

# Assessment of GSO Satellite Capabilities vs. Alternative Internet Access Technologies

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Final Report

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**Roberson and Associates, LLC**  
Technology and Management Consultants<sup>®</sup>  
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# Executive Summary

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- Proven GSO technology is a reliable way to expand broadband connectivity.
- No single technology solution uniformly dominates the rest along various metrics.
- There is no one size fits all solution for broadband deployment at a national scale.
- Decisions regarding optimal technology solutions are best made on a regional or local basis.

# Assessment Approach

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- Analyze Internet Application Categories and Identify Technical Requirements
- List and Compare Technical Characteristics of Internet Access Technologies
- Assess Internet Access Technologies Ability to Meet Application Requirements
- Conclusion

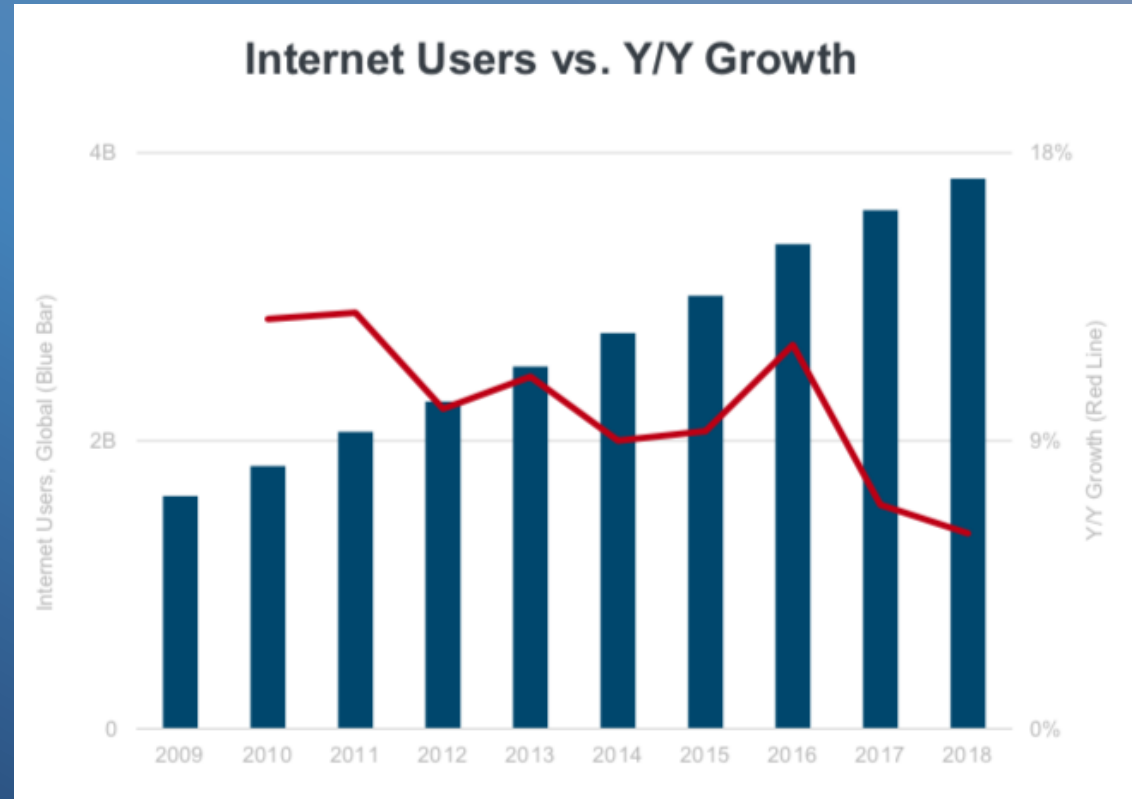


# Internet Trends

## Internet Trends

- Users
- E-Commerce
- Usage ...
- Freemium Business Models
- Data Growth
- ...Usage
- Work
- Education
- Immigration + USA Inc.
- Healthcare

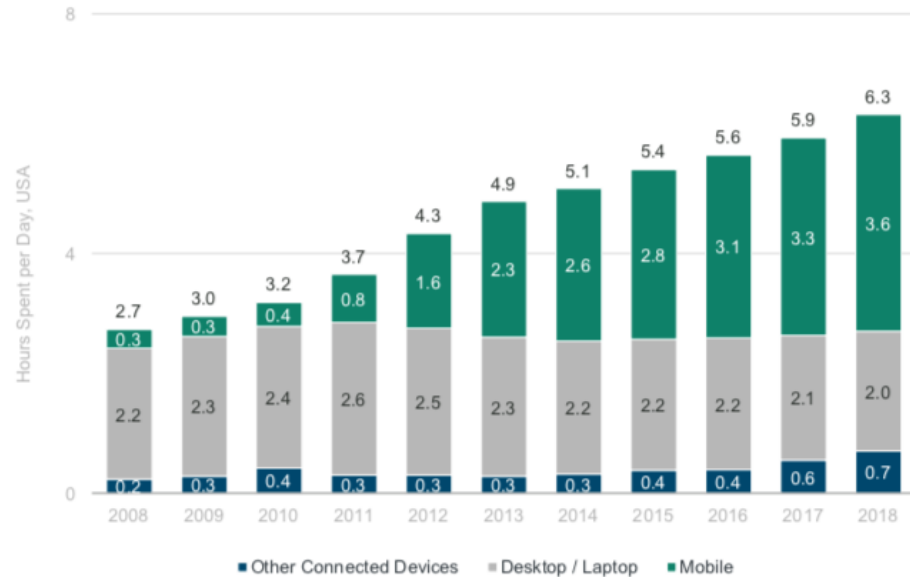
Global Internet User Growth = Solid But Slowing +6% vs +7% Y/Y



**>> The latest Internet Trends report opens by noting that Internet User growth is steady...**

# Digital Media Usage is Accelerating

Daily Hours Spent with Digital Media per Adult User, USA



Video is driving internet growth and is driven by:

- Cord cutting – 20% YoY growth in number of cord cutters
- 4k TV adoption – nearly 30% YoY growth in 4k TV adoption
- Pervasiveness of video in every application experience

Video is ~71% of traffic

<https://venturebeat.com/2022/03/03/comcast-internet-traffic-grew-11-in-2021-over-pandemic-driven-highs-of-2020/>

<https://review42.com/resources/cord-cutting-statistics/>

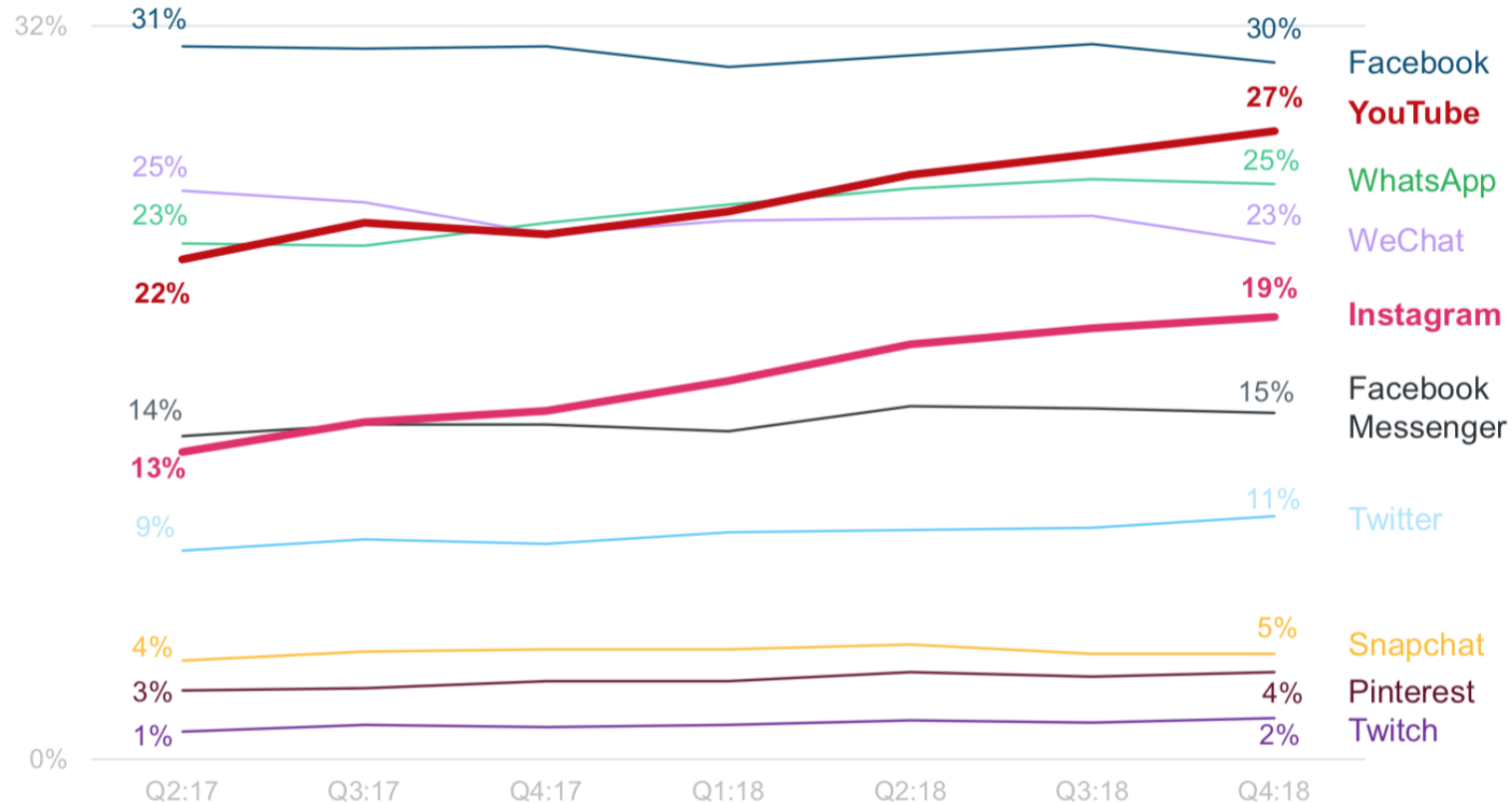
<https://www.statista.com/statistics/1247334/4k-ultra-hdtv-us-household-penetration>

<https://www.sandvine.com/phenomena>

**>> and that more digital media is consumed as it is integrated into more category offerings.**

# Online Platform Time: YouTube + Instagram Gaining Most

% Internet Users Using Select Platforms > 1x per Day, Global\*



>> The most frequently used on-line platforms are growing steadily.

# On-line Platforms and Internet Tasks

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## On-line Platforms

- Facebook
- YouTube
- TikTok
- WhatsApp
- WeChat
- Instagram
- Messenger
- Twitter
- Snapchat
- Pinterest
- Twitch

**>> Mapping the relationship between the on-line platform applications and ...**





# On-line Platforms and Internet Tasks

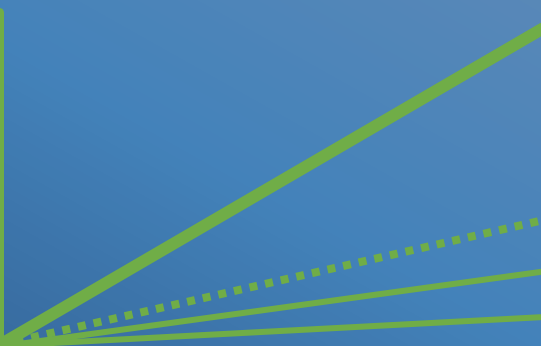
## On-line Platforms

- Facebook
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- Twitter
- Snapchat
- Pinterest
- Twitch



## Internet Related Tasks

- Video
  - Streaming (unicast, multi-cast, broadcast)
  - Conferencing (e.g. Zoom, Teams, GoToMeeting)
  - Integrated in On-line Platforms
- Interactive Applications
- Web Browsing
- Messaging (email, SMS, DM, images, chat)
- Mixed Reality: AR/VR
- File Transfer
- Audio
- Internet of Things
- Interactive Haptic/Tactile

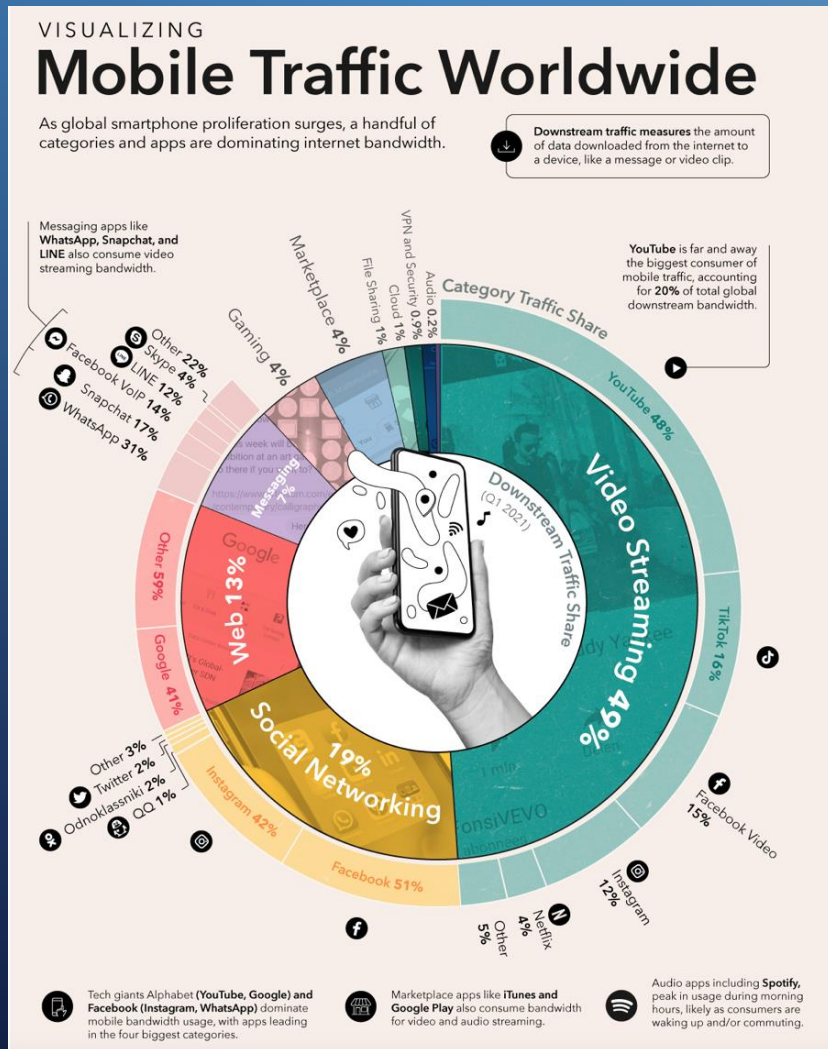


**>> ...common internet related tasks shows that On-line Platforms commonly access four key tasks**





# The World's Most Used Apps, by Downstream Traffic



## Downstream Traffic Share

48.9% Video Streaming  
19.3% Social Networking  
13.1% Web  
6.7% Messaging  
4.3% Gaming  
4.1% Marketplace  
1.3% Filesharing  
1.1% Cloud  
.9% VPN and Security  
.2% Audio

>> The top four categories produce 88% of mobile downstream traffic.

# Video is everywhere

“Our data show in the first half of 2021 bandwidth traffic was dominated by streaming video, accounting for 53.72% of overall traffic, with YouTube, Netflix, and Facebook video in the top three. “

The Global Internet Phenomena Report,  
January 2022, page 12-13

CATEGORY TRAFFIC SHARE			GLOBAL APP TRAFFIC SHARE		
TOTAL TRAFFIC			TOTAL TRAFFIC		
	Category	Total Volume		Category	Total Volume
1	Video	53.72%	1	YouTube	14.61%
2	Social	12.69%	2	Netflix	9.39%
3	Web	9.86%	3	Facebook	7.39%
4	Gaming	5.67%	4	Facebook video	4.20%
5	Messaging	5.35%	5	Tik Tok	4.00%
6	Marketplace	4.54%	6	QUIC	3.98%
7	File Sharing	3.74%	7	HTTP	3.58%
8	Cloud	2.73%	8	HTTP Media Stream	3.57%
9	VPN	1.39%	9	BitTorrent	2.91%
10	Audio	0.31%	10	Google	2.79%

>> The top four categories produced 82% of all traffic.



# Interactive User Experience

User Attention	Gold Standard
The end-user feels that the system is <u>reacting instantaneously</u> . Applies to direct manipulation interactions such as data/text entry and drop/dragging.	100 ms
The end-user's <u>flow of thought stays uninterrupted</u> , even though they will notice the delay. Applies to local application functions such as large table sorting.	1 second
The end-user's <u>attention stays focused</u> on the dialogue. Applies to steps within a coherent task.	10 seconds

**>> The standard for interactive response times for various tasks has been well established.**

Nielsen, Jakob, Usability Engineering, 1993  
<https://www.nngroup.com/articles/response-times-3-important-limits/>



# Internet Application Tasks: Technical Requirements

Internet Tasks	2-way Response Times (to the End-User)
<b>Video</b> <ul style="list-style-type: none"><li>- Broadcast Streaming</li><li>- Two Way Conferencing</li></ul>	< 4 seconds for stream initiation Maintain 25-30 FPS video
<b>Interactive Applications</b>	< 100 ms for real time data/text entry apps < 2 seconds for clicks and browsing
<b>Web Browsing</b>	< 5 sec page load times
<b>Messaging: Email, SMS, Social Media</b>	< 2 sec for user acknowledgement < 10 sec for delivery
<b>Mixed Reality: AR/VR</b>	< 100 ms for highly interactive environments (games, simulations)
<b>File Transfer</b>	< 2 sec acknowledging task initiation
<b>Internet of Things</b>	< 1 sec for Interactive displays < 10 sec for data collection

**>> Based on those response times, GSO systems can serve the dominant share of internet traffic and provide good user experiences**

# Technical Characteristics of Internet Access Technologies

Estimates as of 4 <sup>th</sup> Quarter 2022	GSO Satellite	LEO Satellite Constellation		Terrestrial Wireless FWA	Wireline (Fiber)
		SMALL	LARGE (Best case estimates for an evolving megaconstellation) (see Note 1)		
Capacity (over North America)	> 2.2 Tbps	< 1 Gbps	~ 750 Gbps (as of Jan. 2022) ~1.35 Tbps (Dec. 2022) ~ 1.9 Tbps (if 4,408 sats deployed by Dec. 2023)	60 Tbits/sec with 3K 5G enabled base stations @ 20 Gbps (DL)/10 Gbps (UL)	60,000 Tbits/sec @ 1 Tbits/sec per strand
Speed per customer	150 Mbps	1.5 Mbps	150 Mbps	> 100 Mbps	> 1 Gbps
Link Latency (propagation only)	240 milli-seconds	5.2 milli-seconds (Iridium Next)	3.66 - 8.84 milli-seconds (Starlink – Telesat)	< 10 - 50 micro-seconds (ISD 6 - 30 Km)	5 micro-seconds per Km
2-way Latency	570 milli-seconds	~ 100 milli-seconds	~100 - 110 milli-seconds (best case)	60 - 80 milli-seconds (measured speed)	80 milli-seconds
Jitter	GSO end-to-end path typically use fewer hops and fixed route from source to destination. LEO constellations likely use multiple hops with varying path lengths resulting in potentially larger jitter.			10 – 100 micro-seconds	< 10 micro-seconds
Coverage (in CONUS)	~ 100%	~ 100%	~ 100% (See Note 4)	30% households	43% households
Mean Link Interruption Frequency (Note 2,3)	3.8 x 10 <sup>-6</sup> events/sec (1 event every ~3 days)	N/A	5.5 x 10 <sup>-4</sup> events/sec (1 event every 30 minutes)	1 x 10 <sup>-5</sup> events/sec	1 x 10 <sup>-7</sup> events/sec
Mean Link Interruption Duration (Note 2)	~60 seconds	N/A	~60-300 seconds	60 seconds	~ 10 seconds





# Technical Characteristics of Internet Access Technologies

**Note 1:** a) Percentage of LEO satellites dispensing capacity over CONUS is assumed 2.5%. (The surface area of CONUS is only ~ 2% of earth's surface but a greater percentage is used for the inclination of orbital planes). b) The capacity per satellite is assumed 20 Gbps. The actual usable capacity will be considerably lower if factors such as the size of the phased array antenna dimensions, size of solar power, available spectrum, frequency reuse limitations, density of covered locations and other LEO satellite parameters are taken into full account in a detailed analysis. c) Sunny case scenario is assumed with respect to launching and moving the LEO satellites into final operational orbits over the next 21 months. Estimates used here are based on past record of launch and success in placing satellites to deliver capacity. The long-term challenge to consistently maintain and operate such large constellations, given the 5 year (or less) lifetime of each satellite, is ignored.

**Note 2:** Mean service interruption frequency and mean service interruption duration – There is an adverse impact on user experience due to handover and line of sight issues at low terminal elevation angles for satellite systems and terrestrial wireless systems. Wireline media (fiber) suffer service interruption due to factors like fiber cuts and others. These factors manifest themselves in user experience acceptability of services offered.

**Note 3:** Subject to change as LEO constellations are fully deployed. Sampling of many articles on user experiences are below.

- a) <https://www.itworldcanada.com/article/starlink-internet-is-experiencing-worldwide-service-interruptions/470154>
- b) <https://istheservicedown.in/problems/starlink>
- c) <https://www.cablefree.net/pdf/CableFree%20AN13%20Fibre%20Cuts.pdf>

**Note 4:** Local capacity constrained by limits on frequency reuse and density of covered locations.



# Latency Explained

## Latency

- Transmission Time (= packet size/Capacity of link)
- Queueing Delay
- Processing Time at source, destination and intermediate switches
- Propagation Time = distance / ( $\alpha$  \* speed of light)      $\alpha$  = 1 (free space), 0.7 (fiber)
- Number of hops in end-to-end path (Terrestrial and Satellite components)
- Buffering delay at nodes
- Packet Retransmission (at link level and end-to-end) for reliable communication

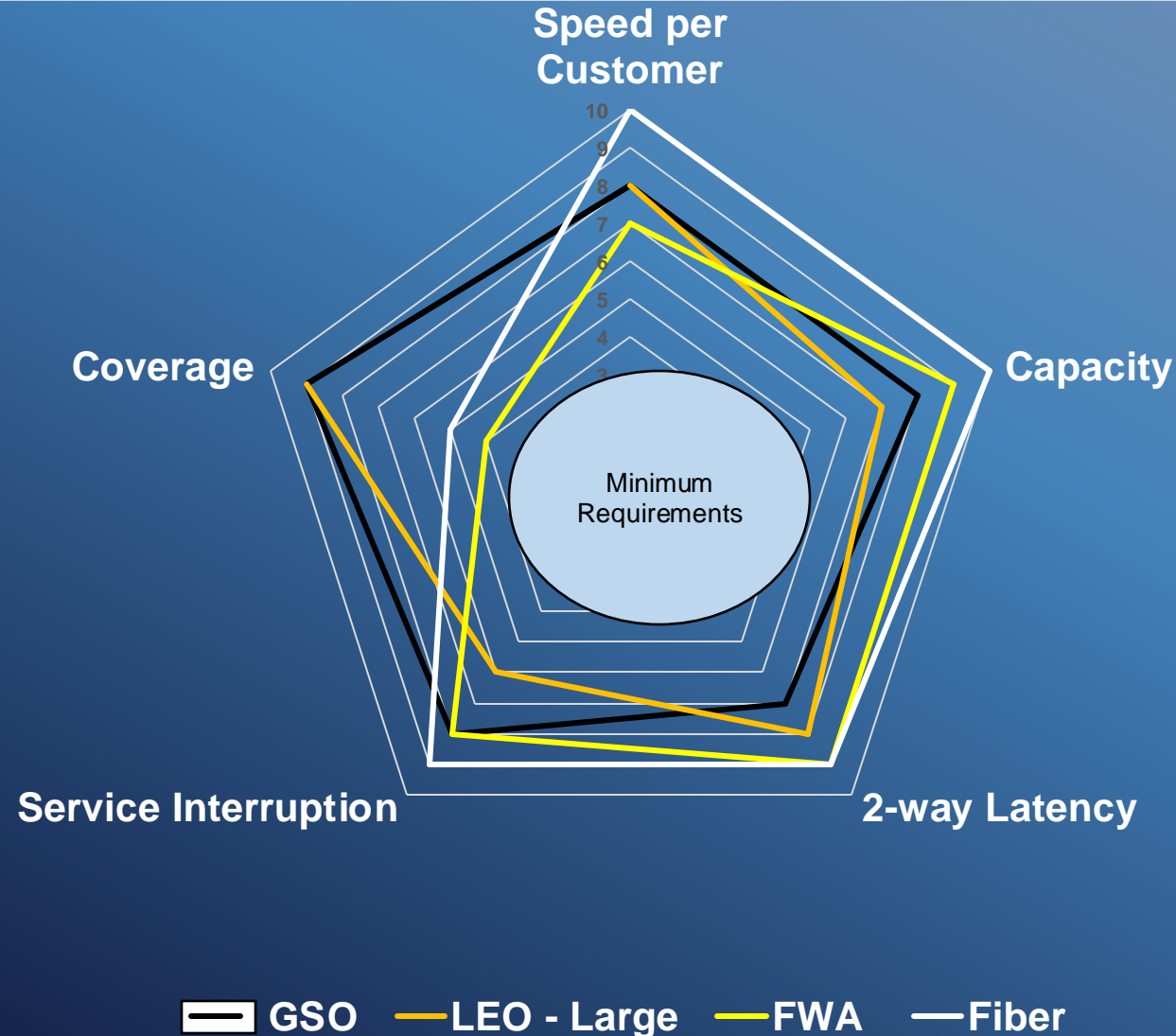
← Elementary  
Network  
Analysis 101

1. Important to assess 2-way latency rather than just one component (propagation time)
2. Application-level requirement for human acceptable latency is important
3. 2-way latency is application specific
4. Mitigation techniques to minimize application impact exist

**>> The Key Requirement Is That an Access Technology Meets the Application Requirement When All Delay Elements Are Considered, Not Meet a Number Based on Link Propagation Delay Alone.**



# Internet Access Technologies – All Technologies Exceed the Requirements



**>> There Is No Technology That Dominates All the Technical Performance Categories.**

**>> There is no clear winner.**

# Additional Characteristics of Internet Access Technologies

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- System reliability (e.g., Service interruption frequency and duration due to line of sight and other factors)
- System availability
- Scalability and number of US customers potentially served
- Relative deployment cost
- Maturity of service (How long has solution been in operation)
- People served globally since inception of service
- Robustness to environmental and/or natural catastrophes (geomagnetic storms, earthquakes, forest fire, blizzard, floods, tsunamis)

**>> These Characteristics Are Just as Important to Users as Capacity, Throughput and Latency**

# Additional Factors in Comparison of Solution Alternatives

	GSO		LEO Large Constellations	Terrestrial Wireless - FWA	Wireline Fiber
Satellite and System reliability (including. line of sight issues)	References . 71, 74		Link Interruptions (handoffs, blockages)		
System availability			Partial deployment now; Likely improve in few years		
Scalability and number of N America customers potentially served (having access to the technology)	~100%		~100%	50 Million (T-Mobile, VZ)	60 Million Fiber+Cable cos
Relative deployment cost (in billions of US dollars)	Small (2-3 per HTS satellite)		~ 10 (for 4408 sats) ~ 25 (for 12000 sats) ~ 85 (for 42000 sats)		Expect several tens of billions (likely exceed 100)
Maturity of service (How long has solution been in operation)	Since 1970's		Early stage of deployment	Nascent (use 5G cellular expertise)	Decades of urban deployment
Customers served in North America since inception of service	2 Million		Beta users	Few million	
	Rural	Urban		Rural	Urban
Robustness to environmental and/or natural catastrophes (geo-magnetic storms, earthquakes, forest fire, blizzard, floods, tsunamis)	Decades of deployment experience		Potential for disturbances in low altitude, politics, debris		
Time to Deploy broadband Internet	Now		Multiple years (~1000 per year)	Several years to reach all users	Many years to reach all users

Excellent (5)

Good (4)

Average (3)

Below Average (2)

Poor (1)

**>> GSO Meets or Exceeds Service Requirements Compared to Other Technologies**



# Comparison of Internet Access Technologies and Application Requirements

Underlying Tasks	GSO	Large LEO	Terrestrial Wireless (FWA)	Wireline (Fiber)
Video				
- Broadcast Streaming	YES	YES	YES	YES
-Two Way Conferencing				
Interactive Applications	YES	YES	YES	YES
Web Browsing	YES	YES	YES	YES
Messaging: Email, SMS, Social Media	YES	YES	YES	YES
Mixed Reality: AR/VR				
-- moderate latency (e.g. strategy games)	YES	YES	YES	YES
-- low latency (e.g. 1st person shooter)	NO	NO	YES	YES
File Transfer	YES	YES	YES	YES
Internet of Things	YES	YES	YES	YES

**>> GSO Meets Requirements for All Applications Except Extremely Low Latency AR/VR and Shooter Game**



## Conclusion: GSO-Satellites can satisfy most internet application categories

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- Terrestrial wireless and wireline offer high performance and capacity but are limited in coverage (due to cost and economic factors). These solutions, especially wireline fiber, are significantly more expensive and take much longer to deploy for benefitting the unconnected users.
- GSO Satellite broadband technologies offer performance and capacity for most applications and users and excel in coverage with proven capability to connect the unconnected in economical manner now.
- NGSO Satellite broadband technologies are new and immature. They may ultimately offer adequate capacity for many applications and good coverage but take a long time to deployment (multiple years). Many serious challenges and risks remain:
  - Technical challenges (good and consistent quality of service to users)
  - Operational challenges (launch and grow and sustain a large stable constellation)
  - Successful business case (Note 1 below)

Note 1: Elon Musk says Starlink will need up to \$30 billion to survive.

<https://www.businessinsider.com/elon-musk-starlink-spacex-bankruptcy-funding-30-billion-2021-6>

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## Conclusion: GSO-Satellites can satisfy most internet application categories

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- Among satellite solutions, a critical comparison of High-throughput (HTP) GSO and planned NGSO constellations reveals no definitive superiority of one over the other.
  - HTP GSO can address most of the applications & use cases; unlike NGSO systems they carry little risk of technical viability or uncertainty of business success
- 
- **In summary:**
    - **Proven GSO technology is a reliable way to expand broadband connectivity.**
    - **No single technology solution uniformly dominates the rest along various metrics.**
    - **There is no one size fits all solution for broadband deployment at a national scale.**
    - **Decisions regarding optimal technology solutions are best made on a regional or local basis.**



# Thank You

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# Backup

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