	*Technological* - Complex systems are required to maintain communications hand-offs between the many orbiting satellites. *Economical* - Past attempts to launch LEO satellites have not proven commercially successful. *Weather Interference* – LEO satellites use the same frequency bands as geostationary satellites, so the same degradation and outage issues exist. *Spectrum Limitations* – The scarcity of spectrum will limit capacity and speed.

Table 3-1: Satellite Technology Summary

3.1 Geostationary Deployment Advances

Since the publication of the VPS 2013 satellite whitepaper, ViaSat and Hughes have developed and deployed new satellite platforms to increase their satellite broadband capability. These key advancements include:

- **ViaSat:** ViaSat has been delivering its Exede broadband services over the ViaSat-1 satellite and older WildBlue satellites. Launched in 2011, the ViaSat-1 satellite has a capacity of 130 Gbps and utilizes 72 spot beams,[22] which made it the highest-capacity satellite at the time. ViaSat has recently launched the ViaSat-2 satellite to increase capacity and coverage. The 300 Gbps capacity of ViaSat-2[23] is mainly accomplished by utilizing more spot beams.[24] In 2019, ViaSat plans to deploy the ViaSat-3 satellite to cover the Americas and provide 1 Tbps of capacity.[25]
- **Hughes:** In March 2017, Hughes deployed its Gen 5 Services,[26] which utilize the JUPITER System networking platform and rely on the previously orbiting EchoStar 17 and EchoStar 19 satellites. The EchoStar 17 has a designed capacity of 100 Gbps using 60 spot beams, whereas the Echostar 19 satellite has 120 spot beams[27] and claims 200 Gbps of capacity.[28]

Since the satellite's capacity is simply the sum of the capacities of the individual spot beams, a satellite's capacity can be increased by using more spot beams. By increasing the satellite's capacity through use of more spot beams, a satellite provider can realize a modest increase in the number of served customers or an increase in the amount of capacity allowed each customer – or a balance of both. However, increasing the number of spot beams does not mean that the capacity can be fully realized. Because customers' usage is unlikely to be uniformly distributed among the spot beams, some spot beams will be at maximum capacity before others. In addition, when large spot beams are split into small spot beams, each beam becomes less efficient. One reason for this decrease in efficiency is that a large spot beam may cover multiple time zones, so when east coast customers' usage declines for the evening, the traffic from west coast customers is just beginning to peak. Thus, the use of spot beams results in more total capacity, but the capacity is used less efficiently since some spot beams could reach

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[22] Will Carlsbad Company's Space Satellite Strategy Pay Off?, The San Diego Union-Tribune, Jun. 24, 2011. (http://www.sandiegouniontribune.com/business/technology/sdut-viasats-space-gamble-2011jun24-htmlstory.html)

[23] Space Odyssey: A Behind-the-Scenes Look at ViaSat-2, Apex, Mar. 23, 2017. (http://apex.aero/2017/03/23/space-odyssey-behind-scenes-look-viasat2)

[24] ViaSat's Dankerg on Satellites Soft Failure Mode and Europe's Invitation, Space Intel Report, Jan. 10, 2017. (https://www.spaceintelreport.com/viasat-dankberg/2017/1/10/viasats-dankerg-on-satellites-soft-failure-mode-and-europes-invitation)

[25] ViaSat, Boeing Complete Preliminary Design Review for ViaSat-3 Satellites, ViaSat, Dec. 19, 2016. (https://www.viasat.com/news/viasat-boeing-complete-preliminary-design-review-viasat-3-satellites)

[26] HughesNet Claims First FCC Broadband Defined 25 Mbps Satellite Broadband Service, Telecompetitor, Mar. 7, 2017. (http://www.telecompetitor.com/hughesnet-claims-first-fcc-broadband-defined-25-mbps-satellite-broadband-service/)

[27] Hughes/EchoStar Orders Jupiter 2 Broadband Craft, SpaceNews, Mar. 21, 2013. (http://spacenews.com/hughesechostar-orders-jupiter-2-broadband-craft/)

[28] Hughes High Throughput Satellite Constellation EchoStar XIX, Hughes. (https://www.hughes.com/technologies/hughes-high-throughput-satellite-constellation/echostar-xix)

capacity while others are underutilized. There are also practical limits as to how small the spot beams can be.

Even with increases in satellite capacity, geostationary satellites still have significant capacity constraints, which necessitate stringent usage controls for customers. To put satellite capacity constraints in perspective, many urban consumers have access to 1 Gbps broadband service. Just 300 customers subscribing to 1 Gbps service would be equivalent to the total capacity of one next generation satellite. A speed of 1 Gbps is 40 times faster than the *maximum* speed offered by satellite providers. Assuming a speed of 25 Mbps satellite service with an oversubscription ratio of 5:1,[29] less than 0.06% of all households in the United States, or 60,000 customers, would deplete the entire satellite capacity. Moreover, as a higher percentage of the traffic becomes constant bit rate, high-volume data streams,[30] acceptable oversubscription ratios will decrease and even fewer households can be served.

Just 300 customers subscribing to 1 Gbps service would be equivalent to the total capacity of one next generation satellite.

3.2 LEO Deployment Updates

Some companies are promoting LEO satellites as a way of providing broadband coverage to unserved broadband customers. LEO satellites orbit much closer to the earth; therefore, the latency problems associated with geosynchronous satellites are significantly less for LEO satellites. LEO satellites are extremely expensive to deploy and operate. Hundreds or thousands of satellites would be required to provide adequate broadband coverage in the United States, which means the initial cost is high. Beyond the initial cost of deploying the satellites, billions of dollars in ongoing investments would be required to maintain service, as the life cycle of a satellite is estimated at between five and seven years. Cost aside, the technical complexity of coordinating the hand-offs between so many satellites has also proven difficult in the past.

Iridium and Globalstar, the two companies that previously deployed LEO satellites, experienced financial difficulties and eventually declared bankruptcy. Nevertheless, two companies (OneWeb and SpaceX), have announced plans to launch LEO satellites. OneWeb (formerly known as WorldVu) plans to deploy 648 satellites[31] and offer 50 Mbps service.[32] As of late 2016, OneWeb had raised $1.2 billion of the $2.5

[29] Evaluating 5G Wireless Technology as a Complement or Substitute for Wireline Broadband, Vantage Point Solutions, Feb. 2017, p. 21.

[30] Video is a constant bit rate, high-volume data stream.

[31] OneWeb Website (http://oneweb.world/)

[32] RUAG's 'To Do List' for OneWeb… Get Busy Building 900 Satellite Structures, SatNews, Nov. 30, 2016. (http://www.satnews.com/story.php?number=1922412818)

to $3.5 billion it claims is required for deployment of the complete system.[33] OneWeb acknowledges that its target market is users that don't currently have broadband access.[34]

According to its FCC application, SpaceX intends to launch 4,425 satellites providing up to 1 Gbps per user.[35] The initial cost of deploying this constellation of satellites is estimated to be between $10 and $19 billion.[36] Neither OneWeb nor SpaceX has begun testing, so it is uncertain how successful these companies will be. SpaceX initially planned to have prototype satellites operational in 2016, but delays have extended the deployment timeframe.

Based on the limited technical information available regarding design and deployment of these companies' satellites, it is not possible to comment on their ability to meet consumers' broadband demand. Nevertheless, the extraordinary cost of these deployments and operations is undeniable, which raises questions about the financial viability and sustainability of such endeavors – especially given the limitations of the services for potential broadband customers. Other experts such as Roger Rusch, a satellite industry consultant, stated, "It's highly unlikely that you can make a successful business out of this. It's inconsistent with experience. These people are up against the laws of physics."[37]

[33] OneWeb Gets $1.2 Billion in SoftBank-Led Investment, Space News, Dec. 19, 2016. (http://spacenews.com/oneweb-gets-1-2-billion-in-softbank-led-investment/)

[34] de Selding, Peter B. (2014-05-30). "Google-backed Global Broadband Venture Secures Spectrum for Satellite Network". SpaceNews. (http://spacenews.com/40736google-backed-global-broadband-venture-secures-spectrum-for-satellite/)

[35] SpaceX Just Asked Permission to Launch 4,425 Satellites – More than Orbit Earth Today, Business Insider, Nov. 16, 2016. (http://www.businessinsider.com/spacex-internet-satellite-constellation-2016-11)

[36] SpaceX Wants to Give You Satellite Internet, The Motley Fool, Nov. 19, 2016. (https://www.fool.com/investing/2016/11/19/spacex-wants-to-give-you-satellite-internet.aspx)

[37] Petersen, Melody (16 January 2015). "Elon Musk and Richard Branson Invest in Satellite-Internet Ventures". Los Angeles Times. (http://www.latimes.com/business/la-fi-satellite-entrepreneurs-20150117-story.html)

4 Satellite Service Plans

Both ViaSat and Hughes offer plans with speeds up to 25/3 Mbps; however, these plans include severe restrictions on the customers' monthly data usage, as shown in Figure 4-1 and Figure 4-2. Data usage is limited to 50 GB for the best Hughes plan and 150 GB for the best ViaSat plan. Once the monthly data limit is exceeded, a customer's speed will be reduced to between 1 and 5 Mbps. Although these plans provide increased speed and monthly data limits when compared to previous satellite broadband offerings, it should be noted that none of the plans currently meet the minimum requirement of the FCC's upcoming CAF Phase II auction. Moreover, ViaSat's 150 GB Freedom plan offering is available only in a few, small geographic areas of the United States.

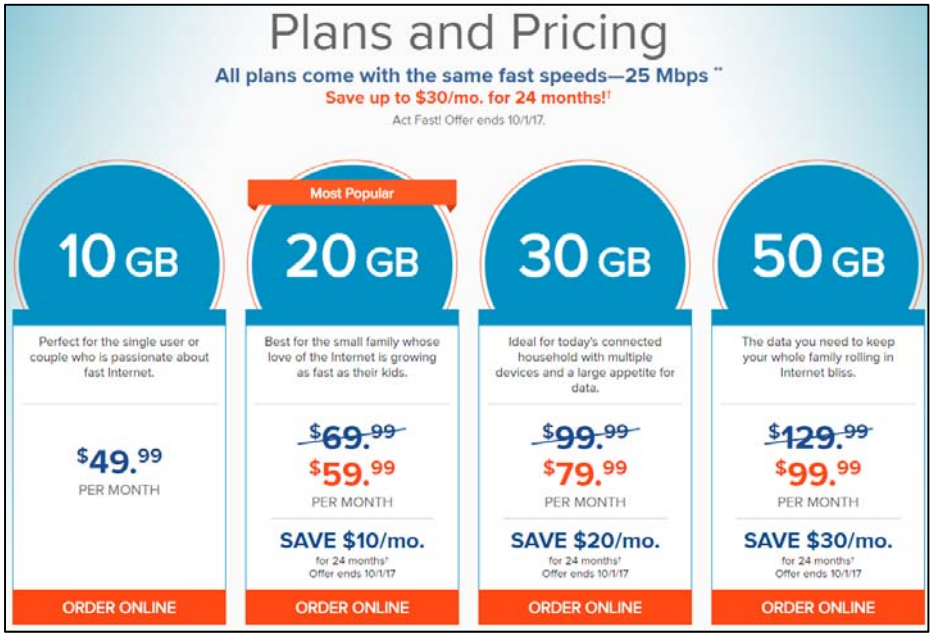

Figure 4-1: Hughes Gen5 Service Plans

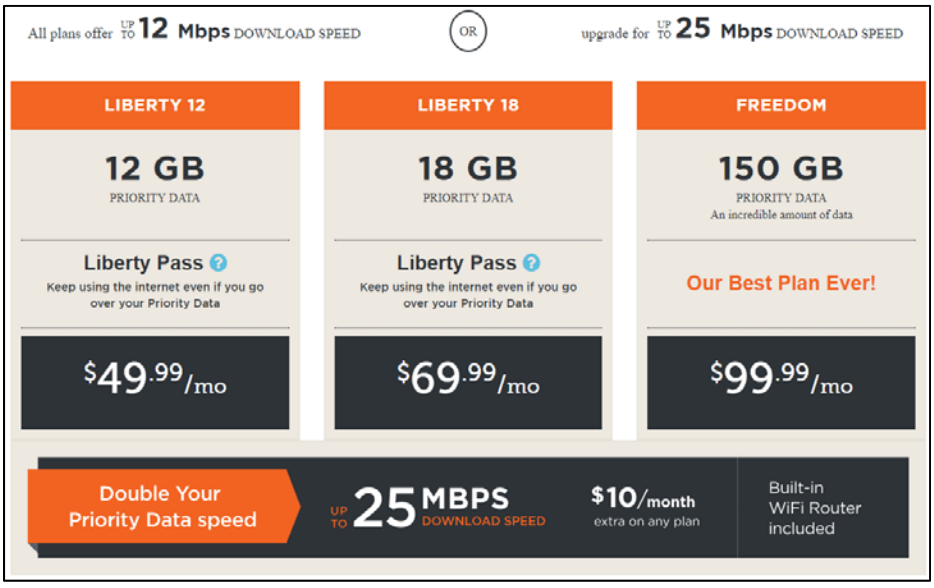

Figure 4-2: ViaSat Exede - Liberty Service Plans

Figure 4-3 compares the *best* satellite providers' plans in terms of capacity and speed to the terrestrial providers' *worst* urban plans. Obviously, the satellite plans do not compare favorably. The data usage controls of the worst terrestrial urban plans are more than five times higher than those of the best satellite plans, plus the speeds of terrestrial plans are more than twice as fast as the advertised satellite speeds. Worse yet, ***advertised*** satellite speeds are considerably higher than customers' ***actual*** speeds for customers that exceed their data thresholds.

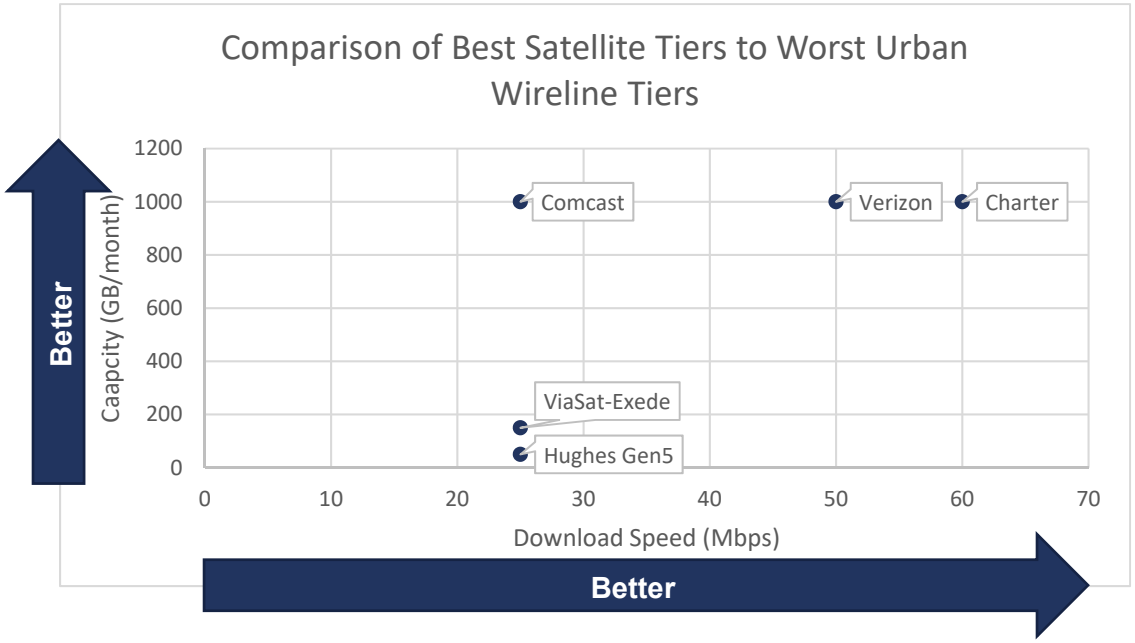

Figure 4-3: Satellite and Terrestrial Broadband Comparison

Given that the data thresholds offered through satellite plans are much lower than the average customer's usage of 190 GB per month and even CAF Program requirements of 160 GB per month,[38] it is reasonable to consider an effective speed that is a weighted average of the advertised speed for the initial usage and the reduced speed for usage above the data cap. Table 4-1 shows such a calculation assuming that the reduced speed above the data cap is 3 Mbps and the average usage is 190 GB per month.

[38] *In the Matter of Connect America Fund ETC Annual Reports and Certifications Developing a Unified Intercarrier Compensation Regime*, WC Docket No. 10-90 14-58, CC Docket No. 01-92, Report and Order, Order and Order on Reconsideration, and Further Notice of Proposed Rulemaking, Released Mar. 30, 2016, ¶¶ 27. (https://apps.fcc.gov/edocs_public/attachmatch/FCC-16-33A1_Rcd.pdf)

Provider	Data Threshold (GB/month)	Initial Speed (Mbps)	Speed above Data Threshold (Mbps)[39]	Effective Speed (Mbps)[40]
Hughes	10	25	3	4.2
	20	25	3	5.3
	30	25	3	6.5
	50	25	3	8.8
ViaSat	12	12	3	3.6
	18	12	3	3.9
	150	12	3	10.1

Table 4-1: Effective Speeds and Prices When Data Thresholds Are Exceeded

Clearly, the effective speeds of the various satellite plans are much lower than the advertised speed when customers exceed the data usage thresholds.

As shown in Figure 4-4, the 25 Mbps speed is only available to a satellite broadband user until the user reaches the plan's data threshold. In just 13 hours, a user consuming 25 Mbps[41] of broadband would reach the 150 GB cap and the user's speed would be reduced to between 1 Mbps and 5 Mbps for the remainder of the month.

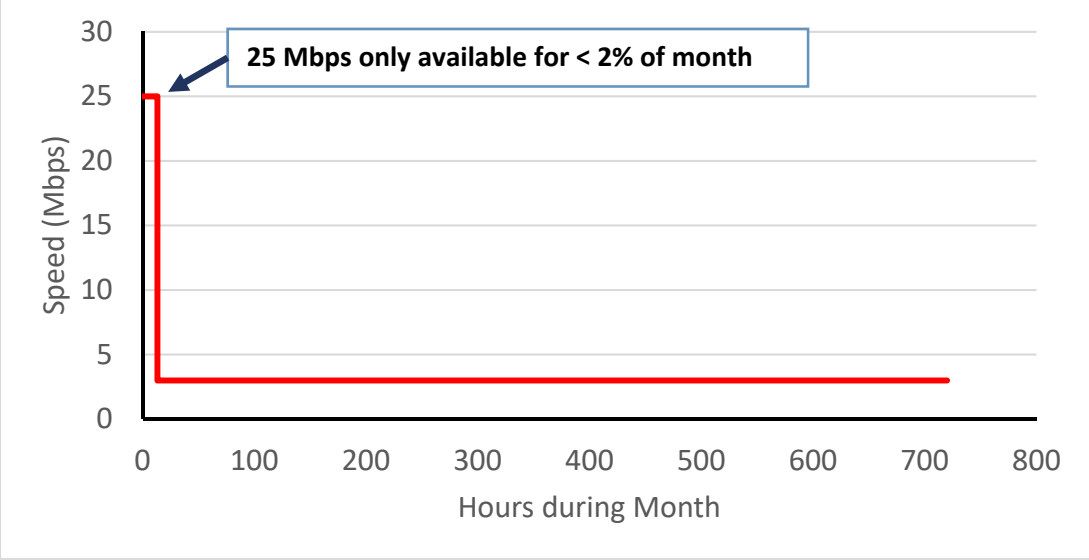

Figure 4-4: Availability of Satellite Broadband Speed during One Month

[39] For ViaSat plans, the speed above the data threshold is assumed to be 3 Mbps but the speed may be lower. It is unclear from ViaSat's promotional material what the speed will be, other than "a good deal slower."

[40] The weighted average speed is calculated as follows: [Speed Below the Data Threshold * Data Threshold + Speed Above the Data Threshold * (190 GB – Data Threshold)]/190 GB

[41] A user can easily consume 25 Mbps when watching one or more HDTV or UHDTV video streams, performing computer backups, or other similar activities.

Even though the effective speeds and data thresholds are much lower for satellite service than for terrestrial service, the cost for a satellite service is much higher. When the ViaSat and Hughes plans are compared to a sampling of offerings from urban terrestrial providers, as shown in Table 4-2, one finds that the satellite packages are two to three times more expensive than terrestrial providers.

	Provider	Monthly Price	Speed	Data Threshold (monthly)
Terrestrial Urban Plans	Comcast (Xfinity)[42]	$39.99	25 Mbps	1 TB in some areas
	Charter (Spectrum)43	$44.99	60 Mbps	None
	Verizon (Fios)[44]	$39.99	50 Mbps	None
Best Satellite Plans	ViaSat	$109.99	25 Mbps	150 GB
	Hughes	$129.00	25 Mbps	50 GB

Table 4-2: Service Plan Samples

[42] Xfinity Website (https://www.xfinity.com/learn/offers)
[43] Spectrum Website (https://www.spectrum.com/packages.html)
[44] Verizon Website (https://www.verizon.com/home/fios-fastest-internet/#fastest-internet-plans)

5 Satellite's Inability to Meet Current and Future Broadband Demands

Even with the new satellite launches, satellite platforms have difficulty meeting both the current and future high-quality broadband characteristics discussed in Section 2.

Speed Issues

To increase speeds, satellites must increase capacity. According to Shannon's law, the speed and capacity of a broadband connection can be increased by increasing power, reducing noise or increasing the channel bandwidth. It is often difficult to increase power or reduce noise, since the maximum power levels are established by the FCC and the amount of noise is largely beyond the provider's control. One way to increase capacity is to increase the amount of spectrum in the K_a and K_u frequency bands—the spectrum used by all broadband satellites. Since there is little or no new spectrum available, the new generation of satellites uses spatial diversity to reuse existing spectrum. Rather than deploying one large beam that covers the continental United States, the new satellites utilize many spot beams to direct capacity to specific geographic regions. The second way to increase capacity is to implement better modulation techniques. To employ significantly better modulation techniques, the signal level would need to be increased or noise must be reduced. Since the power of the transmitting satellites is limited by regulatory agencies and little can be done to change noise levels, the ability to increase capacity through the use of better modulation techniques is limited.

Even with the capability increases discussed in Section 3, the newly launched satellites will not be able to meet high-speed broadband demands. Under the best-case conditions, if only a million subscribers (less than 1% of the broadband subscribers in the United States) were to access the 300 Gbps ViaSat-2 satellite, simultaneously, each subscriber could only receive 300 kbps on average. At a time when it is common for a household to be receiving multiple video streams simultaneously for entertainment, eHealth, video conferencing, and security cameras, this data speed is unacceptable. If one considers this speed limitation from an application perspective, the satellite would have capacity for only 60,000 HD or 12,000 Ultra HD simultaneous video streams.[45] With the proliferation of broadband-enabled devices within a home, it is easy to envision a satellite's capacity to be easily exceeded. In recognition of the increase in the number of broadband-enabled devices, wireless 5G standards now require a minimum connection density of 1,000,000 devices per square kilometer.[46] Satellite cannot come close to matching the capabilities of 5G wireless or landline broadband.

[45] HD and ultra HD steams are assumed to require 5 Mbps and 25 Mbps, respectively. https://help.netflix.com/en/node/306?ui_action=kb-article-popular-categories

[46] ITU Document 5/40-E 22, p. 6.

Today's top speed tiers that are being offered by satellite providers are lower than many of the bottom tiers offered by wireline providers. As high-speed requirements continue to increase, satellite providers will not be able to meet potential demand. While stating that its speeds are "pretty good" during the day, ViaSat cautions subscribers that their service will be "a good deal slower" in the evening when most residential subscribers want to use broadband. See Figure 5-1. Even after the new satellites are launched, it is likely that ViaSat will need to continue to caution its subscribers.

Today's top satellite speed tiers are lower than many of the bottom tiers offered by wireline providers.

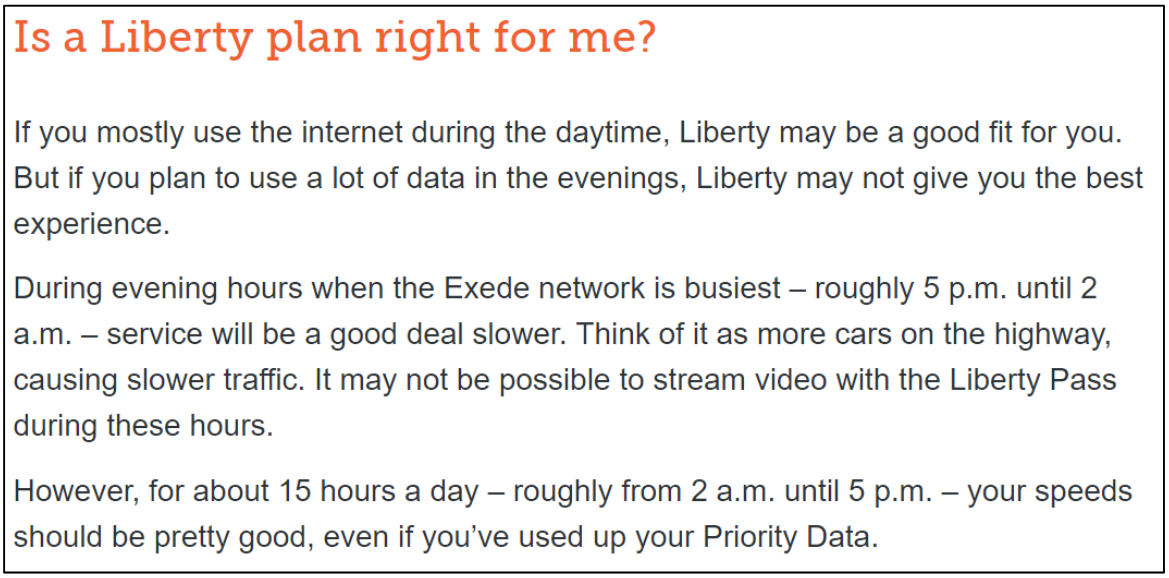

Figure 5-1: ViaSat Exede Usage Caution[47]

Latency Issues

Since geosynchronous satellites orbit 22,000 miles above the earth, high latency will always be a problem. Technology improvements in the newer satellites cannot change the laws of physics. Signals must still travel at less than the speed of light to the satellite and back, which is primarily why the average delay is between 599 and 629 ms.[48] Latency delay is especially undesirable in two-way communications, such as voice and video conferencing. If satellite were to be used to provide service in a specific geographical area, then it is likely that many residents in that area would be satellite subscribers. When communicating with a neighbor or local business that also utilizes a satellite service, the delay is compounded because of the "double-hop" of the signal traveling multiple times to the satellite.

[47] http://www.exede.com/liberty/

[48] 2016 Measuring Broadband America, p. 21.

The FCC required latency to be less than 100 ms for the Rural Broadband Experiments,[49] the CAF Phase II commitments, the rate-of-return carriers' A-CAM CAF Program,[50] and the proposed CAF Phase II Auction.[51] Hughes admitted that satellite broadband cannot meet this threshold requirement, stating: "Thus, the laws of physics make compliance with a 100 millisecond threshold impossible for broadband provided via GSO satellites."[52] Even though the percentage of overall broadband traffic that is sensitive to high latency is relatively small, the services impacted are essential and cannot be sacrificed. These services include critical public safety, healthcare, education and commercial services—none of which satellite can provide.

Capacity Issues

The data limits associated with satellite plans are much more restrictive than those of landline providers. Since each satellite has a maximum amount of data that can be processed at any one time, the satellite providers must control how much data an individual subscriber can utilize; therefore, even with the new satellite capacity, the providers will not be able to meet the capacity requirements of high-quality broadband.

Combined, Hughes and ViaSat satellites currently have about 730 Gbps of total capacity to serve 1.7 million subscribers.[53] Assuming subscriber counts remain constant, the 730 Gbps would only allow each subscriber to simultaneously use 430 kbps. If these subscribers were offered 25 Mbps service, the subscribers' actual speed would be unacceptably slow.[54] Less than 9% of these subscribers would be able to watch an HD movie simultaneously before the entire 730 Gbps capacity would be exhausted. As the satellite providers continue to sell high-speed plans, subscribers' actual speeds will decrease as the satellites approach capacity similar to what has happened in the past.

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[49] *In the Matter of Connect America Fund ETC Annual Reports and Certifications*, WC Docket No. 10-90 and 14-58, Report and Order and Further Notice of Proposed Rulemaking, Released Jul. 14, 2014, ¶¶ 26-27. (https://apps.fcc.gov/edocs_public/attachmatch/FCC-14-98A1.pdf)

[50] *In the Matter of Connect America Fund ETC Annual Reports and Certifications Developing a Unified Intercarrier Compensation Regime*, WC Docket No. 10-90 14-58, CC Docket No. 01-92, Report and Order, Order and Order on Reconsideration, and Further Notice of Proposed Rulemaking, Released Mar. 30, 2016, ¶ 28. (https://apps.fcc.gov/edocs_public/attachmatch/FCC-16-33A1_Rcd.pdf)

[51] Consumer Guide Connect America Fund Phase II FAQs, FCC, Jun. 16, 2016. (http://transition.fcc.gov/cgb/consumerfacts/Connect-America-Fund-FAQs.pdf)

[52] Notice of Ex Parte Presentation – GN Docket No. 14-126, Wilkinson Barker Knauer, LLP, Oct. 15, 2015, p. 12. (https://ecfsapi.fcc.gov/file/60000973555.pdf)

[53] https://www.hughesnet.com/why-hughesnet/news/hughes-becomes-first-satellite-internet-provider-surpass-one-million-active-users and http://www.exede.com/media-center/viasats-history-25-years-of-innovation-and-counting/

[54] The oversubscription ratio is 60:1 in this situation. A commonly used oversubscription ratio for design purposes is 5:1.

The launch of new satellite platforms will provide additional capacity. ViaSat's recent satellite launch will add about 300 Gbps of capacity. Assuming a 5:1 oversubscription ratio, if just 60,000 subscribers, less than 0.06% of the 104.6 million broadband subscribers in the United States,[55] were to simultaneously use their 25 Mbps plans, the ViaSat satellite would be at capacity.

With only 60,000 subscribers, which is less than 0.06% of the nation's current broadband subscribers, ViaSat's recent satellite launch will be at capacity.

Reliability Issues

There are reliability concerns for both the current and the new satellite platforms that can limit or render the service unusable. First, terrestrial blockage affects locations in the northern United States because as a subscriber's distance from the equator increases, the satellite dish must be positioned at a smaller angle relative to the horizon. At these low angles, it is more likely that an object, such as a tree or building, can obstruct the direct view of the satellite. Second, weather interference can affect reliability. The frequencies used by satellite are susceptible to weather degradation causing outages during moderate rains or when ice and snow accumulates on the dish. Weather interference is most severe in northern latitudes because satellite signals must traverse a greater distance through earth's atmosphere. Third, when the sun crosses behind a geosynchronous satellite as it is viewed from the ground station, the alignment of thermal noise from the sun with the satellite signal degrades the signal, as marked by an increase in the error rate, and can cause a total outage. This phenomenon occurs daily during two weeks twice a year. The duration of the degradation or outage, which usually is 15 minutes or longer, depends on the satellite ground station location, satellite orbital location, size of the antenna and the signal frequency. Terrestrial blockage and environmental interference problems cannot be resolved by newer, more technically advanced satellites.

Scalability Issues

Even though new geostationary satellites are being launched to improve capacity, satellite systems will continue to be unable to scale to meet customers' rapidly increasing broadband needs. Many of the constraining factors such as latency for geostationary satellites, spectrum availability and interferences are not possible to technically overcome, and will always limit satellite broadband services.

[55] http://www.oecd.org/sti/broadband/1_1-TotalBBSubs-bars-2016-06.xls

6 Potential Use of Federal Financial Support for Satellite Services

The FCC has limited funds to support broadband in high-cost areas where end-user revenues are not sufficient to support the costs. These limited funds should be focused on networks that provide the best quality, most economical broadband over the long run. As discussed in the previous sections of this report and summarized in Table 6-1, satellite services provide inferior broadband when compared to most landline services.[56] Consumers in urban areas enjoy broadband services that have low latency, high speed, and high or unlimited monthly capacity. Clearly, rural consumers who subscribe to satellite broadband services have been relegated to broadband services that are not "... reasonably comparable to those services provided in urban areas," as required by the Telecommunications Act of 1996.[57]

	Satellite	Landline
Speed	5 to 25 Mbps[58]	100 to 300 Mbps[59]
Median Latency[60]	599 to 629 ms	12 to 58 ms
Capacity	10 to 50 GB/month for most plans	500 GB/month or more

Table 6-1: Satellite and Landline Broadband Service Comparison

The FCC's "2016 Measuring Broadband America Fixed Broadband Report" shows that the median customer broadband speed was 41 Mbps in 2015 and is growing at a rate of 28% per year.[61] Since the data used in the report is nearly two years old, one can expect that the median speed is now about 65 Mbps, more than twice as fast as a satellite provider's best advertised speeds. In addition, the median latency of satellite broadband at approximately 600 ms will negatively affect "the performance of interactive, real-time applications, including VoIP, online gaming, videoconferencing, and VPN platforms," according to the FCC.[62] Finally, the extremely low data thresholds of satellite plans cause customers to experience much lower speeds than advertised.

The median customer broadband speed is about 65 Mbps, more than twice as fast as a satellite provider's best advertised speeds.

[56] The speeds and capacity availability to satellite customers will be limited when larger numbers of customers are online. Once customers reach their capacity limits speeds will be furthered decreased.

[57] Telecommunications Act of 1996, Pub. LA. No. 104-104, 110 Stat.56 (1996), P. 103. (https://transition.fcc.gov/Reports/1934new.pdf)

[58] This comparison uses the highest speed available. Some plans have a speed of 12/3 Mbps.

[59] 2016 Measuring Broadband America, p. 8. The maximum speed for the most popular service tiers was used.

[60] Ibid., p. 21.

[61] Ibid., p. 15.

[62] *In the Matter of Inquiry Concerning the Deployment of Advanced Telecommunication Capability to All Americans in a Reasonable and Timely Fashion, and Possible Steps to Accelerate Such Deployment Pursuant to Section 706 of the Telecommunications Act of 1996, as Amended by the Broadband Data Improvement Act*, GN Docket No. 15-191, 2016 Broadband Progress, Released Jan. 29, 2016, p. 28. (https://apps.fcc.gov/edocs_public/attachmatch/FCC-16-6A1.pdf)

Considering the inferior speeds, high latency and severe capacity constraints inherent with satellite broadband, it is difficult, if not impossible, to conclude that satellite service is reasonably comparable to terrestrial broadband service. Based on the experience of VPS, terrestrial providers that offer satellite service as a broadband option to their customers only do so as a stop-gap measure until a better landline solution can be provided. Once landline broadband becomes available, customers readily give up satellite broadband and subscribe to landline broadband. Appendix A details how a service provider that resells satellite broadband services encountered difficulties meeting its subscribers' needs. As this company's real-world experiences demonstrates, satellite broadband customers do not consider satellite broadband to be comparable to terrestrial service. Policy makers should take these experiences into careful consideration when making decisions about how broadband should be deployed in high cost areas.

The use of public funds to support satellite broadband should be minimized because it not only will divert funds away from networks that can currently provide high-quality broadband and can economically scale to customers' increasing needs, but also will result in higher customer costs for an inferior service. For example, a customer will pay about $70 more per month for ViaSat's 25 Mbps plan than for Comcast's comparable plan.[63] Over 10- and 15-year periods, this difference in price would amount to $8,400 and $12,600, respectively, as shown in Figure 6-1.

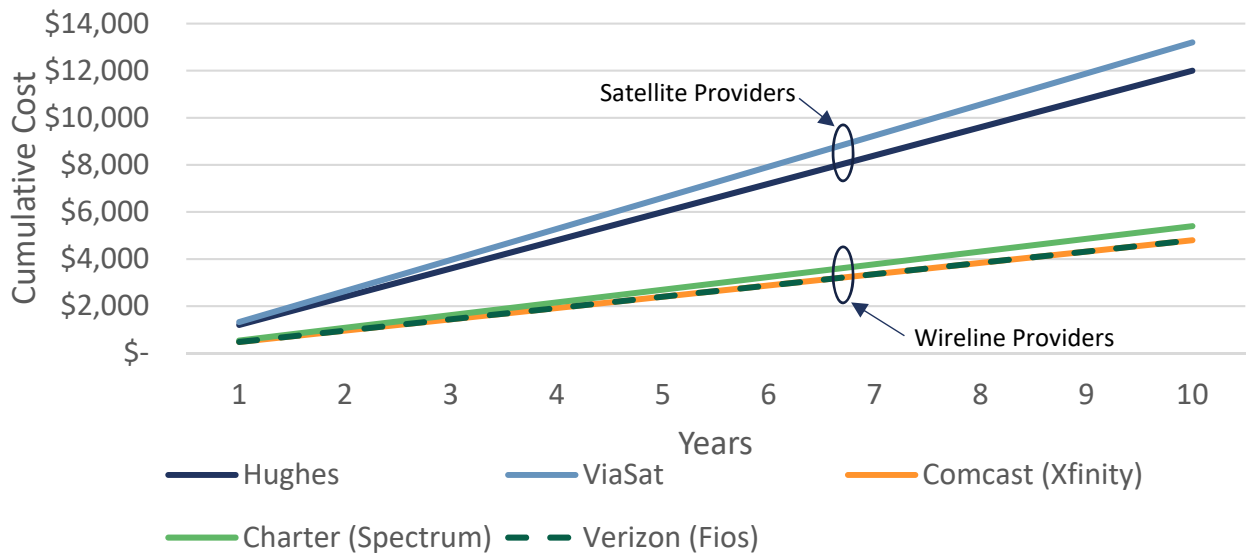

Figure 6-1: Cumulative Consumer Cost Comparison

In a relatively short time, the premium a customer would pay for satellite service is sufficient to pay for an upgrade to the landline network to greatly enhance its broadband capability. Investing in the correct technology upfront will not only ensure that customers have adequate broadband to close the digital divide now, but will also be less expensive over the long run.

[63] ViaSat's 25 Mbps Freedom plan is $109.99 per month. Comcast's 25 Mbps plan is $39.99 per month.

APPENDIX A – Service Provider Experience

Some rural telecommunications and broadband service providers have sales and installation agreements with satellite-based broadband service providers to make satellite broadband available to customers who may not otherwise have access to broadband. One such carrier, Great Plains Communications (Great Plains), has resold satellite services for several years to its Nebraska customers who do not have terrestrial-based options. Great Plains personnel have reported that these satellite services are "stop-gap offerings" characterized by higher prices, slower speeds, high latency that inhibits use of various applications and data capacity limits that are often easily exceeded.[64]

As Great Plains has expanded its terrestrial broadband services in the past two years, satellite subscribers serviced by Great Plains have dropped by about one-third, from more than 600 to about 400. Great Plains expects this decline to continue, and believes it is evidence that customers do not view satellite as a comparable service when terrestrial broadband is available. The company has aggressive plans to expand its broadband availability and thus expects satellite subscribership will continue to decline.

Great Plains often receives complaints from satellite broadband customers about service-related issues. The following is a summary of the most frequent types of issues and complaints:[65]

- Customers quickly reach their capacity limits each month, and additional charges of up to $100 per customer per month are common.[66]
- Satellite usage limits range from 10 to 25 GB per customer, compared to unlimited terrestrial service provided by Great Plains, whose customers typically utilize between 100 and 500 GB per month.
- Satellite beams frequently reach capacity, resulting in discontinuation of sales to new customers. Great Plains has had customers on a waiting list for more than a year.
- Repair times for Great Plains personnel to address satellite customers' premise service issues can range from hours to days, largely due to the satellite providers' back-office issues.
- Satellite does not support virtual private networks, so customers working from home in remote locations cannot reach their employers' servers.
- Frequent storms cause service interruptions because satellite dishes must be realigned to restore service, which necessitates a service call at the customer's expense.
- Higher-bandwidth services, available in more populated areas, are not available in Nebraska and other less-populated states.
- Equipment and installation charges are expensive.

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[64] *See* Ex Parte Communication from Cheryl L. Parrino, LLC, Parrino Strategic Consulting Group, Docket No. 10-90, filed January 19, 2016 on behalf of Consolidated Companies, Great Plains Communications and other rural Nebraska companies.

[65] Vantage Point Solutions received documentation on satellite customer issues from two Great Plains representatives, Natasha Nething-Radnor, Director-Customer Service, and Angela Husk, Customer Service Technical Supervisor.

[66] Satellite plans have now changed to decrease speeds rather than impose overage charges.

About the Authors

Larry Thompson is a licensed Professional Engineer and CEO of Vantage Point Solutions. Larry has a Physics degree from William Jewell College and a Bachelor's and Master's degree in Electrical Engineering from the University of Kansas. He has been working in the telecommunications industry for more than 25 years, which has included both satellite and ground station design and engineering in the 1 to 30 GHz range. Larry was on the engineering team for the Tracking and Data Relay Satellite System (TDRSS), Geostationary Environmental Orbital Satellite (GOES) ground station, T-Star, and other satellite systems. Larry has helped hundreds of telecommunication companies be successful in this rapidly changing technical and regulatory environment. He has designed many wireless and wireline networks as he has assisted his clients in their transition from legacy TDM networks to broadband IP networks.

Brian Enga is a licensed Professional Engineer and part of the Senior Engineering team at Vantage Point Solutions. Brian has Bachelor's of Science degrees in Electrical Engineering and Engineering Physics from South Dakota State University. He has been working in the telecommunications industry for nearly 20 years. Brian has engineered a variety of broadband networks and has been a pioneer in deploying IP video networks.

Credits

Nebraska-based rural telecommunications and broadband companies Great Plains Communications and the Consolidated Companies underwrote the research, documentation and writing of this paper to further public policy discussion.