The new age of Large Low Earth Orbit Satellite Constellations

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Abstract:

The Satellite industry sector is going through continuous innovation since its inception in 1960s.With advancement in technology, in the space communication ecosystem we are experiencing rapid advancement. The 4th industrial revolution has started, it requires more robust and advance communication platforms to support our ambition of "Be Connected anywhere, anytime". Various reports indicate Tens of Billion devices need to be connected over the next several years. New technological involvement requires real-time or near to real-time responses, which in turn requires much lower latency than the traditional 700ms of satellite network in Geostationary Earth Orbits (GEO). Consequently, we notice lots of focus and attention to other form of space communications and None Geo Stationary Satellite Network (NGSN)There are several numbers of providers looking on usage of MEO and LEO. Currently Star-Link is one of the front runners. This report, provides comprehensive overview of the Large Low Earth Orbit Satellite Constellations (LLEOSC), communication application with particular section on Star-link.

Keywords: small satellites constellation, satellites communication, Star-Link, none GEO stationary satellite network.

Introduction:

Satellite industry sector is going through continuous innovation since it is start in 1960s.With advancement in technology, in the space communication ecosystem we are experiencing rapid advancement. The 4th industrial revolution is started, it requires more robust and advance communication platforms to support our ambition of "Be Connected Anywhere, anytime. Various reports indicate Tens of Billion devices need to be connected over the next several years and the numbers are growing. From home entertainment, to various sectors of industry. From agriculture (moisture sensors in a farm) to mining, inflight connectivity, remote medical projects, surgery and so on.[1]

New technological involvement requires real-time or near to real-time response, which requires much lower latency than the traditional 700ms of satellite network in Geostationary Earth Orbits (GEO) and we see to address these industrial players start to look at Medium Earth Orbits (MEO), Low Earth Orbits (LEO) satellite constellation, at last but not least the Nano satellite networks.

Advancement of new technologies such as Cloud computing, Internet of Things (IoT) and 5G presence increase the importance of a hybrid communication network with very small delay in communication, indicating the importance of new satellite constellation to provide much lower latency, while ensuring our world has full connectivity. Hence, we started to revisit LEOs theory, and start with small satellites constellation.

More than 3300 active satellites now orbit the Earth, and amateur astronomers and other observers are seeing more every month. Historically, satellite communication involved GEO large spacecraft systems that have become increasingly capable over the years. Traditional communications satellites with GEO have proved their worth since the 1960s. Although costly, they are highly capable and have long service lives. Their altitude more than 35,000 kilometres from Earth, provides them with a wide field of view, allowing operators to cover most of the planet's surface with three satellites spaced at appropriate intervals. Recent Technological advances, including new high throughput and reconfigurable designs, have improved both efficiency and performance of GEO Communication Satellites.[2]

But now, None Geosynchronous-Orbit (NGO) Constellations, including low-Earth-orbit (LEO) and medium-Earth-orbit (MEO) constellations, are taking to the skies, and their number could soon soar. Up to now, MEO constellations have been used with navigation satellites versus mostly LEO constellations are going to be used with communication satellites. While traditional large geostationary orbit could cover the world for few numbers of satellites, the NGO constellation requires a greater number of satellites to provide 100% world coverage. In other words, to cover larger areas of Earth with NGO satellites, specifically with Low Earth Orbit (LEO) constellation, requires large number of operational satellites that is Large Low Earth Orbit Satellite Constellations (LLEOSC).

The Idea of Large LEO Constellation, is nothing new. It initially started in the 1990s. However, due to high cost of technology and lack of today technological advancement, it was shelfed for a long time. New satellite constellations are on the cusp of deployment, but their long-term success hinges on substantial cost reductions and overcoming still several determinatives operational & technical challenges. If current LLEOSC proposals become reality, about 50,000 active satellites will orbit overhead within ten years. Even if the most ambitious plans do not come to pass, the satellites will be manufactured and launched on an unprecedented scale.[4,5]

Why the renewed interest in Large LEO Constellation?

As it mentioned, the ambitions for the Low Earth Orbit Constellations concepts may recall the 1990s, when several companies tried to provide global connectivity. **Global Star, Iridium, Odyssey, and Telegenic** had impressive plans. In the end, however, all but **Iridium** scaled back or cancelled their intended constellations because of high costs and limited demand. All suffered financial problems. After that experience, many industry analysts and investors remain sceptical about the viability of large LEO constellations. The failures of **Leo-Sat** and **One-Web** (One-Web is back in action) reinforce that impression. [2,3,10]

But much has changed since then Satellite technology has advanced; demand for Bandwidth has soared, with no slowdown in sight; and companies have developed creative business Models to generate profits from connectivity. Moreover, both tech companies and investors now have much larger stores of capital to invest, making It possible to fund large constellations—although this capital clearly does not have infinite patience. These changes could well make satellite connectivity to a success.[1]

The COVID-19 pandemic will also influence the satellite market's future, but as of the date of this article's publication it is hard to say how great the impact will be. In the near term, any company that tries to secure funding will face challenges because of economic uncertainty and immediate public-health concerns. While physical distancing and work-from-home measures remain in place, the development, manufacture, and launch of large LEO satellites Constellations will slow. But the crisis has also caused a spike in demand for internet connectivity and underscored its importance. Investment in any kind of new connectivity infrastructure will be expensive but will almost certainly be needed. Going forward, LLEOSC concepts could play an important role in meeting this increased demand.[4]

Our research suggests that it springs formal convergence of forces that make both the development and the market success of LLEOSC more likely now than in the past: technological advances, the emergence of new business models, better funding, and higher demand for low-latency bandwidth. Thanks to these developments, the current situation bears little resemblance to the 1990s, when LLEOSC concepts failed to gain traction.

So, it could be said that, nowadays there are Greater opportunities for LLEOSC providers because:

- Technological advances in antennas, ground stations, and other areas
- New business models,
- Greater demands for high bandwidth and lower latency,
- More funding available from tech companies and investors

LLEOSC, Cons and Pros!

The new Large Low Earth Orbit Satellites Constellations (LLEOSC) concepts, which orbit 500 to 2,000 kilometres from Earth, offer faster communications (they have lower latency) and often provide higher bandwidth per user than GEO satellites do—even more than cable, copper, and pre-5G fixed wireless. But any technological advancement has its advantages and challenges (at least, until it matures), and space communication platform is not an exception.

In this case management of large satellite constellation is one of the main challenges. The operator of a large constellation must monitor and manage the status and functions of thousands of satellites and also requires more accurate network management. So, with such large number of satellites, the operator requires 100s of Ground based Getaways to help the network![7]

Beside that when communication occurs through a constellation of low Earth orbit satellites; global coverage requires a large number of spacecrafts. These concepts will require major changes in satellite operations, including manufacturing and the supply chain. LEO satellites shorter life span (typically around 5 years) requires faster satellite replacements over shorter period (compare to traditional 15 years of GEO satellite). While the cost of manufacturing and launches is lower for the LEO and Nano satellites, but higher volume can map to higher cost. Obviously, the advantage of shorter life span can be considered as shorter time to catch up and modify with new technological development.

Our analysis, however, indicates that companies planning large LEO Communication Constellations still need to reduce a range of costs significantly to ensure long-term viability. Lowering launch costs is one part of the equation, but it will be equally or more critical to reduce the cost of manufacturing spacecraft, ground equipment, and user equipment. If suppliers and constellation providers can achieve these cuts, they could unlock enough demand for large LEO constellations to transform both the B2C and B2B communications markets.

As mentioned, Cost of user terminal is a challenge for these players. Such cost surely will reduce in coming years, but today to attract market, such User terminals need to be subsidised by the service provider. As per reports the actual cost of Space-link is around US$1200, while as part of current service offering, End User pays approx. US$400 to US$500 depends on their location in limited countries where Star-link service is available today. These challenges will affect the progress of the remaining licensed concepts—Kuiper, Star-Link, and Tele-Sat differently because their ownership and funding approaches vary.

Other aspect is The Users Satisfaction, LEO satellites due to their nature of operation may not be as prone to Interference (Intentional and none intentional) of traditional GEO satellite. This will reduce the impact on wider users significantly.

Lastly, Regulatory Challenges, having enough satellite to cover the world is part of the solution. The regulator aspects need to address. Space link and other LEO/MEO constellation operators has to start regulator work into every country to obtain approval to provide telecoms services. Which will be interesting to see how it works out with countries with rigid Regulatory criteria.[1]

LLEOCC players;

There are number of LEO players are around, some like Iridium operate LEO satellites in the past and new players such as SpaceX, One-Web, Tele-sat, as couple of examples along with new starts up in Nano satellite. There are different focus and application for each. Tele-sat, One-Web more focused on Enterprise sector, while SpaceX (Star-link service) initially focused on Consumer based service. Although we see SpaceX is looking into offering services to Maritime and Aero sector .As of now, that we are completing this report, total number of Star-Link satellites in Orbit are 1800 (as per Reuters report, 23rd June 2021). They expect by September they could cover the globe. (Although it was reported in the past to achieve the goal, they need around 2800 satellites). (Table-1).[8,10,15,16,18]

SpaceX is well ahead in the race to deploy an operational system. For Star-Link, 422 satellites were in orbit as of late April 2020, and the company began offering some services. Tele-sat, with a proposed initial constellation of 117 spacecraft and the potential to deploy more than 500, appears to be moving forward with its plans. Amazon, which has filed to launch 3,236 spacecraft in its Kuiper constellation, also appears to be proceeding and plans to move its growing team into new facilities.

Star-link Service:

As we hear various stories about Star-link services these days, it may be useful to briefly outline and share some facts about its network and operations.

Star-link enables a user to access the internet by connecting their home router to a satellite dish outside. This is pointed at the sky to communicate with the satellites overhead. Each craft receives signals from a user, then connects to a giant SpaceX-operated ground station operated elsewhere. That enables access to the rest of the internet.

Your Star-Link is assigned to a single cell. If you move your Star-Link outside of its assigned cell, a satellite will not be scheduled to serve your Star-Link and you will not receive internet. Initial phase of the services, offered in few countries under the name of "Beta Service"

So, what happens if a given satellite can't see a ground station? SpaceX's plan is to use laser links between the satellites to find a pathway and connect to the rest of the internet. The first satellites lacked these links. Deploying laser links between satellites, can reduce the required number of satellites as well as reduction on number of gateways.

The ongoing beta test shows Star-Link works without the links. As it stands, the Beta speeds fall far short of SpaceX's goals to reach one gigabit per second. The company's long-term ambition is 10 gigabits per second, plus a resilient network with "multiple routing options to every Star-Link and Gateway."

Beta service started for customers in the United States, United Kingdom, and Canada using the laser-less constellation. Users on the "Better Than Nothing" beta reported speeds of around 150 megabits per second. Bearing in mind, although the service is based on a shared platform, during Beta service there is no cap for users. This will surely change at later stage, when Star link service be fully available worldwide. Ultimately, Space X goal is to reach a 1GB to 10 gigabits per second speed.

Although the initial plan was to set up a network to offer Internet to fixed based users, SpaceX wants to connect Star-Link to ships, planes, trucks, and RVs, according to a request the company filed to the Federal Communications Commission (FCC) on March 9 2021.[14]

Where will Star-Link be available?

SpaceX's first goal was to bring speedy satellite internet to rural areas in the US and Canada. After that, company planned to expand service to other parts of the world. This plan for world domain—era, internet connectivity—would require SpaceX to launch at least, about 2,800 satellites—but at higher altitudes between 700 and 800 miles above the Earth.

Star-Links Gateway as of March 2021

1. USA: 55
2. Canada: 1
3. Oceania: 15
4. Europe: 7 (including 2 in the UK)
5. South America; 7

Real-Time satellites map can be seen using the following link: https://satellitemap.space/

Deploying inter-satellite link connectivity perhaps will reduce number of satellites, Ground Gateways and decrease in delay, as laser beam travels 50% faster in the space, hence improving latency. However, Inter-satellite laser connectivity has its own associated cost.

Star-Link isn't cheap. A subscription to the beta is currently $99 a month. It costs a further $499 for the Star-Link kit, which includes a mounting tripod, a Wi-Fi router, and a terminal to connect to the satellites.

In February 2021, SpaceX began offering pre-orders of Star-Link to other countries so users can now put down a $100 deposit to get their hands on the service once it becomes available. The deposit will be applied to the amount due on the Star-Link kit.

- Overall users will be paying $600 upfront for Star-Link.
- Users the UK are paying £439 for the kit and £89 for the subscription fee. Compared to other internet providers that charge £55 per month for speeds of up to 110 Mbps, this isn't cheap.

Conclusion;

Large LEO constellations have emerged and it is here to remain. Although we may expect some consolidation. The reduction in cost of user terminals and ground segment may require few years

This new approach is a great opportunity for connecting the unconnected and compliment any existing Broadband network.

The operators, design and decide what they require from their ground network, in terms of number of gateways and relevant locations globally.

As we mentioned following the Beta Service of Star-Link, more and more area of the world is covered by Star-Link constellation. Service is currently available in US, Europe and some part of the world. This coverage will be expanded as the regulatory matters discussed and resolved.

Other LEO operators indicate that their services will be fully operation by 2023-2025

Practically, if the user terminals will be available and satellites fly over certain territory, the service will be receivable within that territory. The service provider (eg. Star-Link) on its discretion can refuse the service during the registration if the location is within territories where Star-Link has not finalized regulatory agreement.

If the registration of users does not require specific location (as it is required currently by Star-Link), theoretically service provider can ignore regulatory issues.

Because of the fundamental of design of LEO constellation and vast usage of Frequency use, it is expected that such network will be very resilient towards any intentional/unintentional interference created by ground-based facility.

Table 1: Large Low Earth Orbit Communications Constellations

Row	Constellation	Manufacturer	Number	Weight	Unveil.	Avail.	Altitude	Inclination	Coverage	User speed	Band	Inter-satellite links	Services	Status
1	Celestin	Motorola	63(7*9)				1400 km	48°	Global			No	low-latency broadband Internet services	Retired
2	Teledesic constellation	Teledesic	840-288(12*24)		1994	1997	700-1400km	98.2°	Global	100 Mbit/s up, 720 Mbit/s down		No	Internet access	Retired
3	Broadband Global Area Network (BGAN)	Inmarsat	3				36000 km	0°	82°S to 82°N				Internet access, satellite telephony	Active
4	Globalstar	Globalstar	48(7*6)				1400km	52°	70°S to 70°N[6]			No	Internet access, satellite telephony	Active
5	Iridium NEXT	Iridium/ Thales Alenia+ Orbital ATK	66(6*11)	860kg	2009	2018	780km	86.4°	Global	1.4 Mbit/s	L (1 – 2 GHz)/ Ka (26.5 – 40 GHz)	K 23 GHz	Internet access, satellite telephony	Complete
6	O3b constellation	Boeing /O3b Networks (part of SES S.A.)	7-20		2017	2021	8.062-8.00km		45°S to 45°N	1 Gbit/s for a cruise ship	Ka (26.5 – 40 GHz)	none	Internet access	O3bm under development

7	Orbcomm	ORBCOMM	17				750km	52°	65°S to 65°N				"IoT and M2M communication", AIS	Active
8	Defense Satellite Communications System (DSCS)	4th Space Operations Squadron	10	1235 kg [3]	1971	2003	37000 km	13.8	66° E to 70° W	100 Mbps	X-Band 500 MHZ	none	Military communications	Retired
9	Wideband Global SATCOM (WGS)	4th Space Operations Squadron	10				36000km						Military communications	
10	ViaSat	Viasat, Inc.	4				36000km		Varying				Internet access	
11	LeoSat	Thales Alenia	78-108	1,250 kg	2015	2022	1,400 km			in increments of 100 Mbit/s	Ka (26.5 – 40 GHz)	optical		first launches in 2021
12	OneWeb constellation	OneWeb+ Airbus JV	882-1980	145 kg	2015	2020[15]	1,200 km	87.4	Global	up to 595 Mbit/s	Ku (12–18 GHz) / Ka (26.5 – 40 GHz)	none	Internet access	6 pilot satellites in February 2019

13	Star-Link	SpaceX	1740 (1658 in orbit) - (11914 in Schedule)	227-260 kg	January 2015	2020[18] october 2019	540-550-560-570-(1110-1325 in Schedule)	53° 53.2° 70° 97.6° 42.0° 48.0	Global	.50Mb/s to 150Mb/s & latency from 20ms to 40ms	Ku(12–18 GHz) /Ka(26.5 – 40 GHz) /V-Band Ka (40 – 75 GHz) (E-Band(60 – 90 GHz) in Schedule	optical	High-speed, low latency broadband internet		Star-Link was launched in 32 stages: Launch 0 (Tintin) Launch 1 (V0.9) Launches 2-8 (V1.0 1-7) Launches 9-17 (V1.0v 8-16) Launch 18/31 (Transp-1, Transp-2) Launch 19+ (V1.0v 17+)
14	Boeing	Boeing Satellite	1,396-2,956	N/A	2016	N/A	1,200 km	45° 55° 88°	Global	broadband	V (40 – 75 GHz)	none			transferring the application to OneWeb
15	TELE-SAT LightSpeed	Thales Alenia Space	298 in first stage 1671 in second stage	700 kg	2016	2024	Polar orbits: 1,015 km Inclined orbits: 1,325 km	Polar orbits with 98.98° Inclined Orbits with 50.88°	Global coverage	Up to 7.5 Gbps for a single terminal Up to 20 Gbps for a single hotspot	Ka (17.8-20.2 GHz for downlink 27.5-30.0 for uplink)	optical	Internet		two prototypes: 2018 launch (LEO Vantage-1 & 2)
16	CASIC Hongyan		156		2017	2022	160–2,000 km								prototype launched in December 2018
17	CASC Hongyan		320		2017	2023	1,100 km								prototype launched in December 2018
18	Project Kuiper	Kuiper Systems LLC (Amazon)	3236		2019		590 km (784 sats)		56°S to 56°N[28]						FCC filing in July 2019

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