Starlink: Bridging the Digital Divide with Revolutionary Satellite Internet Technology

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Abstract

Starlink is a satellite internet constellation project proposed by SpaceX that is designed to deliver global broadband coverage, especially where it is insufficient or remote. A constellation of low Earth orbit (LEO) satellites is envisioned by Starlink to provide high-speed, low latency Internet access, which could significantly change the landscape of global connectivity. The aim of the project is ultimately to close the digital gap, by making a global connection perfectly reliable (i.e., always connected).

Keywords: Star Link, Star Link Network, Digital Inclusion, SpaceX

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1. Introduction

Starlink, is a satellite network that provides Internet service developed by the American aerospace company SpaceX. More than 6 000 satellites already exist and are in operation to date in June 2024.

half of all active satellites, in the Starlink network. Starlink is a mega constellation, or satellite Internet constellation, that boasts more than three million subscribers (as of May, 2024).

Customers establish a link to the network using a small, rectangular dish. Starlink offers gainsay satellite Internet services in underserved areas where traditional Internet service providers are not available. In 2024 Starlink implemented tests on satellites for cellular data provision jointly with T-Mobile. SpaceX also provides a military variant of Starlink, which is Star shield, and is developing a U.S. defence communication satellite constellation for the U.S. government.

The Starlink constellation has many satellites, tens of thousands are planned, and has caused concern for collisions and space debris. In December 2021 China announced to the UN that its Tianhe modular space station telescope experienced two evasive manoeuvres, coming close to Starlink satellites. SpaceX filed a report with the FCC that Starlink satellites had to avoid other satellites and space debris more than 25,000 times in the period between December 2022 and May 2023, a two-fold increase from the previous six months [1].

2. What is Starlink?

Starlink is a satellite internet constellation developed by SpaceX, an American aerospace company founded by Elon Musk. The project seeks to bring high-speed internet to remote areas worldwide. As of June 2024, the Starlink network includes more than 6,000 satellites, which constitute over half of the total number of operational satellite in space. The service has more than three million subscribers as of May 2024.

Starlink works with a constellation of low Earth orbit (LEO) satellites, which fly at less than).

1,600 kilometers (1,000 miles). This setting makes it possible to achieve lower latency than conventional geostationary satellites which are much further away from the Earth. Users access the Starlink network by way of a form factor of (almost) a rectangle portable dish that links to the satellites in orbit [2].

The benefits of Starlink include providing internet access to areas that are underserved by traditional internet service providers, offering a viable alternative where infrastructure is lacking. However, in addition, Starlink has started to test satellites for mobile cellular service in conjunction with T-Mobile, and has a version for military use, known as Starshield, for the U.S. Government.

There are worries regarding the increased space debris and interference with astronomical observations caused by the high number of satellites. At an operational level SpaceX has taken actions including anti-collision systems and low-reflectivity surfaces in order to address these problems [3].

3. How Starlink works ?

Starlink is a system of beaming internet data over radio frequencies via space. Ground stations then send those signals orbiting satellites, which then send the data to the earth-side users.

The majority of satellite internet services leverage signals from a single, geostationary satellite. They're about the size of a bus and orbit at 22,000 miles from the Earth's surface. Traditional satellites typically max out at between 100 and 150 megabits per second.

In contrast, Starlink operates from thousands of 22 ft long satellites positioned 63 times lower in orbit, compared to [the km]. Due to their being located very close together, they can achieve very high internet speeds of 20-250 Mbit/s.

An additional factor to consider latency shows Starlink at 25 and 60 milliseconds compared to its competitors at 450 to 700 milliseconds [4].

3.1 Starlink System Architecture

Starlink system architecture includes following three segments shown diagram.

1. Space Segment
2. Ground Segment
3. User Segment

3.1.1 Space Segment

This segment is consist of no. of satellite in the Lower Earth Orbit (LEO). These are miniature, low cost, satellite with (mass) 260 kg, operating in Ku- and Ka-band, and active for 5–7 years. These satellite connected the User to the internet. Since a huge amount of satellite is communicating with each other over Inter-satellite link (ISL). Machine vision system that includes phase array antennas is used for both u plink/down link and laser communications within the ISL link. CPE-Satellite communication refers to Ku-band, and Ground Station-Satellite communication refers to Ku-band for downlink and Ka-band for uplink. Ultra small spot size beams can be generated by Starlink's satellites because they are very close to the earth.

3. 1.2 Ground Segment

The Starlink ground segment consists of various facilities that control the network and deliver the internet access to the satellites. These are also used as Ground Stations/Starlink Gateways and are located around the globe to offer coverage for remote and underserved areas (i.e., poor Internet connectivity) [5,6] [7]. The ground station is connected through Internet Service Provider via Fiber.

3.1.3 User Segment

The User Segment include area where people are using the internet services using the Starlink CPE. This CPE[13] consists of a satellite dish installed on the rooftop or on ground having a clear visibility of Sky, a router power supply and a WiFi router. The dish consists of a phased antenna array of the stacked honeycomb structure which automatically align with the available satellite.

The router is adapted with a Gigabit Ethernet port and Wi-Fi to provide connectivity. The satellite dish is connected to the router and both are powered using Power over Ethernet (PoE). One router can support up to 128 devices simultaneously. It is operated with a 56 V DC supply provided through PoE. The router complies with IEEE 802.11 standard and operates at 2.4 GHz and 5 GHz.

3. 2 Starlink Internet Services Cost

In India, Starlink's subscription options have different rates and speeds. Basic package only costs Rs 499 per month with a download and upload speed limit of 50 Mbps and 25 Mbps, respectively. Most costly scheme is Rs 2,499 monthly and offers download and upload of the highest speed of 150 Mbps and 30 Mbps, respectively. Apart from these, Starlink has an installation fee of Rs 6000 that covers the Starlink equipment cost in addition to it. The Starlink terminal, mounting tripod, and two Wi-Fi routers are in the box [5].

4. Applications

- Educational Systems.
- Real Time Projects.
- Travelling.
- File Transfer.
- Agriculture.
- E-Commerce.
- Digital Transactions.

4. Advantages of Starlink

Industrial and Industrial Applications: There are applications for industries, including mining, agriculture, and forestry, that would benefit from Starlink's connectivity potential.[11] This technology could offer real-time data monitoring, show operational efficiency, and enhance safety features in remote work sites. Interstellar communications and space travel: The Starlink satellite communications and terrestrial infrastructure experiences may find their way over to Earth also. Experience gained from the operation and management of a large number of satellite constellations can be used to foresee space exploration missions, like interplanetary communications and data relay.

5. Challenges of Starlink

1. Mitigation of Space Debris: Hundreds or even thousands of satellites are deployed in space and the potential of space debris with the associated impact on other satellites and spacecrafts are a challenge. In order to mitigate space debris and maintain sustainable space exploitation, adequate actions are necessary.[11]

2. Users could use the internet without being subject to the control of the governments of their respective countries. Governments may perceive this to be a threat to their sovereignty. In order to resolve this issue to the satisfaction of all parties involved, Starlink must reach a workable deal with governments.[10]

3. With an increasing number of companies launching their own satellite constellations, the satellite Internet market is becoming increasingly competitive. OneWeb, Amazon (Project Kuiper), and other market entrants compete with SpaceX's Starlink.

4. Customers must be able to connect to the Starlink network via user terminals or satellite dishes that are affordable, simple to install, and able to withstand adverse environmental conditions.[11]

5. Every country where Starlink wishes to operate must, at a minimum, secure regulatory authorization to provide communication services in that country. As of yet, there is no evidence that any "south" developing countries shared their blessing of a particular Starlink.[15] They're anticipated to begin that process soon.

6.Conclusion

Starlink represents a pioneering step forward in satellite internet technology by providing high-performance, low-latency connectivity to the underserved and remote parts of the world. Its groundbreaking system architecture comprising a massive constellation of low Earth orbit (LEO) [12] satellites, strategically located ground antennas, and easy-to-use equipment offer a novel reference point for global broadband services. From education to agriculture to e-commerce and real-time data transfer, Starlink has the capacity to become a force bridging the digital gap and creating socio-economic prosperity.

Nevertheless, the project has to deal with the difficulties since the project has to overcome the conditions under which the use of the same type of spacecraft is regulated by laws, competition from other existing or new technologies, price, and space debris issues. Solving these problems will be especially important for the long-term viability and robustness of the network. However, the Starlink's[17] flexibility, technological breakthroughs, and global alliances will be crucial for Starlink's ability to sustain leadership in the rapidly maturing satellite internet market.

At the end, Starlink showcases the revolutionary capability of space-based internet services, not only for enhancing connectivity on ground, but, at the same time, as a stepping stone for the interplanetary communication systems of the next generation.

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