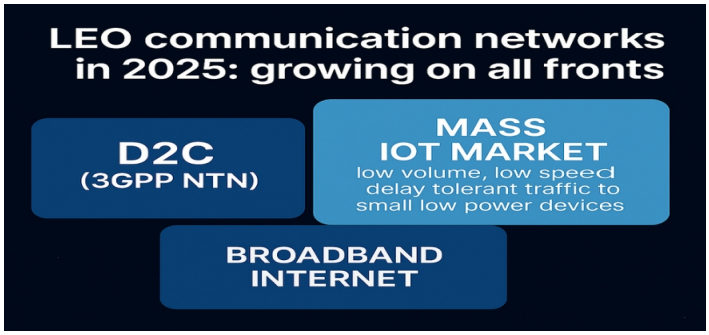

Low earth orbit (LEO) satellite communication networks are part of an emerging supply and demand market, complementing and competing with various terrestrial networks and higher orbit satellite networks. As with our previous articles, our focus is LEO with consideration of its fit in this bigger picture. We kick off with a brief backgrounder for new readers. Then we look at direct to cellular mobile (D2C), non-cellular satellite Internet of Things (IoT), and finish up with broadband satellite Internet.

BACKGROUNDER

LEO satellites orbit some 200 to 2,000 km above the earth. Typically traveling some 7 to 8 km per second, they are only visible from any given point on the earth for a few minutes. To enable continuous service, connections are continually handed off between satellites. For contiguous geographic area or global coverage, a "constellation" with hundreds of satellites are needed (and preferably thousands). Current generation LEO satellites have a typical operating life of 5 to 7 years (after which, the fuel to hold orbit runs low and the satellite must be deorbited safely). Clearly achieving and maintaining scale is a prerequisite to play in this game.

Like any sustainable business, we expect LEO networks to capture market demand at a price point where revenue exceeds cost by some acceptable profit margin. Beyond profit, new international LEO initiatives are being driven by governments desiring sovereign control of a strategic asset and to gain influence in developing markets (a long-term economic strategy).

Although the technology and market for LEO communication is proven (thank you Starlink), issues relating to scale remain, particularly for Starlink competitors. Specifically, there is a need for new LEO companies or consortia to capture a large enough market share to achieve economies of scale. Challenges to achieving scale include: (i) capital to fund the high cost of satellite constellations (manufacture and launch); (ii) spectrum availability and interference mitigation; (iii) national regulations for communication service providers; and (iv) international and national regulations for spectrum.

Our 2024 LEO update was through two market lenses: satellite to small user terminals and satellite for fixed broadband internet. We are seeing satellite direct to cellular mobile user equipment (D2C) technology being added to broadband in ernet satellites (i.e., Starlink). Fixed broadband terminals are shrinking in cost, power consumption and physical size and being used for nomadic and transportable applications (e.g., Starlink "Mini"). Today, demand probably splits better into: (i) D2C that is open-standards based (i.e., 3GPP's Non-Terrestrial Network or NTN specifications); (ii) mass Internet of Things (IoT) market for low volume, low speed, delay tolerant traffic to small low power devices; and (iii) traditional high-speed and high-volume broadband internet. Therefore, this year's review looks at each of these in turn.

DIRECT to CELL (D2C)

The technology necessary for handheld devices to have direct two-way communications with satellites is well established. The 3GPP Technical Specifications for Non Terrestrial Networks (NTN) makes this possible to standard cellular handsets. Mobile network operators (MNO) have been quick to see this as a complimentary service that instantly provides coverage everywhere, without the need to build expensive terrestrial infrastructure in remote areas. Today low-speed data for messaging and location-based services (like SOS) are available from multiple sources, with aspirations to provide voice and eventually video. The next generation of cellular mobile, 6G, is aiming to further advance NTN technology. Watch for the further emergence of models that partner MNOs and LEO network providers. There is a lot to do but interest is high, with lots of eyes on the prize. Here is concise overview of current players.

Starlink has taken an early lead in the D2C market through its hookup to provide T-Mobile's NTN T-Satellite (T-Sat) service [1]. The service uses a 5 MHz slice of T-Mobile's Band 25 spectrum (i.e., 1900 MHz PCS band). During the beta test period over 60 different phone models were used successfully and millions of user messages were exchanged. As of June this year, over 650 Starlink satellites had the T-Sat payload. T-Sat service became commercial on 2025-07-23 with 911 messaging, SMS (texting), MMS, picture messaging and short audio clips. Recently T-Sat added access to location-oriented apps including Google Maps, AllTrails, WhatsApp, Accuweather and X. In addition to T-Mobile customers, the service is available to AT&T and Verizon customers with a compatible phone for $10 per month. Most new phones sold in the last four years should be compatible. In Canada, Rogers Satellite service, which uses the same Starlink satellites as T-Sat, is currently in beta trials and provides text messaging and text-to-911. As the beta trials end, the service is expected to become available to compatible cell phones for CAD 15 per month, regardless of the customer's terrestrial cellular mobile provider [2].

AST SpaceMobile continues testing D2C messaging and voice calling over their five Block-1 Bluebird satellites (1.5 tonne behemoths with 64 square meter phased array antennas). In particular, testing with AT&T demonstrated the first voice over LTE (VoLTE) call via satellite using AT&T's spectrum and network core. Messaging, voice, low-bandwidth data and location services for first-responders has been demonstrated using AT&T-FirstNet Band 14 (700 MHz) spectrum. Voice calling included both cell phone and Mission-Critical Push-to-Talk (MCPTT) group calls. The results are encouraging, although handoff between terrestrial and satellite coverage remains a "work-in-progress" [3]. Next generation Bluebird satellites are expected to be even larger with 222 square meter phased array antennas. AST SpaceMobile's satellite program claims to be fully funded to orbit between 45 and 60 satellites by the end of 2026. This should deliver continuous cellular-based broadband service across the U.S., Japan, and parts of Canada and Europe. AST SpaceMobile has acquired priority rights to global S-band Mobile Satellite

Services (MSS) spectrum (frequencies in the range of 1980-2010 MHz and 2170-2200 MHz) and has leased North American L-band MSS frequencies [4]. These MSS bands are supplemental to SpaceMobile's main strategy of using their mobile network operator (MNO) partners' existing terrestrial spectrum, which requires separate national regulatory approvals. Currently, MNO partners include AT&T and Verizon in the US (for 850 MHz spectrum), Rogers in Canada, and Vodaphone in Europe.

Sateliot provides satellite based 5G NB-IoT service based on 3GPP Release 17 NTN specifications. Their market is wholesale satellite NB-IoT offered as a roaming extension for terrestrial MNOs. The company has 6 operational satellites (4 were launched in 2024). Funding commitments and launch agreements have been secured for an additional 5 satellites that are being manufactured for launch in 2026. The communication payload will support dual use (civilian and defense). The company has aspirations for a constellation of 100 satellites. The company claims to have contracted commitments worth approximately €270 million with over 400 clients across 50 countries [5].

Skylo provides Non-Terrestrial Network (NTN) service over a group of existing satellites direct to cellular devices that support 3GPP Release 17 NB-IoT specifications. Essentially, Skylo owns and operates the ground infrastructure that connects standard cellular devices to various LEO, GEO (geostationary earth orbit) and MEO (mid earth orbit) satellite networks including Viasat/Inmarsat, EchoStar, Ligado Networks and Terrestar Solutions. Current coverage includes US, Canada, Brazil, Europe, Australia and Japan [6].

Lynk Global is beta testing NTN text messaging to unmodified cell phones in several countries over 6 operational LEO satellites. Essentially, Lynk satellites are cell towers in orbit. The business model involves selling satellite network capacity to existing mobile network operators (MNOs). Current MNO partnership agreements cover some 60 countries worldwide. The satellites are in sun-synchronous orbit (SSO), inclined at 97°. This provides near-global coverage, including the polar regions. However, given the current small number of satellites, coverage is periodic, making message delay variable (up to several hours). Lynk's aspiration for a constellation of 24 to 36 satellites has suffered from a lack of capital. In 2025, SES and Intelsat announced investments in Lynk which should lead to additional satellites [7].

Iridium currently operates a constellation of 66 LEO satellites with global coverage using L-band spectrum. The primary service is voice, both telephone and push-to-talk, along with low-speed data to proprietary Iridium user terminals. The company is developing Iridium NTN Direct as a service that will be 3GPP Release 19 compliant for the Narrowband Internet of Things (NB-IoT) in Non-Terrestrial Networks (NTN), or NB-NTN for short. The service applies to 3GPP Release 19 compliant devices as long as the device is equipped with a chipset that includes Iridium's L-band frequency. In short, the service will not work with current smartphones and really targets emerging NB-IoT devices. How soon will that be? Well, Deutsche Telekom has an agreement with Iridium for roaming access to Iridium NTN Direct. A commercial launch is planned for 2026, with anticipated applications in international cargo logistics, smart agriculture, emergency response, and remote utility monitoring [8].

NON-CELLULAR SATELLITE IoT

Although D2C is a new and emerging technology, satellite Direct to Device (D2D) communications for low-speed data and IoT is not new. Iridium and Globalstar have been operating LEO constellations and serving the voice and low speed data markets for over 2 decades. Globalstar partnered with Apple for messaging service to Apple's iPhone series, and Iridium, as noted above, is going all-in for 3GPP NTN compliance. Clearly, the lure of leveraging the cellular mobile ecosystem is strong incentive to follow 3GPP NTN open-standards. However, there are some outliers worthy of mention. Some of these are identified next. How this market niche will evolve as NTN chipsets (e.g., Qualcomm/Edge Impulse), devices and services scale-up, remains to be seen.

Orbcomm was one of the earliest LEO satellite IoT network service providers, launching commercial services in 1998 [9]. Today they operate with about 31 LEO satellites, which are a mix of 1st and 2nd generation satellites. Orbcomm's LEO satellite technology is proprietary and implemented using a specific allocation for Non-Voice, Non-Geostationary Mobile-Satellite Service (NVNG MSS) in the Very High Frequency (VHF) band. Dual mode devices that access both cellular and satellite networks provide cost effective worldwide coverage. Orbcomm also provides IoT management software and analytics for remote asset tracking, monitoring, data analysis, reporting, and control.

LoRaWAN is an IoT communication technology supported and promoted by the LoRa Alliance [10]. Although originally and primarily a terrestrial IoT network technology, satellite implementations are supported. Players in the LoRaWAN satellite ecosystem include: Lacuna Space (provides direct-to-sensor communication with LEO satellites); EchoStar Mobile (provides a real-time bi-directional LoRaWAN network across Europe using a GEO satellite); and Plan-S (operates 10 to 20 LEO satellites currently for its Connecta IoT Network and has aspirations for expanding to 100 satellites or more). Terrestrial and LEO LoRaWAN networks use license-exempt Industrial, Scientific and Medical (ISM) band spectrum. LoRaWAN networks on GEO satellites use licensed S-band spectrum (1980-2010 MHz and 2170-2200 MHz).

Swarm Technologies is an interesting footnote. Swarm was founded in 2016 as a prospective LEO satellite IoT network provider [11]. The satellite network used a narrow slice of the VHF band, Semtech's LoRa® devices (not LoRaWAN) and a proprietary store and forward communications and network protocol [12]. Commercial service went live in February 2021 with 72 satellites. For about $5 per month per device, low volume data service (up to 144 kB per month) was offered to low-cost terminals (about $90 per terminal). A few months later, in July 2021, Swarm was acquired by SpaceX. In 2023, with about 150 satellites and hundreds of customers in 15 countries, SpaceX stopped new device sales and announced commercial service would wind down in 2025 as part of SpaceX focus on the star link D2C initiative.

BROADBAND SATELLITE INTERNET

Today, only Starlink and OneWeb provide commercial broadband internet service over LEO satellite. Starlink dominates the field, and although the top 8 LEO players and hopefuls have permission to orbit more than 50,000 future satellites, Starlink accounts for 12,000 of this future tally [13]. Although OneWeb is not a considered a competitor and has yet to make much of an impact on the overall broadband satellite internet market, Amazon's Project Kuiper may prove more impactful and may have potential to become a Starlink competitor. Other initiatives seem to be looking for high margin and non-competitive government contracts, where sovereignty and/or strategic advantage trump commercial concerns. Here is a quick look at the field.

Starlink absolutely dominates the satellite broadband internet market. Initial "Better Than Nothing Beta" service started in October 2020 to customers in the US and Canada that purchased a Starlink terminal and paid a monthly subscription fee. Today Starlink is available direct to consumers, through value-add resellers and to government and business subscribers. Terminals and plans are available for a range of customer types and use cases. Similar to all internet services, Starlink performance varies depending on a range of factors. This is particularly true for services with channel sharing (i.e., the Starlink spot beam capacity is shared by all active customers in its view). Ookla speed tests in June 2025 for the US showed the median download speed at 104.7 Mbps and upload at 14.8 Mbps [14]. Median delay (latency) ranged from close to 40 ms to over 100 ms in Alaska and Hawaii. Recently, rural communities have become a new target market. Given the traffic averaging benefits of larger groups of subscribers, Starlink will provide a "Community Gateway" with four radome sheltered antennas, providing a 99% uptime 10 Gbps symmetric service, all for $1.25 million to start and $750 thousand per month. We have so much information on the Starlink phenomenon, we are considering compiling a special briefing note just on Starlink. For now, here are the Quick Facts:

► Achieved positive net revenue in 2024.
► Gross revenue for 2025 forecast at $11.8 billion.
► Operational satellites ~8,460 (as of 2025-10-01); almost all of these use laser-based mesh network interconnections with 100 Gbps capacity for direct satellite-satellite communications.
► Plans for 12 to 14 thousand satellites with FCC approval for 7,500 satellites of these.
► Available in 130 countries and territories.
► About 6 million subscribers in September 2025 and forecasting 8 million subscribers by the end of 2025.

OneWeb is the other operational LEO satellite broadband internet provider. Although OneWeb struggled earlier with manufacturing and launch agreements and has been in and out of bankruptcy, they finally became operational over Europe and the US on 2023-03-25 with 36 satellites. Also in 2023, OneWeb merged with Eutelsat [15]. Today (2025) OneWeb has an essentially complete global constellation with about 630 satellites. OneWeb has targeted the business and government markets, with a focus on partnering with communication service providers. As an example, Orange signed with Eutelsat to resell OneWeb satellite service to support global enterprises [16]. This expands Orange's enterprise offering with wider coverage and improved resiliency. The service also pitches “sovereignty" for those with geopolitical and regulatory concerns about data and infrastructure control.

Project Kuiper is Amazon’s "initiative to provide fast, reliable broadband to customers and communities around the world, including in places that are currently unserved or underserved by traditional internet and communications options" [17]. The FCC approval requires half of Project Kuiper's 3,236 planned satellite constellation to be in orbit by mid 2026 – i.e., over 1,600. As of October 2025, there were 153 in orbit, suggesting the need for a time extension. Although commercial beta service was targeted to become available in 2025 [17] in up to five countries (US, Canada, UK, Germany and France), sometime in 2026 is more likely. Realistically Amazon may need until 2027 to 2029 to fully scale their constellation and ground network. Positive notes include financial backing and business commitments from Amazon and launch agreements in place with SpaceX, ULA, Arianespace and Blue Origin. A range of user terminals are in development, with a base model expected to cost under $400. Project Kuiper is currently the only initiative that has even a remote chance to eventually compete commercially with Starlink.

Lightspeed is Telesat's planned entry into the LEO internet market. With subsidy funding from the Canadian government, Telesat has a satellite manufacturing agreement with MDA Space and launch agreements with SpaceX (beginning in mid 2026). The planned 198 satellite constellation will provide global coverage with 78 satellites in near-polar orbit (1,015 km altitude) and 120 in inclined orbits (1,325 km altitude). Lightspeed is targeting government customers (including the Canadian Department of Defence) as well as internet service providers and mobile network operators backhaul [18].

China is actively pursuing at least three major, separate LEO communication satellite mega-constellation initiatives:
(1) Thousand Sails backed by the Shanghai Municipal Government and Shanghai Spacecom Satellite Technology (SSST) with plans for 15,000 satellites, some of which have already been launched.
(2) Guowang project by state-owned China Satellite Network Group (China Satnet) with plans for about 13,000 satellites, of which some test satellites are in orbit.
(3) Honghu-3 project by Hongqing Technology, a private-sector-affiliated company (that is partly owned by the launch company Landspace), with plans for about 10,000 satellites.

In addition to pure commercial imperatives, geopolitical tensions and sovereignty are undoubtedly driving these initiatives. LEO communication satellites are seen as a strategic tool for international influence (in support of China's Belt and Road Initiative) and for military command and control (to wit, Starlink's defence role in Ukraine) [13]. How these initiatives will evolve over time remains to be seen. China is known for successfully playing the long-game. Therefore, even though they are late to the party and currently building up launch capacity, expect significant outcomes.

IRIS², the Infrastructure for Resilience, Interconnectivity and Security by Satellite project, is the European Union's sovereign response to the current lead by Starlink (a US company) and to the potential emergence of China as a LEO juggernaut. Although subject to delays and changes as the project gets traction, there is a general consensus that something will emerge with launches in the 2030 time-frame.

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