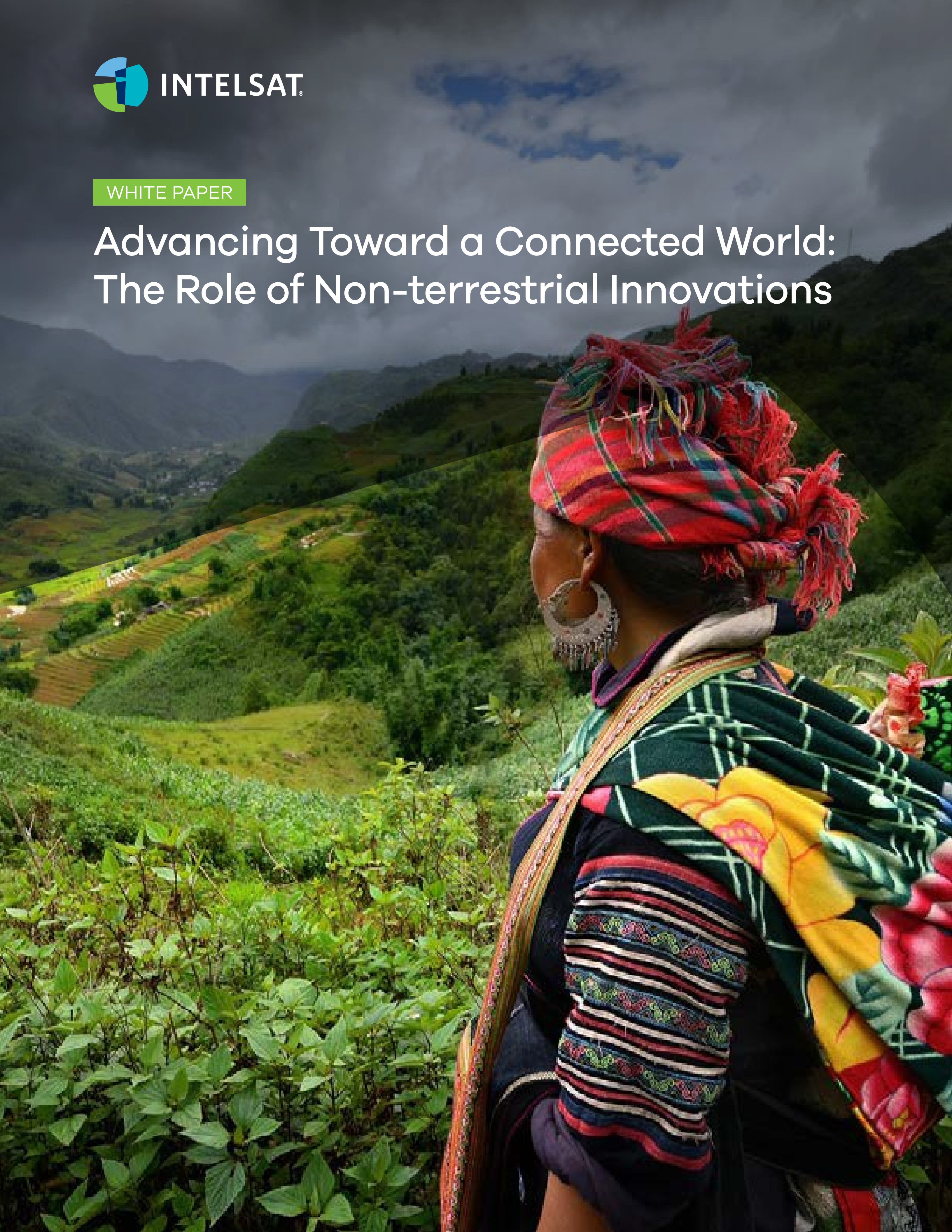
INTELSAT

WHITE PAPER

Advancing Toward a Connected World: The Role of Non-terrestrial Innovations



Introduction

The digital divide is the gap between people who have broadband access to the internet and those who do not. The resulting disparity in access to information and communication services contributes to social and economic inequality globally. Today, roughly half the world's population does not have internet access, which means about 4 billion people are excluded from the socioeconomic benefits of internet connectivity.

The human impact of the digital divide has been starkly revealed by the COVID-19 pandemic. When lockdown measures require people to remain at home for weeks or months, high-quality broadband services keep families connected and businesses, hospitals and schools running. But where reliable broadband is not accessible, children cannot attend online lessons, employees cannot work effectively, some people are disconnected from healthcare services, while social isolation exacerbates mental health issues.

Mobile broadband networks will be the primary means for getting the remaining half of the world online. However, given that just under 600 million people live in areas where there is no mobile broadband infrastructure and nearly two-thirds live in rural or remote areas, deploying mobile networks to eradicate the digital divide will continue to be difficult if relying on terrestrial backhaul alone.

For decades, satellite-based backhaul solutions have supported mobile network operators (MNOs) and internet service providers (ISPs) in connecting the unconnected by enabling rapid and cost-effective network expansion. Satellite technology is a vital component in MNO network planning strategies.

During the COVID-19 health crisis, satellite technology has been providing urgent capacity and connectivity. One such example involves the contributions to relief efforts by the EMEA Satellite Operators Association (ESOA). The organization said its members contributing to relief efforts in many ways, such as providing direct connectivity to keep people online, adding backhaul capacity for MNOs, broadcasting education channels for remote learning, supporting telemedicine services, and providing secure communications for emergency services.

This white paper presents the latest satellite innovations in space and on the ground and examines how these capabilities will strengthen the crucial role of satellite technology in closing the digital divide and contribute to the social and economic development of communities worldwide.

The Rural Dilemma

The digital divide affects every part of the world across low and high income countries, but it is most acute in rural areas where 60% of the unconnected population live.[1] Many of these rural communities are three or more hours from the nearest city. The further people are from urban centers, the harder it is to build mobile network infrastructure to reach them.

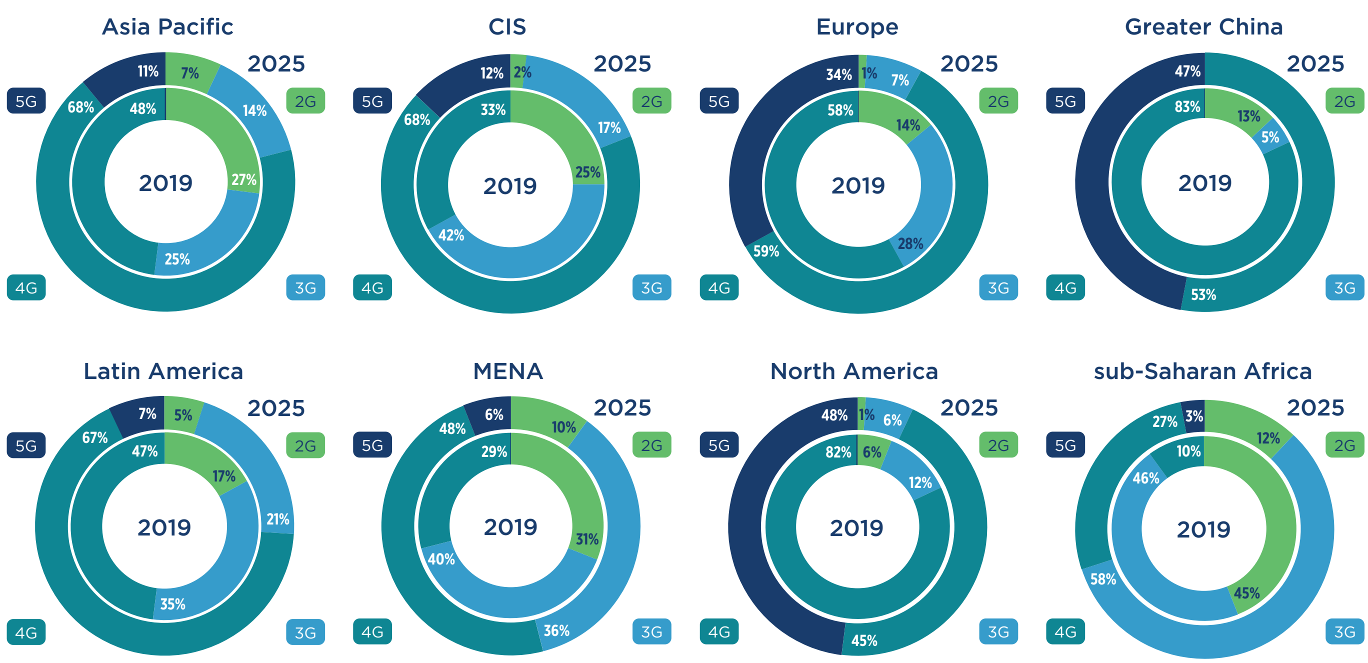
Of the world's unconnected population, just under 600 million people live in areas where there is no 3G or 4G mobile broadband infrastructure (the "connectivity gap"), while 3.4 billion live in areas that have 3G or 4G coverage, but they do not use the internet due to issues of affordability, consumer readiness, and lack of relevant content (the "usage gap"), according to the GSMA.

The region with the largest connectivity gap is sub-Saharan Africa, where 40% of the world's unconnected population live. Southeast Asia has a 16% connectivity gap, while the gap in the Middle East and North Africa is 11% and in Latin America it is 5%. In North America and Europe, the connectivity gap is just 1%.

A closer look at the coverage and population data for individual countries reveals the severity of the digital divide. In Ghana, 15% of the population is not covered by 3G services, which equates to 4.5 million people who do not have mobile broadband or internet access. In the Philippines, 7% of the population (7.5 million people) do not have 3G services, while in Argentina, 5% of the population (2.3 million people) lack 3G services.

By 2025, another 1.2 billion people will start using mobile internet services, bringing the total number of subscribers to 5 billion and increasing the global penetration rate to 61%, up from 49% in 2019, according to the GSMA. Figure 1 shows how the mobile technology mix is forecast to change in the next five years in different regions across the world.

FIGURE 1:
Mobile Technology Mix, Worldwide*

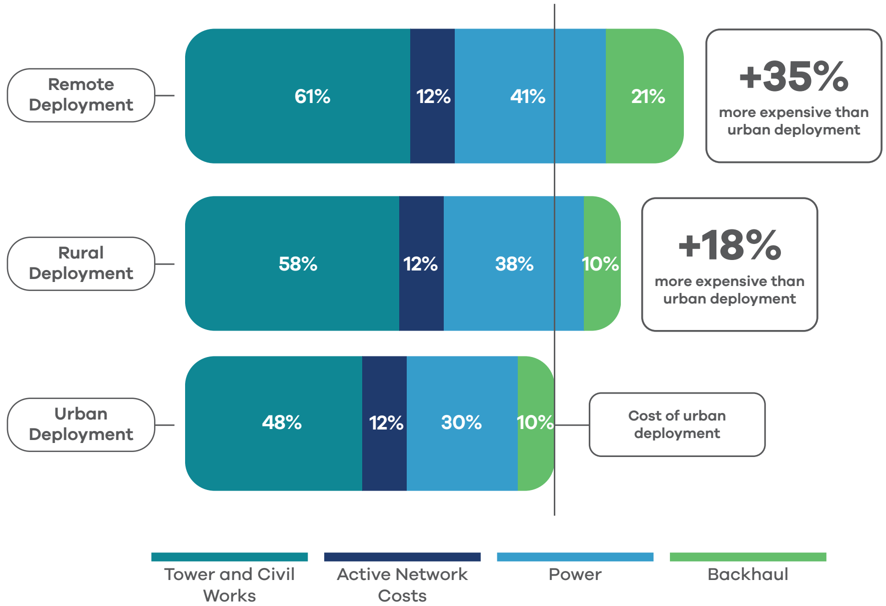


1 Intelsat, "Overcoming Barriers to Providing Mobile Coverage Everywhere," https://www.intelsat.com/wpcontent/uploads/2020/04/intelsatmobilecoveragewhitepaper.pdf
*Source: GSMA, "The Mobile Economy 2020"

Barriers to Closing the Digital Divide

The digital divide persists because there are many barriers to expanding coverage and encouraging usage. For the connectivity gap, where there is little or no mobile broadband infrastructure, the challenges are mainly economic namely, the high costs of deploying network and power infrastructure along with potentially low or slow return on investment due to low income and smaller subscriber densities (Figure 2).

FIGURE 2:
Annualized Cost of Mobile Coverage in Rural and Remote Locations (relative to urban), by Major Component*



To resolve the so called usage gap, where people have access to mobile broadband but are not using services, the GSMA cites three main barriers: many people live in low income areas and cannot afford mobile devices and services; people sometimes lack understanding or awareness of the internet; and the content available is not relevant to them (e.g., not in their own language).

Overcoming these challenges will take concerted efforts by public and private sector institutions (Figure 3).

FIGURE 3:
Everyone in the Mobile Ecosystem has a Role to Play in Closing the Digital Divide

Governments and Telecoms Regulators	Provide economic stimulus through funding, such as the $22 billion Rural Digital Opportunity Fund in the US or the £5 billion ($6.4 billion) Rural Gigabit Connectivity scheme in the UK. Encourage alternative deployment models, such as shared networks, and simplify site planning processes with local authorities.
Nongovernmental Organizations (e.g., UN, ITU, World Bank)	Provide funding and set high level goals, such as the UN's Road map for Digital Cooperation that calls for providing "universal, safe, inclusive, affordable internet access by 2030."
Multinational Corporations (e.g., Facebook, Google)	Use financial resources to invest in unique solutions to bring connectivity to more people.
Device Manufacturers	Produce smartphones, tablets and laptops that are affordable for people in low income regions.
MNOs	Leverage public funding opportunities and create new business models to expand coverage to rural populations.

*Source: GSMA, "The Mobile Economy 2020"

The Role of Satellite

From the launch of the first operational commercial communications satellite in 1965, Early Bird (Intelsat 1), to the more recent launches of Intelsat Epic high-throughput satellite (HTS) platforms, satellite is integral to connecting people, places, devices, and machines around the world. Satellite plays a vital role in providing affordable backhaul for mobile broadband networks, especially in rural and remote geographies.

Fiber vs. Microwave vs. Satellite

There are three primary means of backhauling cell sites for mobile coverage: fiber, microwave, and satellite (Figure 4).

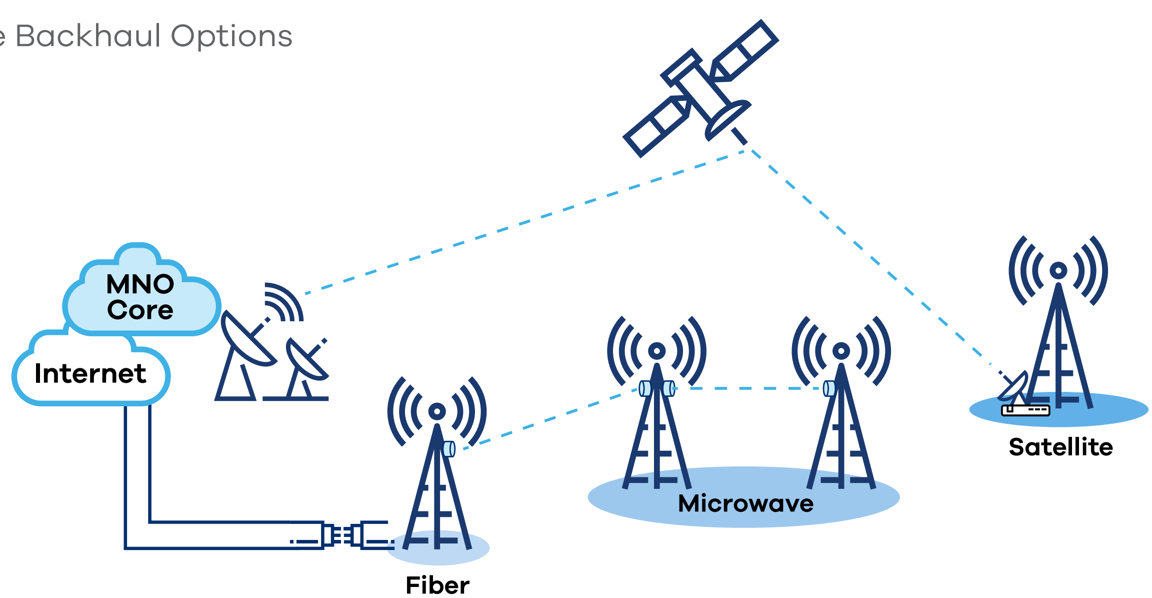
Fiber Backhaul. While fiber is certainly optimal for backhaul, it is not always ideal for building out mobile broadband coverage in rural areas due to high costs and long deployment times. The cost of fiber backhaul is determined by distance and the number of sites to be connected. Just 10 miles of fiber and conduit material can cost around $186,000, according to the U.S. Department of Commerce and National Telecommunications and Information Administration (NTIA). Trenching adds additional costs, especially in rural and remote areas where topography and geology add difficulty. Also, installation can take up to a year or more to cover just 10 miles.

Microwave Backhaul. Microwave backhaul is also not always ideal for rural areas mainly due to line-of-sight restrictions. In mountainous regions or areas with geographic obstacles, multiple microwave stations must be built to ensure line-of-sight, which increases costs and deployment time. One complete microwave relay system (which includes 2 transmitters, 2 receivers, 1 cabinet, 1 generator, 1 battery backup, and a 75 foot tower) can cost on average $70,000 for rural and hard to reach areas, according to the U.S. Department of Commerce and NTIA.

Satellite Backhaul. Satellite provides another way to backhaul cell sites for mobile broadband coverage but is often perceived by mobile operators as a last resort, based on historical experiences. However, advances in satellite technologies, coupled with the availability of professional services, address these operator concerns. Cost-effective, high-performing, fully managed satellite backhaul solutions are available today that enable mobile operators to rapidly deploy 3G, 4G, 5G or even Internet of Things (IoT), in any location.

In addition to rural deployments, satellite backhaul also provides backup solutions in any location in the case of outages on fiber backhauled networks.

FIGURE 4:
Cell Site Backhaul Options



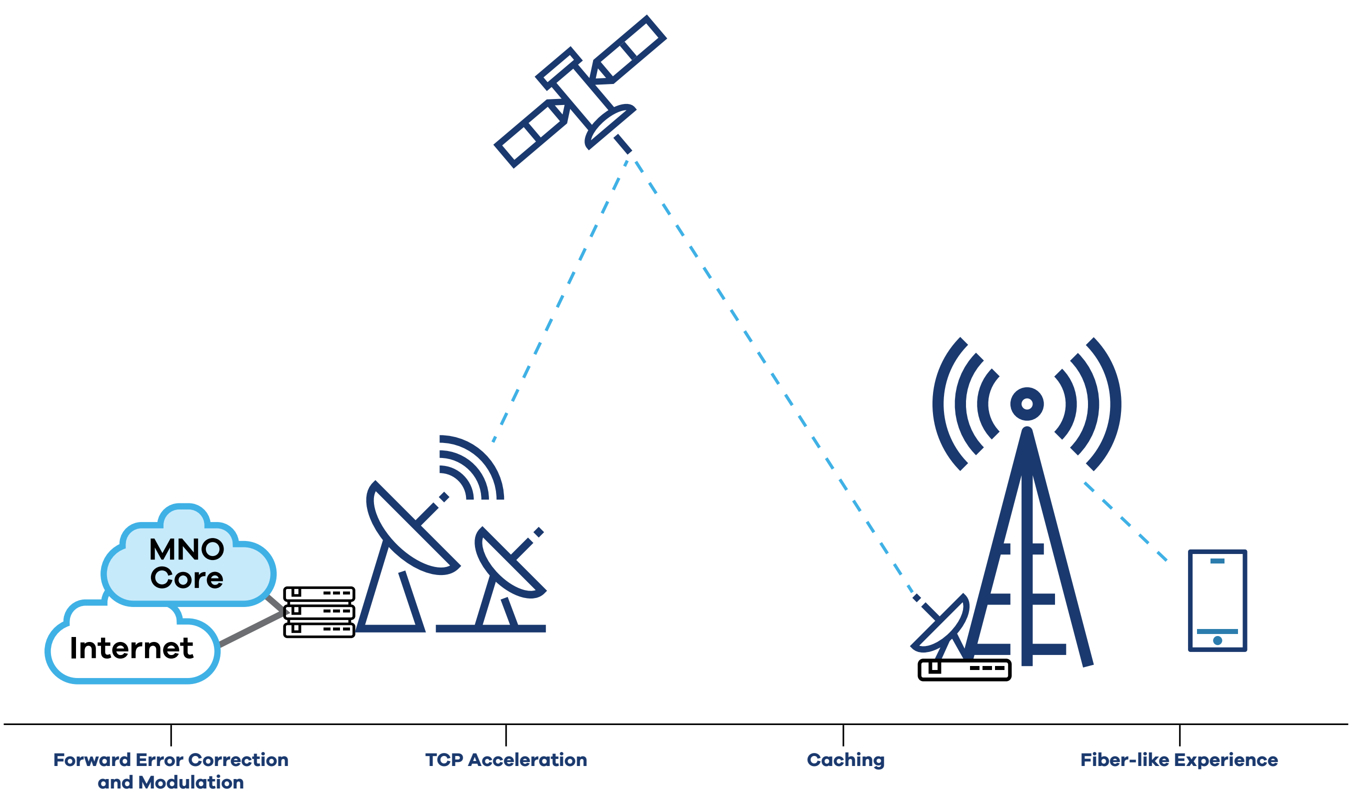
Advantages of Satellite Backhaul

Ubiquitous coverage. Geostationary satellite networks like Intelsat's cover 99% of the world's populated areas. Unlike fiber or microwave backhaul, satellite is not constrained by distance, topography or line-of-sight. Mobile operators can quickly backhaul an entire network of sites and not just one site at a time.

Minimal CAPEX. Since the requirement for satellite equipment at cell sites is minimal, the cost of satellite backhaul is mostly OPEX, which is determined by the amount of bandwidth required to support a network of cell sites. A single pool of satellite capacity can provide backhaul to multiple cell sites based on average usage per site, while also supporting peak usage.

QoS and reduced latency. Today's satellite technologies meet quality of service (QoS) requirements and enable MNOs to provide a fiber-like experience to their customers. While there is inherent latency in satellite, especially geostationary orbit (GEO) satellites, innovations in satellite ground technologies minimize the impact of latency on the end user. For example, forward error correction, TCP acceleration and caching optimize throughput performance over satellite connections, improving overall data speed while minimizing the effects of latency (Figure 5). Specifically, forward error correction reduces processing delays related to errors in the transport of data packets. TCP acceleration speeds up underlying communication protocols. Caching temporarily stores web page data so that users can access data locally rather than from a central location where requests take longer to traverse the network. Caching not only enhances the user experience through faster web page loading, it also reduces the demand for bandwidth during peak hours.

FIGURE 5:
Satellite Technology Meets MNO QoS Requirements

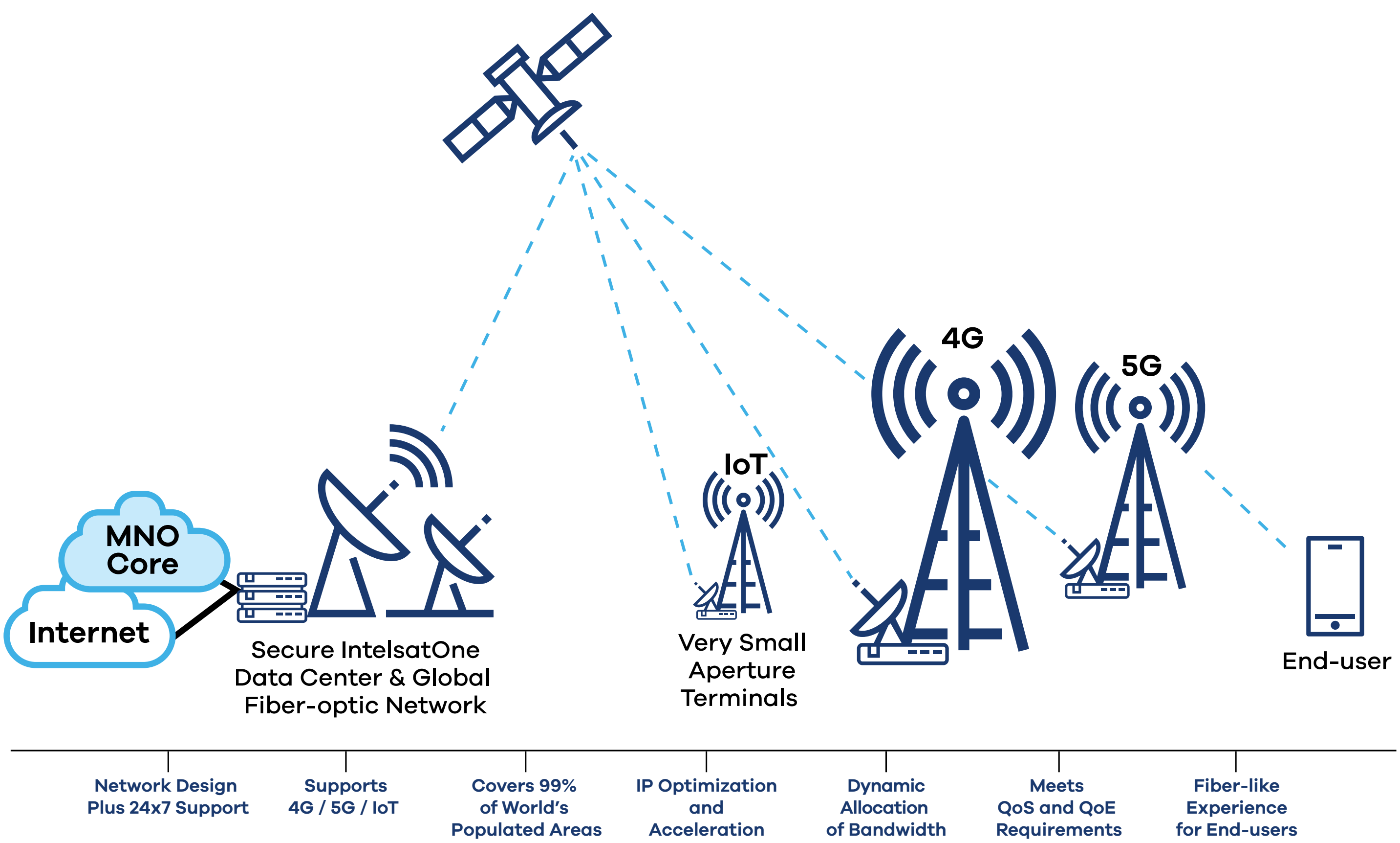


Managed Satellite Backhaul Services

If MNOs prefer to outsource setup and management of satellite backhaul links, Intelsat, the world's largest satellite operator, provides a fully managed, turnkey backhaul service (Figure 6). This means providing end-to-end management of the satellite backhaul, from the Earth-based ground stations, data centers, and fiber network across the globe, to the satellite in space, down to the antenna and modem located at each cell site, and back again, with guaranteed service level agreements.

The managed service helps MNOs by reducing the hassle of hiring, training, and equipping satellite experts within their own organizations, enabling them to instead focus their resources on business priorities. Intelsat's turnkey service includes access to a global space and terrestrial network that mobile operators around the world rely upon, as well as satellite and mobile telecommunications industry experts who provide consultation and assistance during the network design phase.

FIGURE 6:
Intelsat's Fully Managed Backhaul Service



AMN's Innovative Model

Tower company Africa Mobile Networks (AMN) started a unique revenue-share model that allows MNOs in sub-Saharan Africa to bring connectivity to ultra-remote communities.

AMN provides MNOs with a lowcost cell site solution consisting of a highly reliable, small cell solar-powered system that can be rapidly deployed in less than six hours. Utilizing Intelsat's satellite network, AMN enables mobile operators to bring mobile coverage to millions of people in sub-Saharan Africa for the first time, including remote communities in Cameroon, Liberia, Nigeria and Zambia.

Real-world Connections

Satellite backhaul is often the only practical and cost-efficient means for providing life-changing connectivity in rural or hard-to-reach areas.

For example, a leading mobile operator in Japan planned to expand 4G, and eventually 5G, coverage to the most hard to reach areas of the country and needed a backhaul solution to connect thousands of remote cell sites. Japan consists of several thousands of islands, with more than half of the country covered by mountains and forests. It also experiences frequent earthquakes, which can lead to lengthy disruptions of mobile services if fiber becomes damaged.

Intelsat provided a fully managed, end-to-end satellite backhaul service that enabled the MNO to provide 4G coverage in all their rural site locations. The solution included network design consultation, a dedicated managed services team, as well as a network operations center (NOC) located in Japan providing 24/7 support.

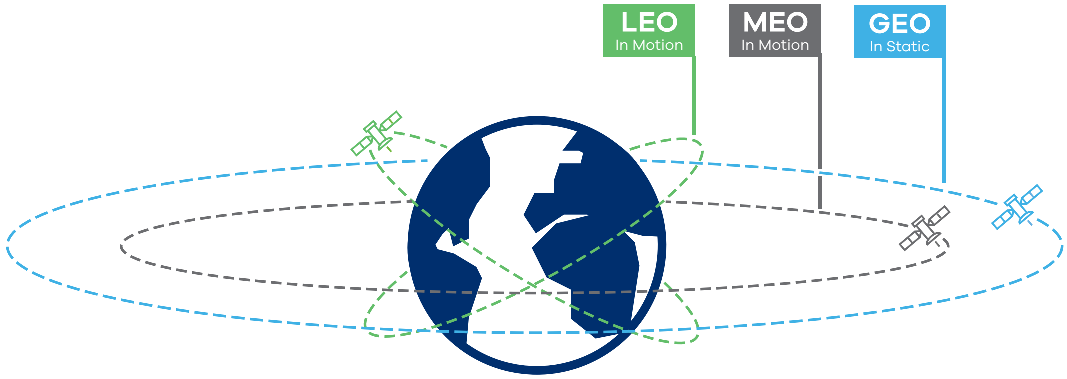
In Uganda, 75% of the population lives in rural areas. A leading operator in the country worked with Intelsat to expand mobile coverage into remote off grid communities, utilizing solar powered small cell base stations backhauled over Intelsat's network.

Satellite Innovations for Today and Tomorrow

Satellite technology has come a long way since the launch of Early Bird (Intelsat I). Satellites today can operate for 20 years, or longer, given recent advances in life-extension services, such as Mission Extension Vehicle (MEV) technology. Intelsat collaborated with Northrop Grumman on the first such life extension mission involving two commercial satellites in geosynchronous orbit, docking MEV-1 with Intelsat 901 in February 2020.

Recent innovations, and many on the horizon, make satellite technology essential for helping to connect the world quickly, efficiently, and cost-effectively. Indeed, there is no way to connect the people, businesses, and IoT devices located in rural and hard-to-reach areas without satellite technologies.

To put the latest innovations into context, it's important to understand the systems that operate in different satellite orbits: geostationary orbit (GEO), Medium Earth Orbit (MEO), and Low Earth Orbit (LEO).



GEO
Geostationary Orbit

GEO satellites are synchronized with the Earth's rotation 36,000 km above the equator. Few satellites are needed to provide ubiquitous coverage. Intelsat's network, for example, covers 99% of the world's populated areas. Given the "fixed" orbit, GEO satellites do not require expensive antennas that track the satellite's motion, making ground antennas easier to install and manage. The satellites are ideal for cellular backhaul applications because GEO coverage is ubiquitous, and bandwidth can be dynamically distributed to multiple cell sites. As noted in the previous section, latency is mitigated by ground technologies.

MEO
Medium Earth Orbit

MEO satellites operate below GEO up to 20,000 km above Earth and are mostly used for navigation applications, such as global positioning systems (GPS). Orbiting the Earth between two and 24 hours, more MEO satellites are required to cover the entire globe compared to their GEO counterparts. MEOs also require ground-based satellite antennas to track the motion of the satellites.

LEO / SMALLSATS
Low Earth Orbit

LEO satellites are positioned at lower altitudes up to 1,600 km above Earth, which means they can have stronger signal strength, less delay and smaller coverage areas, compared to GEO and MEO. They are typically deployed in large constellations to provide broad coverage because each LEO satellite only covers an area with a radius of about 1,000 km.

Well-known technology companies like Amazon and SpaceX are among the thousands of LEO SmallSat launches planned over the next decade, which has raised awareness and optimism about the systems' potential to fill connectivity gaps.

However, there are many unknowns and challenges regarding the promises of LEO constellations as a cellular backhaul solution for connecting the unconnected, especially with respect to cost, complexity, and return on investment.

While LEO provides better signal strength and lower latency, the constellations are more CAPEX intensive because so many more satellites are required for broad, uninterrupted coverage. Also, because LEO satellites orbit the Earth quickly, the business case requires new ground equipment and antenna technology, such as electronically steered flat panels, which are costly and complex.

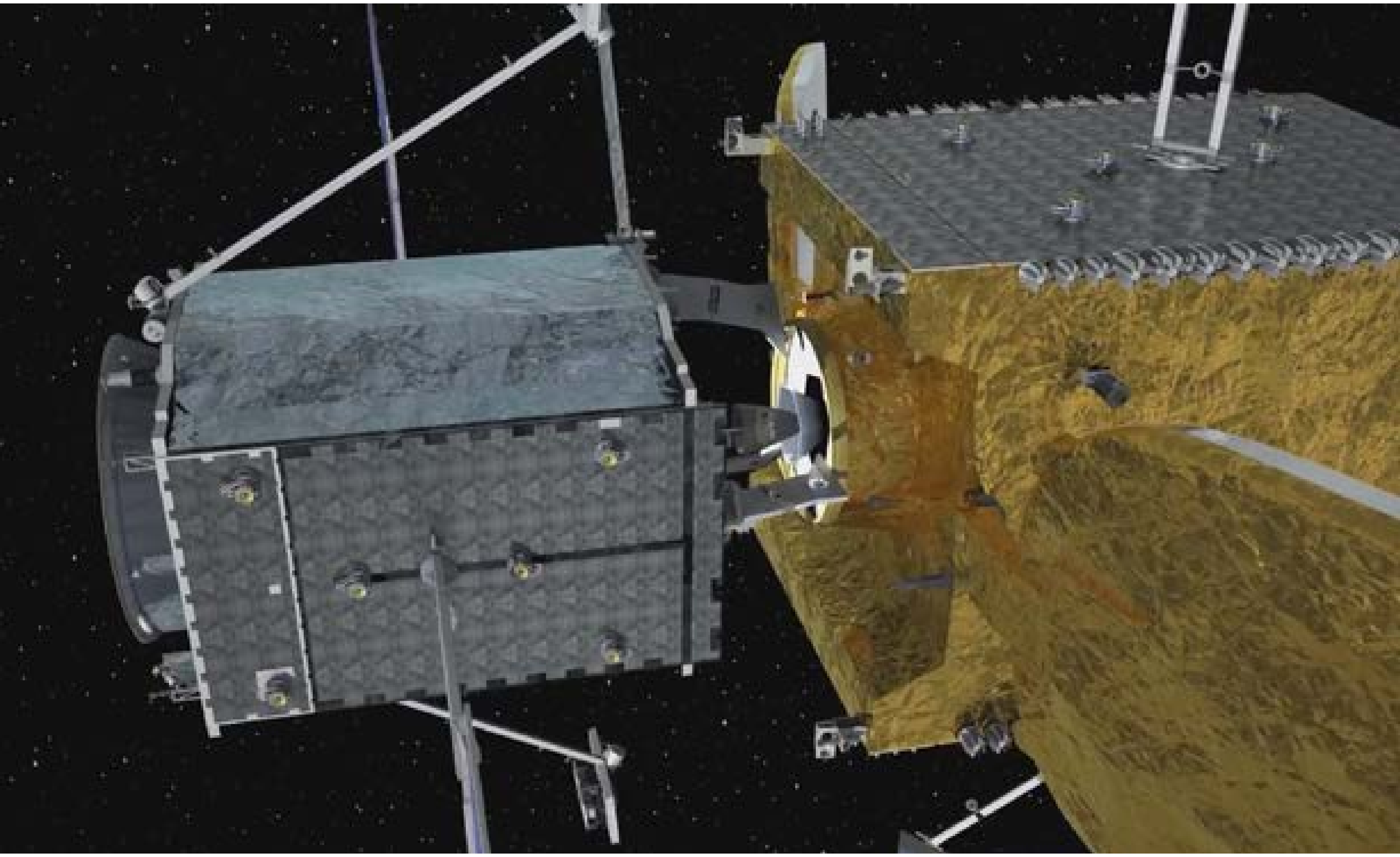
Furthermore, with so many LEO satellite systems planned, there are questions about the potential for signal interference as well as the risk of contributing to "space junk," the accumulation of orbital debris from defunct satellite equipment left in space.

Mission Extension Services

Most major communications satellites have a lifespan of about 15 years before they run out of propellant, but recent advances are extending their life. Northrop Grumman Corporation and the company's wholly owned subsidiary, SpaceLogistics LLC, developed the first Mission Extension Vehicle (MEV-1) and completed the first successful docking in February 2020 with Intelsat 901, which originally launched June 2001. Intelsat 901, while still functional, was running low on fuel and nearing the end of its life. MEV-1 provided Intelsat 901 an additional five years of service.

As described by Northrop Grumman, MEV-1 is "the industry's first satellite life extension vehicle. MEV is designed to dock to geostationary satellites whose fuel is nearly depleted. Once connected to its client satellite, MEV uses its own thrusters and fuel supply to extend the satellite's lifetime. When the customer no longer desires MEV's service, the spacecraft will undock and move on to the next client satellite."

Another mission is underway with the launch of MEV-2 in August 2020, which is set to dock with Intelsat 10-02 in 2021 and provide it another five years of service.



The Historic First Docking of Mission Extension Vehicle 1 (MEV-1) to the Intelsat 901 (IS-901) Spacecraft to Provide Life-extension Services

High-throughput Satellites

High-throughput satellites (HTS) are recent innovations, exemplified by the introduction of Intelsat Epic. Intelsat Epic is a high performance, next generation satellite platform that delivers global high-throughput technology without sacrificing user control of service elements and hardware. It utilizes C-, Ku- and Ka-bands, wide beams, spot beams, and frequency-reuse technology.

HTS technology enables moving from wide beams to multiple smaller spot beams. This multispot beam architecture is the primary feature of HTS, which concentrates power on a smaller area, increasing link performance, as well as making it possible to reuse spectrum multiple times, increasing the amount of capacity per satellite. As a result, smaller remote terminals can be used, lowering equipment cost. Also, the increased power and bandwidth result in faster speeds.

For cellular backhaul, Intelsat Epic provides the high throughput required to support 3G/4G backhaul, dynamic bandwidth allocation for asymmetric multimedia requirements, and load sharing of links during network congestion. The efficiency of the Epic platform helps overcome lower-revenue-per-site barriers in remote areas and enables satellite as a primary or backup solution in populated areas.

Software-defined Satellite Networks

Software-defined Networking (SDN) introduces flexibility and programmability into traditional telecom networks, which simplifies management, uses network resources more efficiently, and reduces operating costs.

Intelsat, for example, is creating a global network ecosystem for software-defined satellites, modems, antennas, wave forms, and the interoperability required to realize the full potential of future applications and connectivity needs. This software-based approach will give its satellite networks massive scale, agility and the right cost structures for meeting coverage and capacity demand anytime and anywhere.

Separately, Intelsat is providing assistance to regulatory organizations to ensure applications, like the connected car, will have the proper licensing framework that can drive the greatest levels of adoption. In that regard, Intelsat's focus on Ku-band provides access to the most favorable regulatory environment and greatest cost advantage. But new frequencies will also be explored, including Ka-, Q- and V-bands, as well as optical links.

In total, these types of software-defined innovations will open the door to new markets and applications that were previously limited by the constraints of traditional satellite solutions.

High Altitude Platform Station (HAPS)

High Altitude Platform Stations (HAPS), also known as High Altitude Pseudo Satellites, are "radio stations located on an object at an altitude of 2050 kilometers and at a specified, nominal, fixed point relative to the Earth," as defined by ITU Radio Regulations (RR).

HAPS vehicles are typically lightweight, solar-powered aircraft that operate in the stratosphere much closer to the Earth than LEO, which means they offer lower latency and the ability to connect directly to mobile devices.

Since they can provide cellular backhaul as well as fixed broadband connectivity for subscribers with minimal ground infrastructure, HAPS is potentially a viable, cost-effective solution for closing the digital divide in hard-to-reach areas or for providing disaster recovery services. HAPS is also quicker to deploy and at a fraction of the cost compared to LEO constellations.

Intelsat is one of the founding members of the HAPS Alliance, which was established in February 2020 to help close the digital divide. The Alliance brings together companies in telecoms, aviation, and aerospace to create an ecosystem to develop standards and interoperability as well as advocate for spectrum harmonization.

> As the foundational architects of satellite technology, Intelsat sees HAPS and the stratosphere as a complementary step towards furthering our mission to connect people and devices with hybrid networks even in the most challenging locations.
>
> The key to our collective success will be a coordinated public and private advocacy for standards, interoperability and regulations.
>
> **Stephen Spengler, CEO, Intelsat**

The Role of Satellite in 5G

5G is envisioned as providing capacity and connectivity for anything and in any place, taking the use cases for mobile broadband networks beyond simple consumer propositions to industrial applications and massive Internet of Things (IoT) connectivity. The satellite innovations described above will extend the benefits of 5G to new use cases and to places not covered by terrestrial networks.[2]

Satellites will enhance 5G deployments by providing broadband connectivity to end users, communications for moving vehicles, satellite backhaul, content distribution, and backup for large, critical IoT sensor networks. Work is underway within the 3GPP to incorporate satellite technology into 5G standards, which will facilitate the integration of satellite and terrestrial networks and enable end devices to connect to both network types.

The complementary benefits that satellites bring to 5G include ubiquitous coverage, multicast and broadband capabilities, traffic offload for mitigating network congestion, and robust security to protect against cyberattacks. Vertical sector use cases for satellite-supported 5G networks include disaster recovery, emergency services, media and broadcast, remote healthcare and education, smart agriculture and remote industries, such as mining.

Terrestrial networks alone will not deliver the promise of 5G. But with the support of innovative satellite technologies, 5G will reach its full potential.

2 Intelsat, "The Role of Space-based Communications in the 5G Era," https://www.intelsat.com/wpcontent/uploads/2020/03/intelsatmobileworldlive5Gwhitepaper1.pdf

Conclusion

The COVID-19 pandemic has revealed the stark differences between people who have good-quality broadband access and those who do not. The health crisis renewed the sense of urgency to close the digital divide and spurred initiatives that put ensuring connectivity for more citizens at the heart of global and national recovery efforts.

Satellite technology is critical to closing the digital divide by enabling MNOs to expand coverage to reach the remaining 600 million people across the globe who have no access to communications infrastructure. To connect unconnected populations in rural and remote locations, satellite backhaul is often the only viable option for a rapid, reliable, cost-effective connectivity solution.

As this paper explains, Intelsat is leading a number of innovations that make satellite an integral part of MNO network strategies for connecting the unconnected:

- Mission extension services to extend the life of satellites in space.
- Intelsat Epic global high-throughput technology, ideal for 3G/4G backhaul.
- Intelsat's global network and ecosystem for software-defined satellites.
- HAPS technology, which holds the potential to offer lower latency and improved economics that could complement satellite technology and present another avenue for closing the digital divide in remote areas.
- Integrating satellite and terrestrial technology to enable more 5G use cases.

For information on how to incorporate satellite innovations into your network planning strategies, and to quickly and cost-effectively expand access to quality, reliable mobile broadband coverage when and where it's needed, visit intelsat.com/cellbackhaul to learn about Intelsat's CellBackhaul Managed Services.

About Intelsat

As the foundational architects of satellite technology, Intelsat operates the world's most trusted satellite telecom network. We apply our unparalleled expertise and global scale to connect people, businesses, governments and communities, no matter how difficult the challenge. Intelsat is building the future of global communications with the world's first hybrid, multi-orbit, software-defined 5G network designed for simple, seamless, and secure coverage precisely when and where our customers most need it. Follow the leader in global connectivity and "Imagine Here," with us, at intelsat.com.

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We also publish five regular eNewsletters to keep the mobile industry upto-speed: The Mobile World Live Daily, plus weekly newsletters on Mobile Apps, Asia, Mobile Devices and Mobile Money.

What's more, Mobile World Live produces webinars, the Show Daily publications for all GSMA events and Mobile World Live TV – the awardwinning broadcast service of Mobile World Congress and exclusive home to all GSMA event keynote presentations.

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