Achieving Ubiquitous Broadband Access Through Next-Generation Non-Terrestrial Networks

Lawrence National Centre for Policy and Management

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Key Highlights

- High-speed Internet access remains limited in many of Canada's Indigenous, remote, and rural communities, risking increased socio-economic disparities if not addressed.
- Technological advancements in non-terrestrial networks (NTNs), such as Low Earth Orbit (LEO) satellites, offer a promising solution to broadband connectivity in areas where financial costs and geographic obstacles impede the deployment of terrestrial networks.
- Policymakers have the opportunity to unlock the connectivity potential of emerging NTN innovations by crafting a robust, flexible and future-oriented policy framework.
- Specifically, spectrum and interference policies must evolve alongside technological advancements to ensure competition and fair utilization of spectrum resources.
- Learning from global practices, regulators should ready themselves to: manage surges in licensing, address complex technical and policy issues, and effectively manage growth.
- Canada's expansive geography and sparsely-populated regions provide an unparalleled opportunity for NTNs to deliver connectivity to underserved communities, and over time, as the technology matures, bring ubiquitous broadband access, coast to coast to coast.

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Introduction

In recent years, commendable progress has been made in expanding high-speed Internet coverage across Canada. Yet, many Indigenous, remote and rural areas continue to lack broadband access with a minimum download speed of 50Mbps and upload speed of 10 Mbps (50/10 Mbps). The continued existence of this digital divide risks increasing economic disparities, especially as more digital applications are developed to provide essential services and enhance human capital.

While further efforts must be made to bridge the connectivity gap, a combination of rugged, inaccessible terrain, low population density and dispersion significantly limits the prospect of deploying terrestrial infrastructure in many non-coverage areas. Policymakers need to look for innovative solutions that overcome these obstacles to ensure equitable digital access for all Canadians.

Emerging technologies like LEO satellites and high-altitude platform stations (HAPS) offer new opportunities to tackle Canada's broadband challenges. These technologies are rapidly developing, with investments already flowing in globally. However, creating sustainable solutions around them necessitates significant advancements in telecommunications policies and regulation.

Key issues outlined in this brief revolve around spectrum management, encouraging investments, and fostering alliances to ensure security and space traffic coordination within the burgeoning landscape of NTNs. The governance of spectrum allocation and interference is a contested space, with the need for regulators to address technical feasibility tests to manage coexistence within NTNs and between NTNs and terrestrial networks. Another important priority is developing licensing terms that encourage innovation and allow new competitors to enter the market. A well-resourced regulatory body with simplified procedures is essential to keep pace with increasing NTN activities. The brief will highlight examples where regulators have been faced with these challenges.

Given NTNs operate across international borders, cybersecurity is paramount; Canada has to develop strong alliances to ensure the coordination across jurisdictions for standardized policies, monitoring and potential responses. Importantly, within Canada, collaborative efforts are necessary among regulatory bodies, service providers, and other stakeholders to drive reliable service delivery across Canada and innovation, which entails continuously evaluating and adapting the current regulatory policy and oversight to the rapid advancements in NTN technology.

This policy brief will first discuss the importance of broadband connectivity; then examine the limitations of existing options and explore new potential solutions; and finally identify policy gaps and offer policy directions to harness the potential of the NTN technologies in enhancing broadband coverage. Acknowledging that affordability stands as the second crucial pillar for broadband access, this brief will concentrate on the aspect of availability.

The relevance of NTN technology in Canada extends beyond rural Internet connectivity to potential nationwide mobile wireless access as the technology matures and becomes more cost-effective. Proactive investment and capitalization of Canadian expertise in this field are essential for maintaining a competitive edge in the evolving telecommunications landscape.

Why Broadband Matters

Broadband access is paramount for all Canadians, as it underpins many vital daily activities and is integral to a range of societal systems, including education, healthcare, and professional engagements.

The Rogers cable internet and cellular service outage in 2022 illustrated the gravity of our reliance on connectivity, revealing the breadth of impact across sectors.[1] The outage led to disruptions in emergency services, with Toronto Police Service warning that residents using Rogers services might face difficulties calling 911. Critical financial services like Interac reported disruptions, affecting debit transactions and impairing e-transfers. Large corporations, such as Walmart and McDonald's, were unable to process customers payments. Several hospitals were affected, including SickKids in Toronto, prompting the issuance of a Code Grey (infrastructure loss or failure).

Bridging the digital divide is a key focus of Canada's Ministry of Rural Economic Development, embodied in the aptly named Canada's Connectivity Strategy.[2] Tasked with monitoring the progress of this strategy, the Canadian Radio-television and Telecommunications Commission (CRTC - the national telecommunications regulatory authority), reported a rise in national 50/10 Mbps download/upload speed broadband coverage from 84% in 2016 to 93.1% in 2022[3] and the number of Internet non-users and basic users decreased by about 1.4 million between 2018 and 2020.[4] The Covid-19 pandemic accelerated the use of broadband with the shift to remote work/school and many companies formally adopting a hybrid work model.

Examining trends in First Nations reserve areas, for example, reveals that 50/10 Mbps coverage has been steadily increasing from 27% in 2017 to 50.1% in 2022.[5] Across rural communities, government and telecom sector investments have pushed 50/10 Mbps coverage from 37% in 2017 to 67.4% in 2022.[6] Despite increasing coverage to First Nations reserve, rural and Far North (57.5%) areas, these regions fall far behind the 93.1% national level (Figure 1).[7]

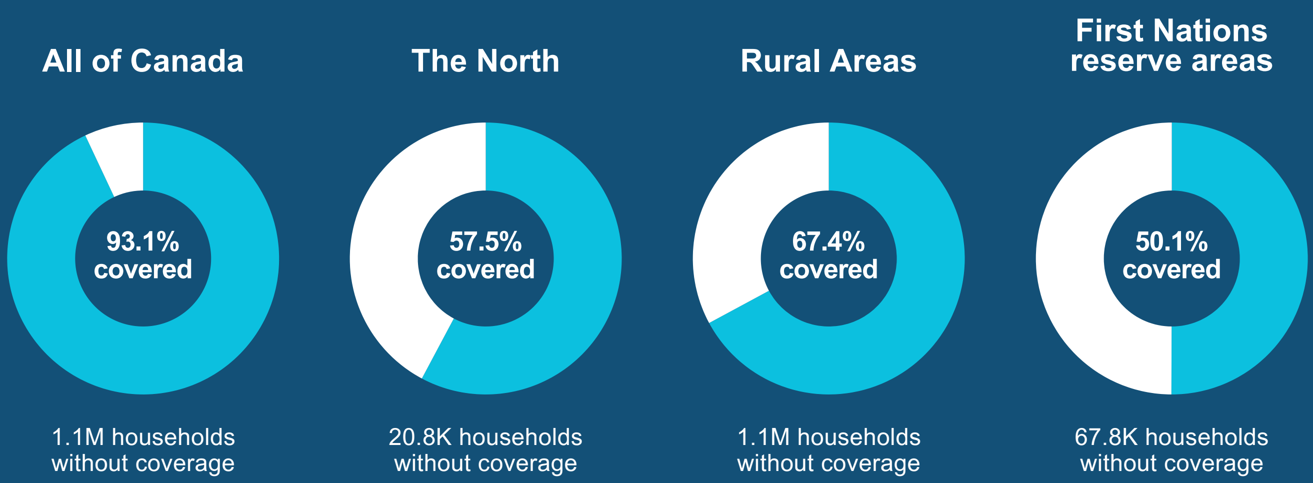
50/10 Broadband Coverage

> Leaving the digital divide unaddressed risks widening socio-economic inequalities between these regions and the broader Canadian landscape, especially as digital platforms continue to evolve and enhance quality of life and human capital development.

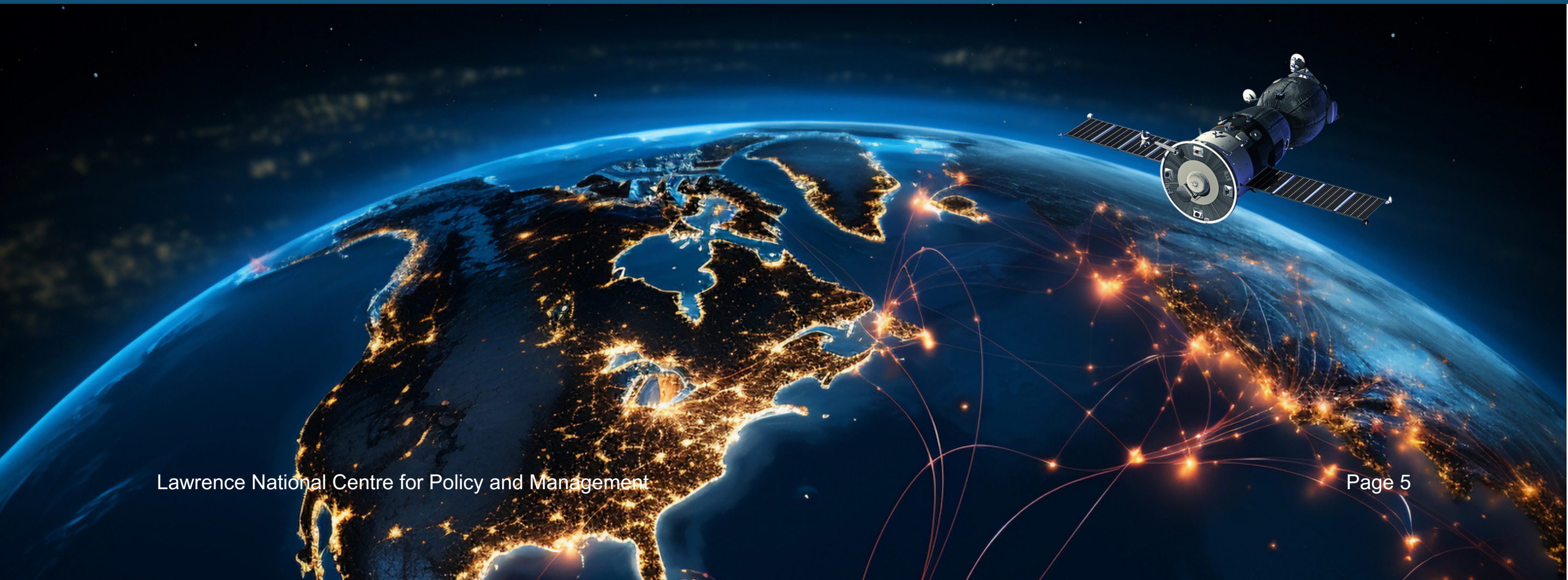
The potential benefits of extending broadband access to these areas are substantial, especially for the commonly isolated populations in northern Canada. Internet access could transform essential service delivery, such as healthcare and education, and unlock new economic possibilities. It can also carry critical cultural value, offering a means to preserve and promote Indigenous languages and traditions, enabling communities to share their heritage and knowledge globally.

Yet, the task of bringing broadband access to rural, Northern, and Indigenous communities is daunting. The challenge is twofold: the small, dispersed nature of these populations, and the rugged terrain, both of which present and compound logistical obstacles. Consequently, the provision and maintenance of connectivity infrastructure in these regions is a particularly complex endeavour.

FIGURE 1: Summary of total year-end 2022 50/10 unlimited broadband coverage



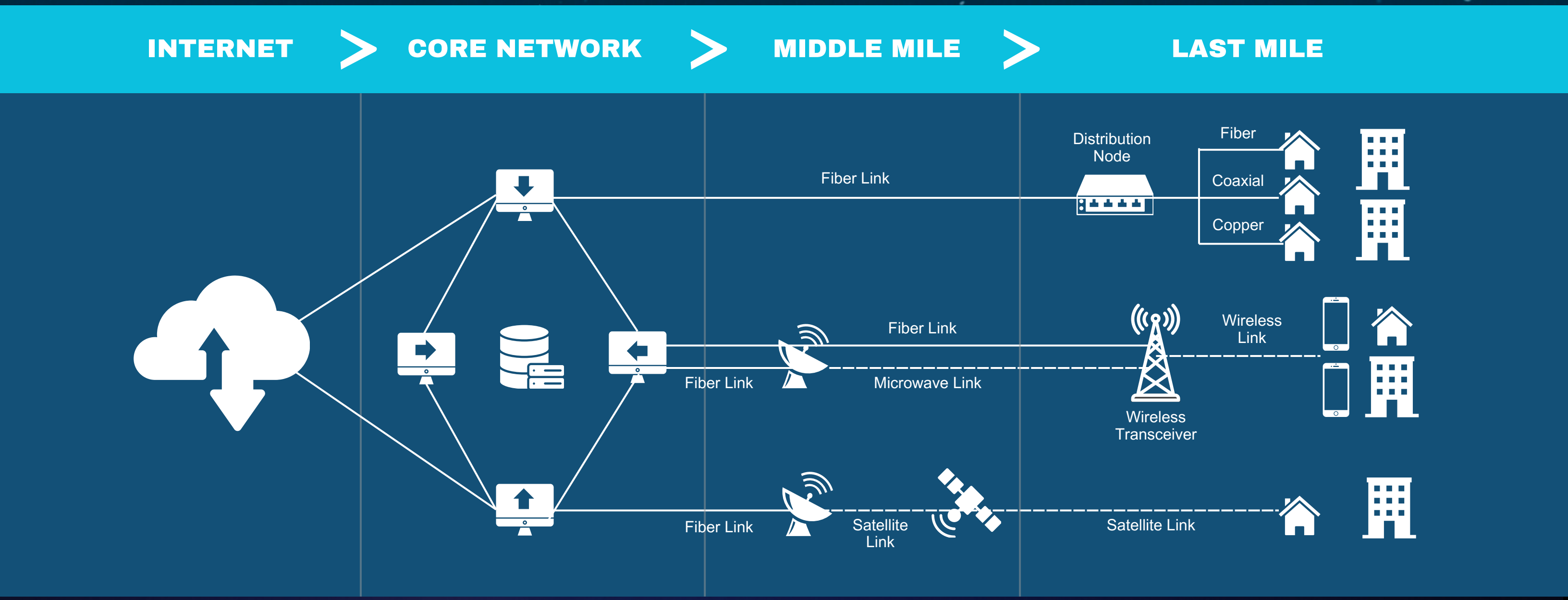
SOURCE: CRTC Communications Market Reports[8]



A Basic Overview of Current Network Architecture

To comprehend the barriers to broadband accessibility and potential solutions, it is essential to grasp the basics of existing telecommunications network architecture. Figure 2 illustrates the pivotal segments of a telecom network.

FIGURE 2:
Representation of network architecture showing delivery options for middle mile and last mile.



Conventional telecom network architecture is partitioned into three principal segments: the core network, the backhaul/transport network or 'middle mile,' and the last mile.

Core Network: Acting as the central processing hub, the core network ensures that communication, be it a phone call or Internet data, is seamlessly processed and directed to its destination.

Middle Mile (Backhaul/Transport Network): Pivotal in efficiently transporting communication data, the middle mile plays a crucial role in bridging the core network to the last mile. It has primarily employed terrestrial networks through infrastructure such as fibre optic cables and microwave transmission. Satellite links are also used, typically geostationary satellites, which have certain limitations. Recent advancements in NTNs, including LEO satellites and HAPS, offer opportunities to connect remote areas (see Figures 4 and 5).

Last Mile: The segment closest to end-users, the 'last mile' includes cell towers and the signals transmitted from these towers to user devices (e.g. smartphones, fibre or coaxial links that go directly to premises). This segment facilitates the direct interaction between the network and the end-user.

Terrestrial Network Deployment Challenges in Remote Areas

Telecom companies often hesitate to invest in infrastructure in regions with low population density and diminished expected ROI. The primary barrier in enhancing connectivity in underserved areas is often Middle-Mile infrastructure. The expansive distances between sparsely populated regions and metropolitan hubs housing the core network, compounded by rugged terrain, pose formidable investment challenges.

The Canadian Northern Economic Development Agency notes that northern regions, including Nunavut, Northwest Territories, and Yukon, cover nearly 40% of the country's land mass and host a population of about 114,000.[9] These metrics challenge the viability of models based on current network architecture. In comparison, London, Ontario, is an urban centre with a regional population exceeding 540,000 residents.[10] The vast Northern regions are nearly 9,000 times larger than London but have less than a quarter of the population, highlighting the stark contrasts in population density and urbanization between northern regions and urban centres.

Additionally, laying down fibre optic cables over such expansive, rugged terrain involves hefty installation expenses along with substantial ongoing costs for maintenance and repair, amplified by severe weather conditions and logistical complexities.

Microwave transmission is often considered as a wireless solution to bridge large distances. However, this technology comes with its own set of challenges when deployed in the Canadian North. Microwave transmission relies on a line-of-sight (LoS) connection between towers for signal transmission. The diverse and often challenging topography of the region, characterized by mountainous terrain, dense forests, and large bodies of water, can obstruct these LoS connections and impede consistent signal flow.

Remote regions lacking commercial power and roads also present logistical and financial challenges to building and maintaining a tower network, exacerbated by a limited potential user base, leading to high per capita operational costs for radio sites.

The geographical factors that complicate the development of the middle-mile infrastructure also impact the Last Mile. Deploying last-mile connectivity in rural areas, whether through cell tower construction for wireless services or fibre-to-the-home installations for broadband, also faces high financial hurdles. For instance, cell towers, require a connection to fibre optics or microwave links to function effectively, but establishing these connections means overcoming terrain and distance barriers. These costs are again magnified by the low population density, with towers serving fewer customers, diminishing the potential return on investment (ROI) for telecom providers.

Consequently, the dispersed population and challenging terrain in many Indigenous, remote, rural communities across Canada make for a poor business case to invest in terrestrial networks.

Deploying Terrestrial Network Using P3 Models and Community Involvement

In recent years, Canadian governments have been encouraging telecom operators to invest in bringing broadband services to underserved areas. One such strategy involves the implementation of public-private partnerships (P3 agreements), whereby the government partially fund capital costs, while private network operators assume the duties of deploying fibre optic cables or building cellular towers.

In 2021, Ontario launched the Accelerated High-Speed Internet Program (AHSIP), a significant P3 initiative to expand high-speed Internet access.[11] This program, managed by Infrastructure Ontario, collectively awarded over CAD 1 billion in provincial subsidies to eight Internet Service Providers (ISPs).[12] The goal of this funding was ambitious: to connect up to 266,000 homes and businesses in areas overlooked by ISPs because of the low potential for return on investment (ROI) and/or the extended payback periods necessitated by infrastructure development.

The ASHIP bidding employed a reverse auction procurement process (to encourage competitive pricing) that focused on specific geographic areas, each with its own requirements for high-speed internet infrastructure deployment.[13] The broad scope of telecommunications infrastructure work ranged from laying fibre-optic cables to building cell towers, tackling both middle- and last-mile challenges. This approach was designed to allocate resources to areas identified as most in need, targeting unserved and underserved homes and businesses in approximately 339 municipalities.[14] Furthermore, the initiative has extended beyond the basic requirements set by the funding; many ASHIP contractors have committed to self-fund additional last-mile infrastructure. These extensions, often near primary rollout areas, further bridge the coverage gap by expanding connectivity to areas outside the scope of the primary project.[15] The AHSIP initiative represents a significant step in reducing the digital divide and promoting equal access to digital resources across Ontario.

In 2023, a broadband project was initiated in the Nass Valley of British Columbia, home to the Nisg̱a'a Nation. Known for its remote and rugged terrain, this region had long faced challenges due to unreliable phone service along the roads connecting its four villages.

The project represents a unique convergence of efforts, where the middle- and last-mile connectivity are subsidized by both Nisg̱a'a and federal governments through Innovation, Science and Economic Development Canada (ISED).

Meanwhile, the technical expertise for the rollout is provided by TELUS, a leading telecom operator, and the ongoing maintenance and administration of the network are managed by Lisims Internet and Technology Services Inc., an Indigenous-owned ISP.[16] Supported by CAD 8.8 million from both the Nisg̱a'a government and the Universal Broadband Fund (UBF), this collaborative effort aims to extend TELUS' high-speed coverage to over 800 residential customers in the region.[17] A pivotal aspect of this project is TELUS' construction of cell towers in the region, which will significantly improve communication networks—and, as a result, safety—for the Nisg̱a'a citizens, visitors, and first responders.

This initiative is particularly noteworthy for its Indigenous-led dimension. TELUS is not only responsible for building the necessary infrastructure but also committed to empowering the Nisg̱a'a Nation by providing training in network technology. This training is designed to expand the capabilities of LITS and enable Nisg̱a'a citizens to maintain the infrastructure.[18]

Such cooperation of governments and communities with private players have become an important mechanism for middle- and last-mile broadband deployments where market-based initiatives are limited. They effectively bridge the financial gap between ISPs' investment thresholds and the capital expenditure (CAPEX) required, paving the way for more inclusive and widespread internet access. Despite these efforts, some remote areas still present significant investment hurdles, as the capital costs associated with deploying networks via fibre optics or microwave technology can be prohibitive.

Non-Terrestrial Network Solutions

New NTN options are emerging as promising solutions for coverage in remote and challenging areas, offering competitive alternatives. This section explores technologies enhancing connectivity in hard-to-reach locations, from traditional Geostationary Orbit to novel options like LEO and HAPS.

Geostationary Orbit (GEO)

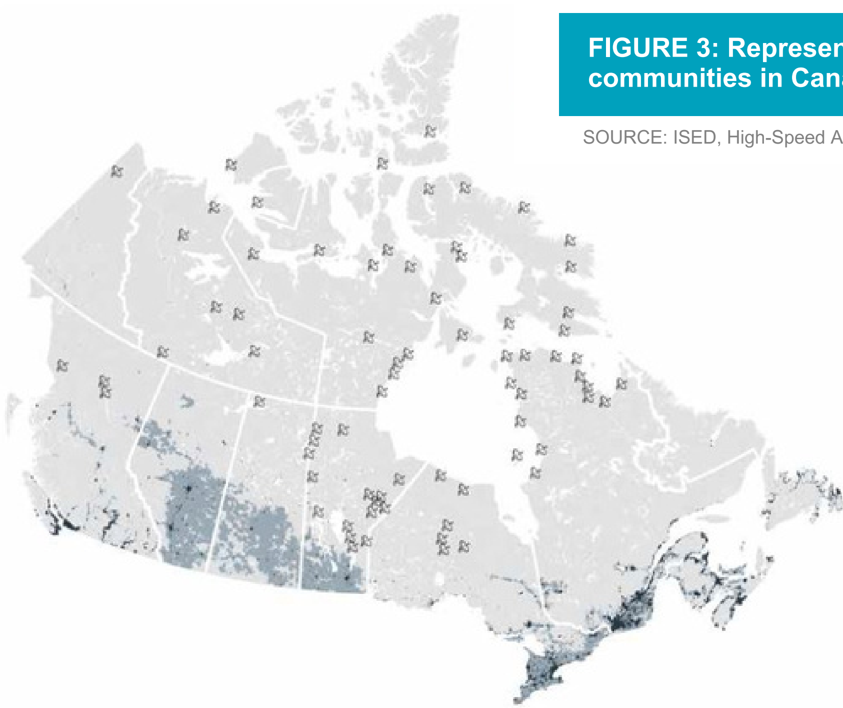
Historically, telecom operators have tackled this middle-mile backhaul challenge by turning to satellites to connect the last mile to their core networks. However, the satellites used in the past have operated in geostationary orbit (GEO) which means they remain in the same position relative to the Earth's surface (approximately 36,000 km). This distance results in prolonged signal travel times, significantly increasing latency (delays in network communications) compared to fibre optics and terrestrial microwave alternatives.

The most common implementation of GEO satellites is through a Direct-to-Home (D2H) model by providers such as Xplore Inc., predominantly serving users in low-density areas. (See Figure 3 for Satellite-dependent communities in Canada as of March 2019.) Another widely-adopted model involves direct-to-community aggregators, who then facilitate distribution to closely-knit communities through fibre-optic last-mile connectivity.

GEO satellites once pivotal for communications in remote areas, are now less suited for modern applications requiring higher bandwidth and lower latency. GEO latency can reach 600 milliseconds, far greater than terrestrial networks' 20 milliseconds. Although fractions of seconds might seem trivial, this high latency has a considerable impact on real-time applications: video conferencing and voice calls experience synchronization issues; real-time collaboration tools (eg. Google Docs and Microsoft 365) and telemedicine consultations face operational lags; and navigation and tracking systems might show outdated data. These latency effects compromise real-time response and the effectiveness of voice or data applications, adversely affecting user experience and hindering technology adoption. Despite the current use of GEO satellites, its latency and bandwidth limitations will not meet the demands of evolving use cases.

FIGURE 3: Representation Satellite dependent communities in Canada as of March 2019

SOURCE: ISED, High-Speed Access for All: Canada's Connectivity Strategy[20]



Low Earth Orbit (LEO) Satellites

A new generation of companies are addressing latency by launching satellites into Low Earth Orbit (LEO), between 300km to 2,000 km from Earth, which cuts latency to approximately 30 milliseconds – a 20-fold improvement. The lower altitude of LEO satellites necessitates them to travel at higher speeds to maintain orbit, completing a revolution in about 90 to 120 minutes, but also limits their coverage area. This constraint demands the deployment of many satellites—a “constellation”—for global coverage. In contrast, GEO satellites, positioned at a much higher altitude and effectively stationary to Earth (orbiting at a speed that matches Earth’s rotation), can cover about one-third of the planet’s surface with a single satellite.

SpaceX leads this category, having launched over 5000 satellites into LEO as part of its Starlink constellation.[19] Other active and planned players in the LEO space race include Oneweb, Telesat, Amazon’s Project Kuiper and AST SpaceMobile.

Low Earth Orbit (LEO) Satellites to Direct Homes

Currently, several LEO-based services, including that of Starlink, adopt a D2H business model, addressing the last mile and middle mile. They provide end-user customers with receiver dishes, roughly the size of a pizza box, to install in locations with an unobstructed view of the sky (e.g. rooftops, the ground) to establish a high-quality connection with the satellites, enabling Internet access.[21]

However, this solution is limited as connectivity is restricted to the receiver dish location (home, van, ship). Consequently, solutions enabling connectivity to mobile devices are also needed to grant users mobility while still enjoying broadband access.

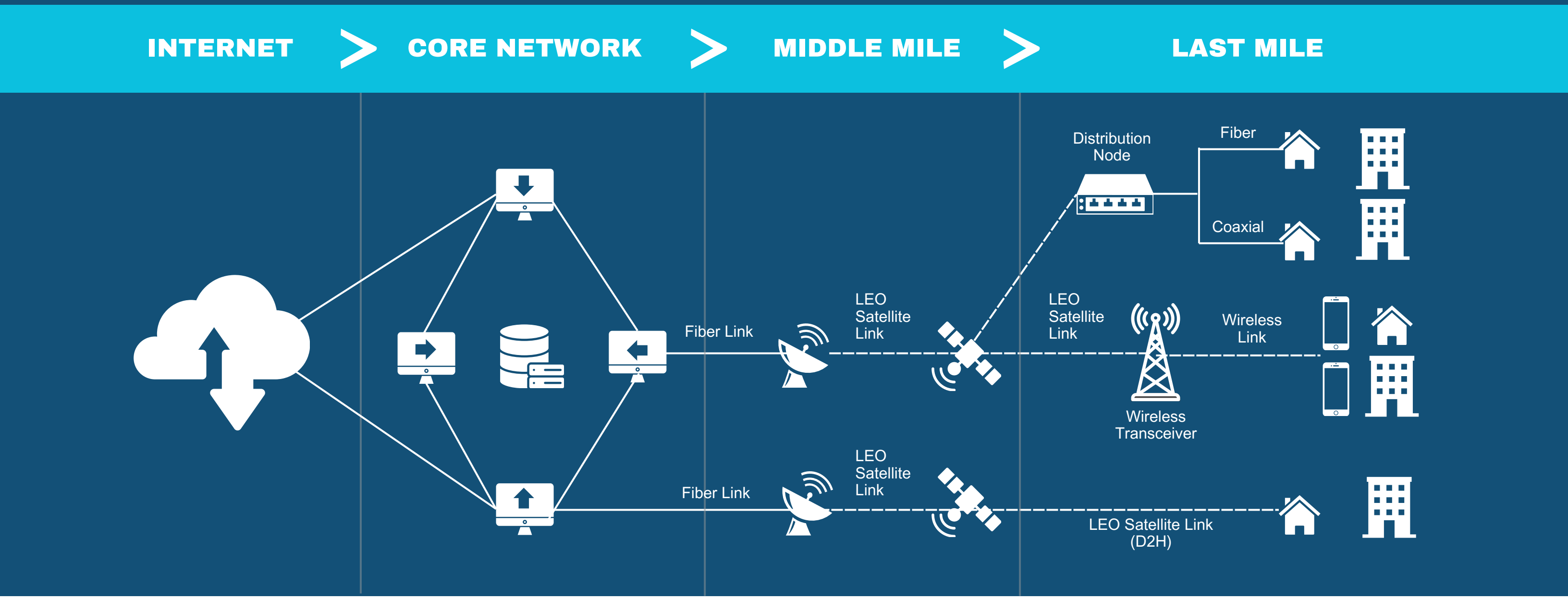
Low Earth Orbit (LEO) Satellites to Towers to End-user Devices

LEO satellites could be used to provide reliable backhaul services to telecom operators, like GEO satellites but with near-terrestrial latencies. SpaceX, Telesat, and OneWeb are a few of the operators poised to offer LEO services tailored for middle-mile connectivity solutions.

The Canadian government has taken a proactive step by spearheading a funding initiative to support Telesat in launching a constellation of 198 LEO satellites, aptly named the ‘Lightspeed’ project.[22] Telesat, a Canadian engineering firm with more than half a century of experience in operating GEO satellites, has partnered with MDA, another Canadian engineering firm known for its satellite construction expertise, to oversee the engineering design and construction for Lightspeed. These satellites, which will orbit at about 1,000 km from Earth, are planned to be launched by SpaceX.[23]

FIGURE 4:

Architecture with LEO wireless backhaul solutions (towers to devices) and Direct to home (D2H)



Importantly, unlike a LEO D2H service, Lightspeed's middle-mile architecture will consist of a fibre link to a landing station, which then connects to the LEO satellite for backhaul to a cell tower, creating a 'fibre in the sky' solution. The last mile to users could be through wired connections like fibre or coaxial cable for remote locations with dense communities, or wirelessly through fixed wireless access from the cell tower to user devices including phones and Wi-Fi modems for more spread out populations (see figure 4).

LEO backhaul promises to provide a cost-effective alternative to laying extensive fibre cables or installing microwave links. For telecom operators, LEO backhaul could serve as either a primary backhaul link or as a reliable backup to existing fibre optics, enhancing network resilience by reducing downtime due to fibre cuts.

Highlighting the significance of this development, the Government of Ontario committed CAD 109.2 million to secure 40 gigabits of broadband capacity on Telesat Lightspeed.[24] This capacity will be available for local service providers to purchase at reduced rates, demonstrating the government's subsidization of middle mile infrastructure to supporting enhanced connectivity solutions.

In South America, telecom providers facing terrain challenges similar to Canada are experimenting with replacing their GEO backhaul with Starlink.[25] This involves mounting Starlink receiver dishes on cell towers to connect these remote towers to the core network. Initial demonstrations show improved performance metrics compared to traditional GEO solutions.[26] However, Starlink's backhaul service offers a "best-effort only" service without guaranteed minimum bandwidth, which can be problematic for network operators who require consistent, high-priority backhaul capacity. This scenario highlights the need for solutions that balance improved performance with the reliability demanded by network infrastructure.

Since networks based on satellite backhaul depend on ground-based infrastructure for providing last-mile connectivity, their coverage is limited to the extent of the terrestrial network. Consequently, telecom providers still need to construct cell towers or lay fibre to premises to bridge the last-mile gap in order to bring mobile broadband access to those remote communities.

Low Earth Orbit (LEO) Satellites to End-user Device

> **Technology is continuously evolving, and new innovations are opening the door to a ground-breaking connectivity possibility: the direct communication between satellites and devices, including cell phones–direct-to-device (D2D).**

In early 2023, Qualcomm and MediaTek, the two leading mobile phone chipset manufacturers, announced the development of chips capable of facilitating two-way satellite communications directly to smartphones.[27,28] This led to a series of exciting announcements around D2D satellite usage, promising to provide seamless and omnipresent coverage.

Soon after, Apple introduced a satellite SOS feature for iPhone users, which enables users to send emergency messages when they are beyond the reach of cellular or Wi-Fi networks[29]. Enabled by a constellation of 24 LEO satellites operated by Globalstar, this service is currently limited to text-based communications.[30]

In April 2023, Rogers Communications stepped into this space by signing an agreement with SpaceX to introduce satellite-to-phone coverage in Canada[31] through use of Starlink's extensive LEO constellation paired with Rogers' national wireless spectrum. This satellite-to-phone service will work with existing LTE phones wherever they can see the sky, with no required changes to hardware, firmware or special apps. Initially offering coverage for SMS text, services are expected to expand to voice and data by 2025. In scenarios where traditional cell towers might be compromised due to natural disasters like wildfires or hurricanes, this type of service could act as a vital redundancy, thereby adding digital infrastructure resilience.

SpaceX announced that new satellites would be equipped with an advanced eNodeB modem, acting as a space-based cell tower; the first batch of such direct-to-cell enabled satellites launched in January 2024.[32,33] A lineup of global partnerships—T-Mobile in USA, Optus in Australia, One NZ in New Zealand, KDDI in Japan, and Salt in Switzerland—highlights collaboration as a means of effective spectrum leverage.[34]

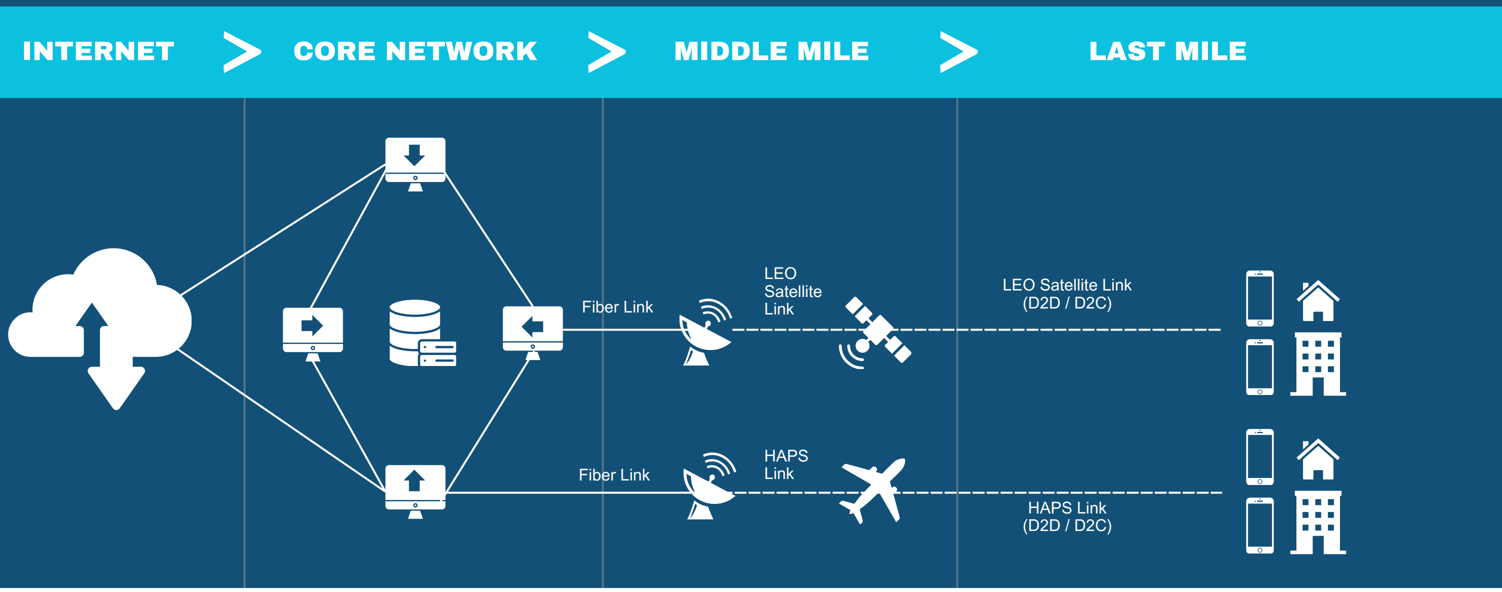
Bell Canada, through Bell Ventures, has invested in the LEO satellite sector, exemplified by its October 2022 investment in AST MobileSpace.[35]AST offers partnership with terrestrial network providers by utilizing their spectrum to offer D2D broadband services and middle-mile solutions, as demonstrated through AST's successful tests of 5G calls with AT&T in Hawaii[36].

In an another noteworthy development, TELUS announced the successful completion of Canada's first two-way communication test between smartphones and satellite.[35] Although this test exploited a GEO satellite connection, it showcased the potential for D2D to eliminate coverage gaps. It was conducted in collaboration with TerreStar Solutions and Skylo.

These developments suggest a promising future where satellite technology can be leveraged to ensure basic phone service across Canada, effectively eliminating no-coverage zones.

FIGURE 5:

Network architectures based on LEO satellites (D2D) and HAPs to directly connect to mobile devices and modems (Tower in the Sky)



HAPS: Balloon/aircraft to End-user Devices

High Altitude Platform Stations (HAPS) are aerial systems, including high-altitude balloons, airships, or powered fixed-wing aircraft, that are positioned around 20 kilometers above the Earth's surface in the stratosphere.

These systems are engineered for prolonged airborne duration, utilizing either solar power or an onboard energy source such as hydrogen for operation. While this innovative technology is in early maturity, various telecom companies are exploring HAPS as a frontier to deliver 4G and 5G signals directly from the stratosphere. Figure 5 shows networks that use LEO satellites or HAPs in the middle mile, which then directly connect to end-user devices, such as mobile phones or modems.

HAPS are a more responsive and efficient option than satellite-based services for telecommunications as they provide higher capacity and lower latency (10 milliseconds, compared to 30 milliseconds for LEO) due to lower operating altitude and smaller service footprint.

One of the most promising and advanced HAPS projects is Airbus Zephyr. In the summer of 2022, Airbus introduced a HAPS connectivity service business, establishing it as a standalone entity and marking a significant stride towards redefining the future of connectivity.[38] Zephyr is designed to function as a "cell tower in the sky," providing D2D low-latency 5G connectivity.[39] Furthering the development in this field, the Government of Rwanda and Hapsmobile, a subsidiary of SoftBank Corp announced a successful test of SoftBank's proprietary 5G communications system in September 2023.[40]

Canada's harsh, northern climate poses a challenge for HAPS, which typically rely on solar power, a source that is less effective at higher latitudes due to limited sunlight and low sun ray angles. HAPS using alternative energy sources, like Leichtwerk AG's hydrogen-powered StratoStreamer, may be better suited to Canada's environment.[41] However, perfecting hydrogen storage is crucial, due to complexities of deep cryogenic properties in its liquid state. Leichtwerk AG is developing a specialized tank for handling liquid hydrogen's unique storage requirements.[42] This highlights the need for innovative solutions to address the specific energy requirements of HAPS in diverse environments.

These HAPS technology developments may also complement other NTNs contributions in making promising strides towards 100% geographic coverage

Pros and Cons

NTN technologies, though promising, face several challenges. Varying levels of availability and functionality illustrate the diverse landscape of satellite Internet services and the ongoing development of these technologies.

D2H services such as Starlink are commercially available on a large scale, while middle-mile solutions like OneWeb are available but on a more limited scale and D2D options are also accessible, though limited mainly to text communication. SpaceX's D2D data and voice service is expected by 2025[43] and Telesat's Lightspeed, "fibre in the sky" offering, by 2027.[44] D2D and D2H will likely evolve to complement each other, with D2H for the high data needs of homes and businesses, and D2D for mobile connectivity and as a backup during network outages.

LEO systems, facing challenges like radiation and atmospheric drag, have a shorter lifespan (circa 5 years) compared to GEO systems (circa 15 years). Consequently, regular satellite replacement is essential to keep the constellation functioning effectively over the long term.

The operations of LEO satellite constellations are expensive, with major players typically not revealing the costs associated with manufacturing these satellites. SpaceX, which accounts for nearly 80% of all satellite launches,[45] primarily utilizes the Falcon 9 rocket for these missions. SpaceX has disclosed that each launch costs USD 67 million,[46] with a rocket capable of carrying an average of 23 Starlink satellites,[47] suggesting a launch cost of approximately USD 2.9 million per satellite. LEO satellites also have relatively short useful lives, necessitating replacement approximately every five years.

Ground stations, essential for providing Internet connectivity in this system, also require construction and operation investments. The financial commitment to LEO satellite operations appears substantial, underscoring the fact that engaging in LEO is a capital-intensive endeavour.

HAPS solutions have struggled with commercial viability. Google Loon was discontinued due to challenges in reducing costs sufficiently to build a sustainable long-term business.[48] Similarly, Meta (formerly Facebook) ended its HAPS project, Aquila, in 2018, choosing instead to collaborate with companies such as Airbus.[49]

Additionally, LEO and HAPS networks face limitations in quality compared to terrestrial networks. A significant challenge is indoor coverage for D2D offerings; both LEO and HAPS require a clear line of sight to the sky, making reception difficult without additional equipment.

These technologies vary in maturity, with terrestrial networks and GEO satellites being the most mature and HAPS Direct to Cell still in the prototype stage. Emerging technologies like LEO D2H, LEO D2D and Backhaul are promising but require further development and cost reduction.

Table 1 summarizes the advantages and disadvantages of these technologies, ranging from bandwidth capacity to infrastructure reliability and challenges in deployment and maintenance. This comparison provides insights into the diverse landscape of emerging communication technologies and their suitability for different applications and environments.

TABLE 1: **Comparisons of Existing and New Network Solutions**

SOLUTION	PROS	CONS	MATURITY
Traditional Terrestrial Networks	• High bandwidth and data rate capacity • Established, reliable infrastructure with widespread coverage in populated areas. • Lower latency within the network • Mobile coverage within cell tower coverage zones	• Expensive and time-consuming to deploy in remote or rugged areas • Susceptible to physical damage (e.g., natural disasters, vandalism) • Requires significant ongoing maintenance	**MATURE**
Traditional GEO Satellite	• Offers wide coverage area from a single satellite • Established technology with a long track record • Long operational lifespan, (approx. 15 years), due to stable orbital position	• High latency due to distance of GEO satellites from Earth • Limited bandwidth and data rate capacity • Susceptible to signal delay and interference, especially in adverse weather conditions	**MATURE**
LEO Direct to Home (D2H)	• Provides broadband access to remote areas without ground infrastructure • Much lower latency compared to GEO satellites • Scalable as more satellites can be added	• Requires end-user premises to have a receiver dish • Receiver dishes are relatively expensive • Mobility limited to location of receiver dish • Initial setup costs are high • Constellations require frequent replacements due to short operational lifespan (approx. 5 years)	**EMERGING**
LEO Backhaul	• Augments existing fibre networks, extending reach to remote areas • Reliable for areas where laying fibre is impractical • Can provide redundancy for ground networks' middle mile • Much lower latency compared to GEO satellites	• Still dependent on some ground infrastructure, cell towers for last mile • Initial setup costs are high • Constellations require frequent replacements due to short operational lifespan (approx. 5 years)	**EMERGING**
LEO Direct to Device (D2D)	• Extends cellular coverage to areas without ground-based towers • Enables mobile operators to expand their network footprint • Can provide redundancy for ground networks' last mile Much lower latency compared to GEO satellites	• Limited bandwidth and data throughput compared to terrestrial networks • Not usable indoors, requires mobile device view of the sky • Initial setup costs are high • Constellations require frequent replacements due to short operational lifespan (approx. 5 years)	**EARLY-STAGE**
HAPS Direct to Cell	• Offers a stable communications platform • Can provide coverage in a targeted area with less infrastructure than satellites • Lower latency compared to other satellites	• Limited by payload and power capacity • Solar energy source not suitable for Canada's latitude • Not usable indoors, requires mobile device view of the sky	**PROTOTYPE**

Policy Considerations

In the development of NTNs, it is vital to recognize Canada's unique position to become a global leader. Canada's vast geography, with sparsely populated rural and northern regions, presents an unparalleled opportunity for NTNs to connect underserved areas, addressing a critical national challenge. As NTN technologies mature and become more cost-effective, they hold the potential to bring ubiquitous national broadband access.

To unlock NTNs' potential, Canada must develop a robust, flexible and forward-thinking regulatory framework that addresses key areas including spectrum, regulatory capacity, as well as operational and security considerations (Figure 6).

FIGURE 6: Key areas of focus for NTN policy

	Spectrum	Competition	Operational & Security
Key Areas of Focus	• Minimize interference between Non-Terrestrial Networks and Terrestrial Networks • Need for service level agreements with NGSO providers for essential Canadian services	• Outdated regulations struggle to match the rapid pace of tech innovation • Growing NGSO projects overload regulators, leading to operator uncertainty and delays • Market initiatives may fall short of NTNs' capital needs	• LEO satellites span the globe and necessitate cross border co-ordination on issues like space debris managements • Cybersecurity threats across the various components of NTNs including satellites and landing stations
Policy Directions	• Flexible and adaptable regulatory approach • Dynamic Spectrum Allocation to resolve interference in real time • Weigh in on bandwidth capacity reservation and prioritization for Canadian use	• Regulatory bodies need to be adequately resourced to deal with tech innovation and overload • Conduct technical studies to assess the necessity of reviewing equivalent power flux-density (epfd) limits	• Establishment of a global space regulatory body to address issues such as debris management and cybersecurity standards enforcements • Expand CCSPA to explicitly apply to Non-Terrestrial Networks

1 Spectrum Allocation, Interference and Competition

Canada faces serious challenges in NTN spectrum management, highlighted by global disputes, necessitating vigilant, adaptive regulatory approaches. A critical aspect of NTN regulation is spectrum allocation management, which must balance fair access and minimize interference between NTNs and terrestrial networks.

An illustrative spectrum case emerged in 2021 when Dish Network sought FCC approval to use the 12GHz band for 5G services.[50,51]

Dish's submission included a technical study advocating the coexistence of 5G and LEO internet services within this spectrum, espoused by the '5G for 12 GHz', a coalition of 35 companies pursuing the same goal.[52] However, SpaceX challenged the proposal, citing potential interference issues with a study indicating that terrestrial 5G operating alongside satellite services in the 12GHz band could lead to frequent Starlink outages, affecting service in 74% of cases.[53] Ultimately, the FCC sided with SpaceX, deciding not to authorize high-powered terrestrial mobile service in the 12.2-12.7 GHz band already used by Starlink customer terminals for downloads.[54]

This dispute between Dish and SpaceX reveals the complexities of spectrum sharing between terrestrial and NTNs and illuminates the delicate balance regulators must strike between economic and public interests stemming from varied uses of the spectrum. It demonstrates the necessity for a regulatory framework that is not only informed and proactive but also flexible enough to navigate an evolving telecommunications landscape.

In addition to LEO and terrestrial networks disputes, interference regulations are at the centre of NTN tensions between LEO and Geostationary satellite operators (GSO), and featured prominently in an Amazon Kuiper and Viasat dispute. LEO operators, like Starlink and Kuiper, face stringent equivalent power flux-density (epfd) limits, with these LEO satellite power limits designed to protect GSO networks from interference.[55] Established under ITU's Radio Regulations Article 22 since the late 1990s, these limits are now deemed outdated by some who argue that innovations such as smaller, steerable spot beams, enhanced non-GSO (NGSO) constellation designs, and adaptive coding technologies have reduced GSO network interference risks.[56]

Amazon has spearheaded the Alliance for Satellite Broadband, advocating for epfd rule revisions, arguing they enforce unnecessarily large exclusion zones,[57] which limits the customer base of a single satellite, effectively restricting broadband capacity, increasing satellite counts and operational costs, and reducing NGSO innovation due to lower potential ROI. An Amazon study claims that revising epfd limits could boost a generic NGSO network's capacity by 181% and reduce satellite count by 28%.[58] A paper by former FCC chairman, Furchtgott-Roth, notes that reviewing epfd limits would lead to considerable consumer benefits, including reduced prices and a broader selection of LEO providers.[59]

However, GSO operators like Viasat and SES argue that interference is still a concern and argue that updating epfd limits is unnecessary for fostering NGSO competition.[60]

Slated for review at the 2027 World Radiocommunication Conference (WRC-27), the issue of epfd limits emphasizes the delicate balance between fostering innovation in NGSO constellations and protecting the integrity of GSO services.[61]

This ongoing debate underscores the complexities of regulating an increasingly crowded space environment, where regulatory frameworks are crucial to ensure a harmonious coexistence of satellite networks.

Innovation, Science and Economic Development Canada (ISED) recently updated national regulations for NGSO systems to address the emerging challenges and potential of commercial satellite constellations. These updates focus on efficient spectrum management, mandate 24/7 uninterrupted service coverage across 100% of Canadian territories (including remote and northern regions). They also require primary control facilities within Canada and mandate satellite capacity reserved for Canadian capacity needs,[62] a condition that applies to Canadian-licensed NGSO systems, not to international systems such as Starlink.

Canada's regulatory framework for NGSO systems is designed for operational flexibility to foster innovation and adaptability in satellite communications. However, this approach, which currently does not stipulate a specific capacity reservation for Canadian use, may benefit from refinements to ensure that this flexibility doesn't compromise the availability of adequate service coverage.

Introducing minimum bandwidth requirements could ensure baseline service in remote areas, with prioritized bandwidth allocation for Indigenous communities and critical functions such as healthcare and emergency response to keep essential services remain operational. This approach may conflict with net neutrality principles which advocate for equal treatment of all data without prioritization. Bandwidth reservation also diverges from the common regulatory practice of auction-based spectrum allocation and historic reservations have resulted in unused spectrum and inefficiencies.

Implementation of monitoring and enforcement mechanisms is crucial to ensure compliance with service standards and to hold providers accountable for maintaining consistent service levels. Dynamic allocation strategies could optimize available spectrum use, allowing for adaptation to changing demands and usage patterns. However, such regulatory obligations come with trade-offs: they might deter global investments into the sector, which could then necessitate government incentives to attract international players and private investments.

The elimination of coexistence assessments from the licensing process also raises interference concerns, highlighting the need for regulatory vigilance in these evolving domains.

These changes would require collaboration between regulatory bodies, service providers, and other stakeholders to balance innovation with reliable, high-quality service across Canada. It is then important to continuously evaluate and adapt the regulatory framework in the context of emerging challenges to ensure optimal, ongoing connectivity.

2 Regulatory Capacity

To effectively navigate the evolving satellite communications landscape, Canada must anticipate technological advancements and a surge in licensing demand, which could strain regulatory resources.

The U.S. House Commerce Committee recently introduced the Satellite and Telecommunications (SAT) Streamlining Act and Secure Space Act to foster competition and spur innovation in the commercial satellite communications industry.[63] These bills aim to modernize Federal Communications Commission (FCC) satellite licensing rules and encourage investment and innovation. The impetus for this legislation stems from the complex and slow current licensing process, in which operators have faced significant delays and approval hurdles for satellite constellations. This is compounded by the FCC's struggle to keep pace with rapid technological innovation, hindered by outdated rules that no longer align with today's market realities.

The FCC, responsible for authorizing and regulating the radio spectrum for U.S. communication systems, including satellite services, oversees processes for licensing NGSO and GSO systems. The increase in proposed and operational NGSO constellations has strained FCC resources, creating a regulatory bottleneck and consequent uncertainty and delays for operators seeking to launch or modify satellite systems.

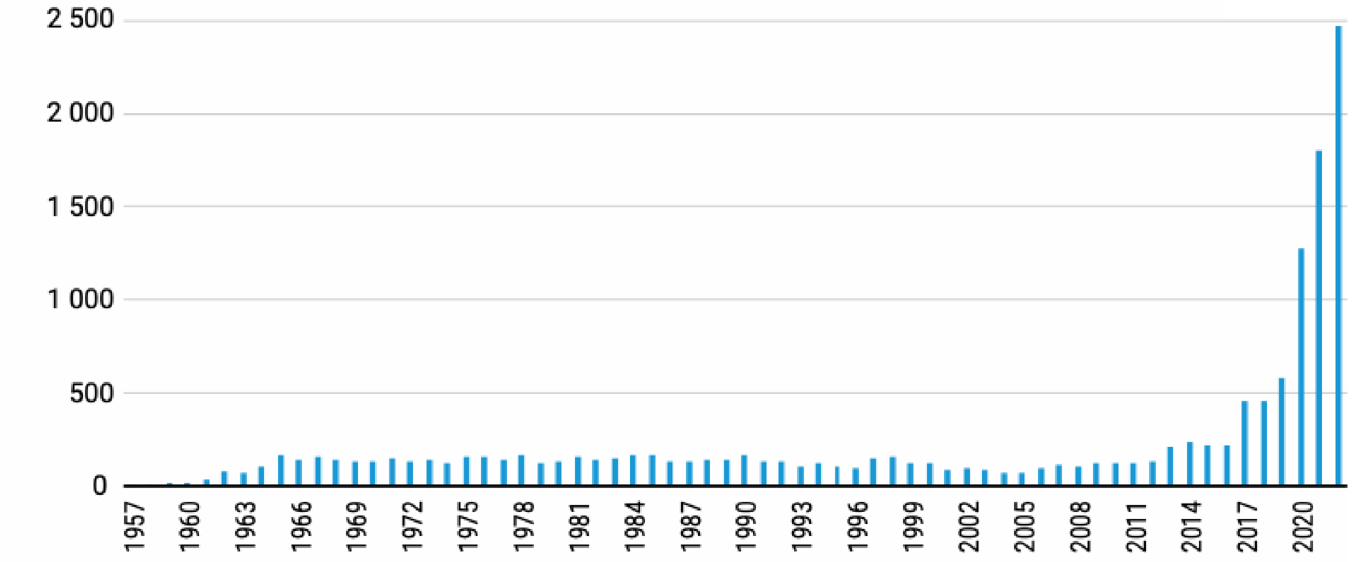
Figure 7 illustrates the number of satellites launched per year since 1957, the year Sputnik 1 was launched as the first satellite. The figure indicates a substantial rise in annual satellite launches began in 2017.

Addressing satellite licensing hurdles, the FCC introduced the Space Bureau in 2023 to lead policy and licensing for satellite and space-based activities, aiming to streamline regulations and ensure efficient use of spectrum and orbital resources.[65] This bureau is tasked with authorizing satellite and Earth station systems and liaising with federal agencies on space issues, which complements the legislative efforts with the SAT Streamlining Act. Furthermore, the FCC proposed licensing reforms in August 2023 aimed to modernize regulation to match the rapid evolution of the satellite industry through simplified licensing (including eliminating paper requirements) and innovation.[66] A new provision would also permit Earth station operators to secure a provisional license, streamlining the launch of setup for satellite services.

Canadian regulators can expect similar challenges to the U.S. with the growing interest in LEO satellites. It becomes increasingly important for Canadian regulatory bodies to anticipate a surge in licensing requests by ensuring regulators are adequately resourced. This capacity preparation will enable regulatory bodies to handle the growing volume of applications, address complex technical and policy issues of emerging technologies, and in the process, effectively manage growth while avoiding the obstacles experienced by the FCC.

FIGURE 7:
Satellites launched to space annually

2,470
2022



Source: United Nations Office for Outer space Affairs For all Humanity[64]

3 Operational Regulation

Telecommunications operational regulatory responsibilities are extensive, encompassing network resilience, data protection, consumer rights and privacy.

Canada needs clear cybersecurity regulations for NTNs to manage massive data flow and safeguard against cyber threats. Moreover, cross-borders regulatory coordination poses a significant challenge due to international 5G NTN services spanning multiple countries with disparate regulations. Key considerations include: space debris regulations that facilitate the responsible lifecycle management of satellites; effective management of space traffic; and addressing issues related to radio astronomy and light pollution.

Although Canada's Critical Cyber Systems Protection Act (CCSPA) proposed in Bill C-26 is based on terrestrial telecommunications, it has potential applicability to NTNs like satellite communications.[67] The Minister's power to issue binding cybersecurity directions and the potential classification of satellite infrastructure as "critical" under the CCSPA highlight this possibility. However, the absence of explicit mention of NTNs leaves room for ambiguity and potential overreach. Traditionally, legislation like the Telecommunications Act has adopted a technologically-neutral approach in the industry. To effectively address the growing importance of these networks, future iterations of the legislation could benefit from explicit provisions and definitions covering NTNs, ensuring clarity and a proportionate approach to cybersecurity regulations in this rapidly evolving area.

Regarding airspace regulation, civil aviation authorities typically govern airspace up to 60,000 feet (~18 Km),[68] while traditional air traffic control systems do not manage aircraft above this altitude, or to unmanned aircraft. In Europe, the U-Space system is proposed to manage Unmanned Aircraft Systems (drones), within controlled and uncontrolled airspace classes below 60,000 feet, but a unified approach is still in development.[69] There's an acknowledged need for Space Traffic Management above 60,000 feet, but it remains undefined to date. Consequently, HAPS operations must be coordinated with local authorities in the absence of a regulatory structure. As HAPS activity and usage increases, the demand for regulatory framework for operations above 60,000 feet becomes more pronounced, but concrete strategies have not been solidified.

For LEO satellites, the International Telecommunication Union (ITU) and the WRC, held every four years, play a crucial role in global oversight. Companies planning to launch satellites must first obtain approval from their national licensing authority, followed by an ITU clearance request to use specific radio frequencies, as governed by the ITU's Radio Regulations.[70] The ITU's primary focus is managing radio frequencies to avoid interference between satellites and other radio systems.

With a growing number of satellites in LEO, the issue of space debris grows too, stressing the need for a globally coordinated regulatory framework. Akin to the ITU's spectrum oversight, such a framework could offer a comprehensive and unified approach to regulating activities in space. A dedicated space regulatory entity would manage satellite trajectories and operational standards to mitigate the risk of collisions and minimize space debris. It would also develop and enforce international standards for satellite operation and decommissioning, paralleling the ITU's role in establishing technical standards for telecommunications. Furthermore, this entity would monitor compliance and facilitate global cooperation to address the challenges of space sustainability. This underscores the necessity for international collaboration, standard-setting, and regulatory oversight tailored to space activities.

Canada must take an active role in crafting effective operational regulations that address these specific challenges. By spearheading this effort, Canada can become a role model in responsible development and deployment of NTNs. This leadership will be instrumental in bridging the digital divide and ensuring that Canadians in all regions have access to the transformative power of NTNs.

Adopting the ITU's model for international coordination and regulation offers a robust blueprint for sustainable and safety of space activities, reflecting the critical need for a comprehensive approach to light pollution, radio astronomy, space traffic and debris management.

The Inter-Agency Space Debris Coordination Committee, which issues guidelines (not legally-binding) on best practices for space debris, serves as a prime example of the type of alliances necessary in this field.[71]

Furthermore, Canada's engagement in international NTN regulatory discussions is crucial. Active participation internationally and the development of strong alliances will enable Canada to influence the creation of a harmonized global framework that fosters innovation, facilitates cross-border connectivity, and promotes the sustainable use of space resources. This collaborative effort will help realize a future where NTNs become an integral tool for connecting the world.

Conclusion

Bridging the digital divide in Canada is multifaceted and complex, requiring a concerted effort across technological and regulatory fronts. The challenges in deploying traditional network infrastructure in remote and underserved areas underscores the need for innovative solutions such as NTNs. These NTNs, including technologies such as LEO-based satellite connectivity, offer a beacon of hope in regions where geographic and financial barriers have long impeded terrestrial connectivity. However, their deployment is not without challenges. Spectrum allocation, international regulatory coordination, and considerations around data privacy and cybersecurity are critical components that must be carefully navigated. Therefore, a flexible, regulatory frameworks that can adjust with the evolving telecommunications landscape is needed to address them.

The goal for Canada is clear:
to ensure that every community, regardless of location, has equitable access to the digital world. This commitment both bridges the digital divide and also fosters broader socio-economic development, improving the lives of all Canadians.

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