How to Bridge the Digital Divide and Provide Connectivity to Rural and Remote Areas Using NGSO Satellites

Bharat Bhatia, FIETE
ITU-APT Foundation of India, 504, World Trade Center, New Delhi 110001
bharat.bhatia@itu-apt.org

Abstract **-- In the quest to connect the unconnected and bridge the digital divide, Non-Geostationary Orbit (NGSO) satellite constellations, particularly those in Low Earth Orbit (LEO), have emerged as a transformative force. These systems are reshaping global connectivity by providing high-speed, low-latency internet access to even the most remote regions. This article explores the current status of NGSO technology, the advantages of LEO constellations, and their potential impact on developing countries like India.**

Keywords: *Low earth satellites, Broadband access, Digital inclusion, Disaster Relief, SpaceX', OneWeb, Project Kuiper, Telesat Lightspeed*

I. INTRODUCTION

NON-GEOSTATIONARY Orbit (NGSO) satellite constellations are designed to orbit the Earth at altitudes ranging from 500 km to 2,000 km, significantly lower than traditional geostationary satellites [1]. This lower altitude results in reduced latency and higher data speeds, making NGSO systems ideal for real-time applications such as video conferencing, online gaming, and telemedicine. Major players in the NGSO market include SpaceX's Starlink, OneWeb, Amazon's Project Kuiper, and Telesat's Lightspeed.

- **Starlink**: SpaceX's ambitious project aims to deploy nearly 12,000 satellites, with plans to expand to 42,000 in the future. Starlink has already launched thousands of satellites and is operational in several countries, including the United States, Canada, and parts of Europe [2].
- **OneWeb**: Despite initial setbacks, OneWeb has resumed launches and aims to provide global coverage with a constellation of 648 satellites [3].
- **Project Kuiper**: Amazon's initiative plans to launch 3,236 LEO satellites to offer broadband services to underserved communities worldwide [4].
- **Telesat Lightspeed**: This Canadian project aims to deploy 198 LEO satellites to deliver ultra-high-speed, low-latency internet to various sectors, including aviation, maritime, and remote communities [5].

II. ADVANTAGES OF LEO CONSTELLATIONS

LEO constellations offer several key advantages over traditional terrestrial networks and geostationary satellites:

1. *Low Latency and High Data Speeds*: The lower orbit of LEO satellites reduces signal delay, making them suitable for real-time applications. This is particularly important for applications requiring fast response times, such as video conferencing and online gaming.
2. *Signal Quality:* Due to the shorter distance, LEO satellites can provide stronger and more stable signals, resulting in better quality of service.
3. *Innovation and Scalability:* LEO satellite constellations are constantly expanding, opening the door to technological innovations and increased network capacity.
4. *Cost-Effective Deployment*: Launching satellites into LEO is generally less expensive than reaching higher orbits, partly due to the lower velocity required to achieve orbit and the increasing availability of launch options. This cost-effectiveness facilitates the deployment of large constellations, offering global coverage and redundancy.
5. *Global Coverage:* LEO constellations provide ubiquitous coverage across the globe, even in remote and underserved regions, making them increasingly important for bridging the digital divide.

III. BROADBAND SERVICE USING LEO SATELLITES

1. *Altitude and Speed:* LEO satellites orbit at approximately 300-1000 kilometres above Earth, much closer than traditional geostationary satellites that operate at 35,786 kilometres. This lower altitude significantly reduces latency, allowing for faster data transmission.
2. Compact Design: Each satellite features a compact design that minimizes volume, allowing for a dense launch stack.

This design maximizes the number of satellites that can be deployed in a single launch.

3. Advanced Navigation and Communication: Custom-built navigation sensors survey the stars to determine each satellite's location, altitude, and orientation, enabling precise placement of broadband throughput.

Antennas: NGSO satellite typically use advanced Ku-band, Ka-band and E-band phased array antennas and multi-band antennas to provide high-bandwidth connectivity to users.

Efficient Propulsion and Power Systems: Efficient thrusters enable many NGSO satellites to raise orbit, manoeuvre in space, and deorbit at the end of their useful life. This technology ensures that satellites can be safely removed from orbit, reducing space debris.Dual solar arrays and high-capacity batteries provide power to the payloads, enabling faster on-orbit manoeuvres [6].

IV. USER HARDWARE AND INSTALLATION

NGSO user terminals typically use a compact, motorized dish designed for easy installation, featuring an aperture-coupled patch antenna optimized for efficient signal transmission. The dish uses advanced beamforming and phased array beam steering technologies to maintain a continuous connection with the rapidly moving LEO satellites.

V. DATA TRANSMISSION AND CONNECTIVITY

NGSO features include Low Latency, Continuous Connection and High Speed. Due to the lower orbit, NGSO satellites achieve significantly lower latency compared to traditional satellite internet services. Latency is around 25 milliseconds, compared to 600+ milliseconds for geostationary satellites. NGSO satellites promise high-speed internet connectivity with speeds up to 1 Gbps, making it suitable for activities like streaming, online gaming, and video calls. As one satellite moves out of range, another takes over, ensuring continuous connectivity. This seamless handover is facilitated by the dense constellation of satellites and advanced communication systems.

VI. GLOBAL COVERAGE

Rural and Remote Areas: Most NGSO constellations provide internet access to underserved regions, including rural areas, remote villages, and disaster zones. This connectivity is crucial for education, healthcare, and economic development.

Emergency and Disaster Relief Use: During the emergencies, NGSO terminals provided crucial internet access when traditional communication networks were disrupted, demonstrating the system's reliability in crises.

VII. BRIDGING THE DIGITAL DIVIDE IN DEVELOPING COUNTRIES

The digital divide remains a significant challenge, with billions of people lacking access to reliable internet services. In countries like India, where vast rural areas are underserved, NGSO technology offers a lifeline. By providing affordable and reliable broadband access, LEO constellations can help close the gap between those who have access to the digital economy and those who do not.

Education and Healthcare: Access to high-speed internet can revolutionize education and healthcare in rural areas. Telemedicine and online learning platforms can bring quality services to remote communities.

Economic Development: Reliable connectivity can spur economic growth by enabling digital entrepreneurship and access to global markets.

Government Services: NGSO technology can support government initiatives aimed at improving connectivity in rural and remote areas. For example, the Indian government has been exploring partnerships with NGSO operators to enhance broadband access.

VIII. CHALLENGES AND FUTURE OUTLOOK

While the potential of NGSO technology is vast, several challenges need to be addressed. These include regulatory issues related to spectrum sharing and orbital debris management. Additionally, the high cost of satellite launches and the need for ground infrastructure pose significant hurdles.

Regulatory Frameworks: Effective regulatory frameworks are necessary to manage the deployment and operation of NGSO constellations. This includes ensuring efficient and equitable

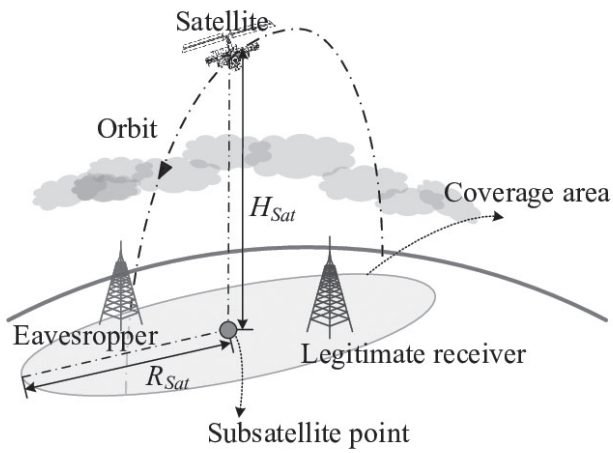

Figure 1. Model of NGSO satellite communication system.

spectrum sharing, mitigating the risk of orbital debris and collisions, and addressing concerns raised by the astronomy community.

Hybrid Systems: To leverage the strengths of both LEO and geostationary (GEO) systems, there is increasing interest in hybrid satellite networks. These networks use GEO satellites for high-coverage, low-bandwidth applications, and LEO satellites for high-bandwidth, low-latency applications.

Innovative Technologies: The development of new materials and technologies, including more efficient propulsion systems, lighter and more durable satellite components, and advanced communication payloads, is critical for enhancing the capabilities and lifespan of LEO satellites.

IX. CONCLUSION

NGSO satellite constellations, particularly those in LEO, are poised to play a crucial role in bridging the digital divide. By providing high-speed, low-latency internet access to underserved regions, these systems offer a powerful tool for connecting the unconnected. As technology advances and regulatory frameworks evolve, NGSO systems will continue to transform global connectivity, bringing the benefits of the digital age to every corner of the world. Governments and policymakers should consider how to leverage NGSO constellations as part of their broader strategies for expanding broadband access and promoting digital inclusion.

REFERENCES

[1] Hayder Al-Hraishawi *et al.*, "A Survey on Non-Geostationary Satellite Systems: The Communication Perspective", IEEE Explore, Vol.25, no.1, 2023, pp. 101 – 132.

[2] Tereza Pultarova, "Starlink satellites: Facts, tracking and impact on astronomy", https://www.space.com/spacex-starlink-satellites.html.

[3] A. Shaji George, "OneWeb: Revolutionizing digital connectivity in India", *Partners Universal International Innovation Journal*, Vol.1, no.4, pp. 72-97.

[4] Michael Koziol, "Amazon's Project Kuiper", *IEEE Spectrum*, Aug 2020.

[5] "Telesat Lightspeed", https://www.telesat.com/leo-satellites/

[6] Hayder Al-Hraishaw *et al.,* "Broadband non-geostationary satellite communication systems", *Proc. IEEE International Conference on Communications Workshops, 2021*.

Bharat Bhatia, FIETE is President, ITU-APT Foundation of India and Vice Chairman, World Wireless Research Forum (WWRF). He possesses over 45 years of experience in Public Protection and Disaster Relief (PPDR), Spectrum management and ICT policies and regulations. Earlier, he served as President of Telecom Equipment Manufacturers Association of India (TEMA) and Vice President of Association of Telecom Industries of Singapore (ATIS). He was a senior regulator with government of India for 22 years as a spectrum regulator and Telecom policy specialist and was actively involved in opening of the Indian telecom to the private sector, including the first ever GSM metro licensing in India. He was also a key architect of India's first ever National Frequency Allocation Plan (NFAP) in 1981 and the first ever published NFAP in 2000. Mr Bhatia holds a BE degree from University of Delhi in Electronics and Telecommunications and completed a number of management courses from various institutes and universities including National University of Singapore and George Washington University, USA.