Access Partnership

The future of smartphones:

Effectively regulating direct-to-handset services

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Overview of the discussion

The rapid progress in Direct-to-Handset (DTH) satellite communications has opened up exciting new possibilities for better connectivity and improved communication capabilities. By extending coverage to remote and hard-to-reach areas, people who were previously underserved may be able to access message, voice, and data services. Thanks to recent developments in satellite communications, radio antenna technologies and device manufacturing, two segments of communications which have been separate neighbours for decades, have come together for the first time. Dubbed direct-to-handset, this new paradigm brings smartphones which would have the capabilities of satellite phones without compromising the user-friendly and accessible comforts of the newest mobile devices. The impact of the DTH upcoming market goes beyond just connecting people. It has the power to transform economies, boost GDP, and increase productivity.

DTH technology leverages satellite networks to provide additional connectivity to consumers worldwide. DTH networks can be designed using GEO satellites, NGSO satellites, or a combination of both. GEO satellites have longer signal travel times, requiring higher transmission power and affecting the size and capacity of DTH services. NGSO satellites offer reduced travel times, lower power requirements, and the ability to process and retransmit signals directly to handsets.

Different constellation options exist for DTH networks, including geostationary orbit (GEO) and NGSO configurations. NGSO satellites offer reduced latency and power requirements, enabling smaller smartphones. Multi-orbit networks combine the advantages of different satellite orbits for optimal performance. Smartphone components, such as chipsets, antennas, and network access technologies, need to be designed or modified for DTH communication. Chipsets with additional capacity may be required, and advancements in antenna design have made it possible to create smaller and lightweight antennas for satellite DTH.

However, the regulatory landscape for DTH remains uncertain, posing challenges that need careful consideration to avoid hindering the emerging market directed to DTH.

This paper identifies and expands on the two businesses-model and regulatory approaches currently under consideration: the "by-the-Book" approach, which utilises MSS spectrum and partnerships with existing satellite operators and the "alternative" approach, which relies on partnerships with Mobile Network Operators (MNOs) to access terrestrial mobile spectrum. Both approaches require careful regulatory oversight to address specific challenges and ensure successful implementation.

The by-the-book approach involves handset modifications to enable satellite communications using the existing global spectrum allocation. However, it faces availability issues as more MSS spectrum is needed. On the other hand, the alternative approach integrates non-terrestrial satellite networks with 5G technology, eliminating the need for handset modifications. Nevertheless, it requires new regulatory policies for satellite spectrum usage and

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mobile service bands, which can only be addressed and harmonised during a World Radiocommunication Conference (WRC).

Another critical regulatory and technical challenge in the DTH debate is the risk of interference, particularly in border areas. The alternative approach, which involves the convergence of satellite and terrestrial coverage, presents specific challenges in this regard. The paper stresses the importance of defining spectrum allocations, standards, and parameters through international agreements and recommendations to prevent harmful interference and ensure the expansion of these services.

The white paper expands on additional regulatory challenges for DTH communication, including the need for updated licensing frameworks for mobile services, potential need of modification of chipsets (to allow for routing and switching methodologies between non-terrestrial and terrestrial networks), the incorporation of DTH services into universal access initiatives, and the consideration of security measures. It also highlights the need for regulatory interventions to incentivise market deployments of infrastructure and technologies, particularly in areas where the market fails to provide coverage due to lack of incentives or end-user capacity. Technology neutrality and flexible network architectures are emphasised as key regulatory elements to address these challenges effectively.

The paper's "Road ahead" section explores the strategic foresight necessary for tackling such challenges. It outlines the potential regulatory options for DTH devices, ranging from no regulation to dedicated regulations,

and emphasises the importance of balancing innovation with certainty in obligations and licensing, ensuring healthy market competition and consumer confidence. Efforts will focus on efficient spectrum management, harmonious coexistence of DTH and other networks, innovative spectrum management methods, robust data protection frameworks, high service quality, and universal accessibility.

Finally, it calls for a balanced approach to the regulation of DTH devices, highlighting the importance of avoiding premature regulation without a thorough understanding of the implications and advocates for regulatory frameworks that foster innovation while addressing challenges.

2. Introduction

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Not long ago, mobile phones required large power supply modules and sizable deployable antennas to communicate with satellites, a service known as 'mobile satellite service' (MSS). These independent MSS services, operating on assigned satellite spectrum, often encountered technological and commercial challenges, resulting in the financial downfall of many satellite operators.

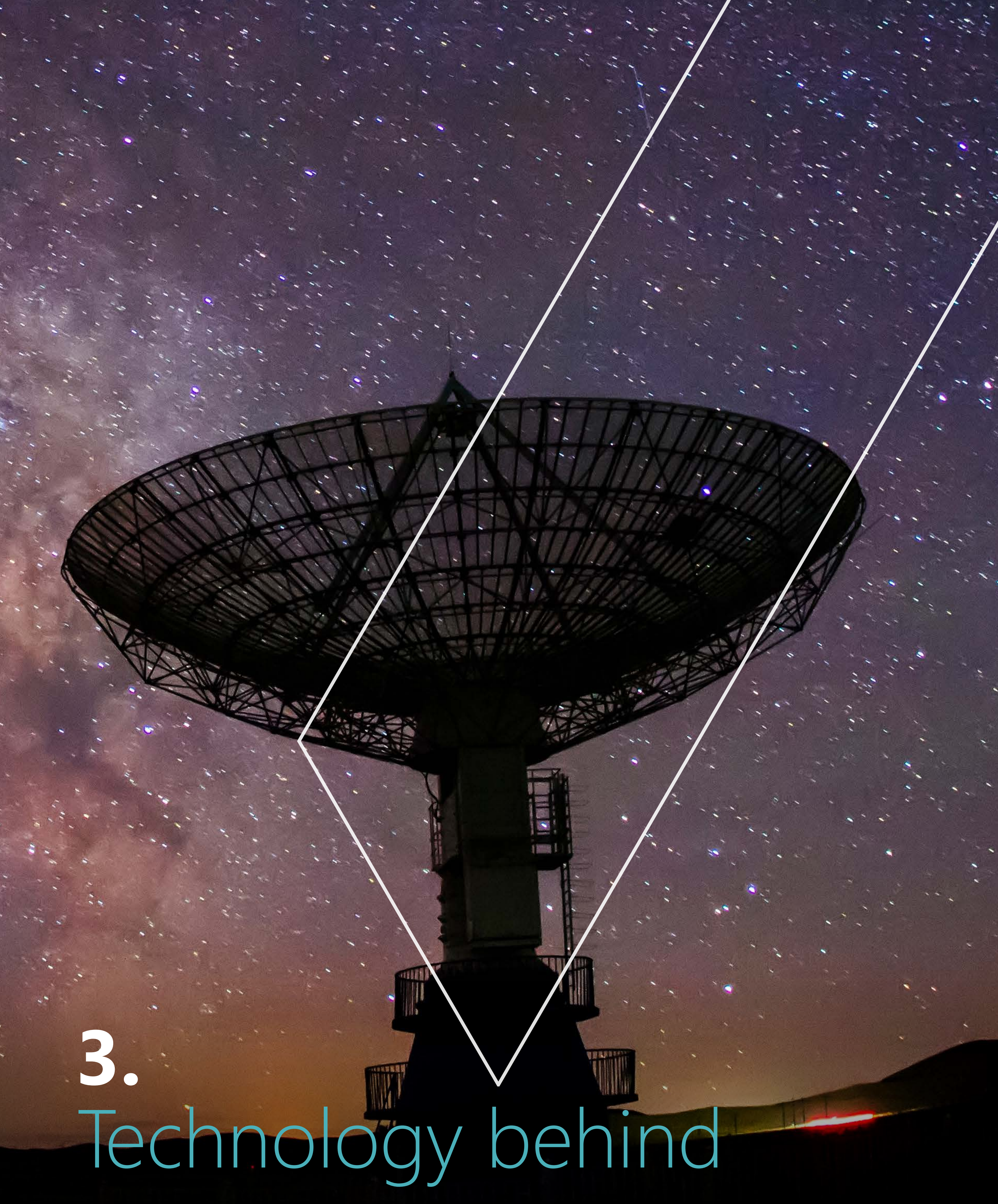
However, recent technological advancements in design and manufacturing have substantially reduced the size, weight, power, and cost of electronic communication equipment. Consequently, smaller phone form factors can now accommodate the necessary power supply and antenna, leading to several players announcing their intention to enter the emerging Direct-to-Handset (DTH) market.

While the advent of DTH services represents an exciting and unprecedented technological milestone — addressing long propagation delays, the Doppler effect, and moving cells for DTH communications — there are still many aspects to consider. Currently, DTH devices mostly operate in a regulatory vacuum or are subject to two separate regulatory regimes, and policymakers are increasingly attentive to the need to create regulatory and technical certainty. This involves the regulatory status of satellite operators and Mobile Network Operators (MNOs) implementing DTH services, potential changes to spectrum leasing rules, wireless alerts, construction milestones, and spectrum aggregation rules for DTH, among others.

The UN's Office of the Secretary General's Envoy on Technology has outlined a framework for a universal and meaningful digital inline with the UN's Sustainable Development Goals (SDGs), as they share a common purpose – to bridge the digital divide and ensure that every individual is meaningfully connected. In this case, DTH satellite communication technology can revolutionise connectivity by providing connectivity in remote and underserved areas, directly contributing to SDG 9 (Industry, Innovation, and Infrastructure) and SDG 4 (Quality Education), among others. These services can foster digital inclusion, empower local economies, enhance education, and ultimately, support the achievement of all the SDGs. As such, DTH is a strategic tool in the pursuit of meaningful connectivity and the global effort to ensure that no one is left behind in the digital age.

Premature regulation without fully understanding the implications could stifle the emerging market, diminish consumer confidence, and negatively impact last-mile connectivity goals.

To further the discourse on how DTH services could function, as well as address the challenges of spectrum coordination, interference mitigation, and resource allocation, this white paper seeks to contribute expert knowledge from technical, economic, and policy perspectives, as well as outline regulatory challenges and propose encompassing solutions.



3.
Technology behind Direct-to-Handset

3. Technology behind Direct-to-Handset

In a world where tech-savvy consumers demand high-speed broadband connectivity for various bandwidth-intensive mobile applications — regardless of location — decades of rapid innovation in satellite networks and mobile phone ecosystems have made this possible. Generally speaking, these consumers do not concern themselves with the network architecture that delivers this connectivity. Additionally, as MNOs face substantial capital costs in building 'last mile' terrestrial infrastructure to serve end-users in remote and challenging regions, new non-geostationary orbit (NGSO) satellite networks are evolving. These networks aim to provide connectivity to underserved areas, with performance increasingly competitive with terrestrial networks.

This section will delve into the technology behind DTH, fostering a comprehensive technical understanding of its operation and global standardisation.

3.1 Technical requirements

Ensuring the DTH conversation is accessible to all stakeholders is crucial. For policymakers, this entails grasping technical concepts.

First, it's essential to understand the communication journey in the context of DTH services. Generally, when a user initiates communication via satellite, the satellite relays the transmission to a ground station, which processes and routes it to a destination worldwide. Some satellites can process the signal before relaying it directly to earth stations or indirectly through other satellites via Inter-Satellite Links (ISL). Similarly, for terrestrial networks, satellites can automatically hand over voice or data communications between satellites as they pass overhead and between spot beams within the same satellite's footprint.

Setting up satellite DTH typically requires a satellite network and associated earth stations configured for mobile communications. These operate at a lower frequency range of 1-3 GHz within the L and S bands of the frequency spectrum. Lower frequency signals are preferred for their higher penetration capability and overall resistance to signal degradation due to environmental factors. This allows signals to reach their destination through walls and dense forests. However, advancements in mobile technology may prompt a shift towards frequencies above 6 GHz to increase networks capacity and improve services[1].

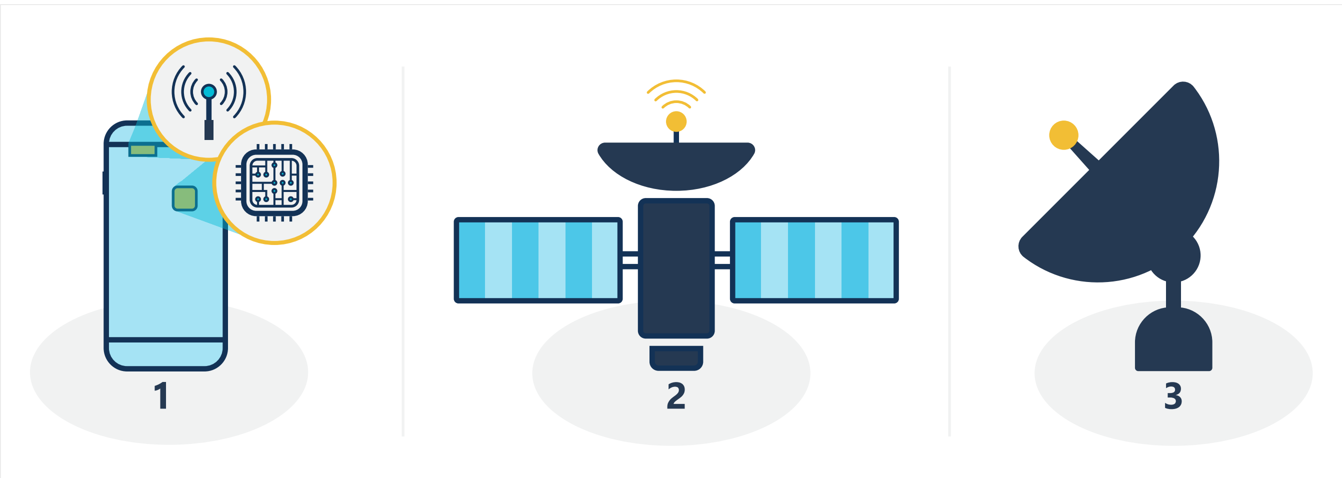


Figure 1: Direct to handset as part of the Direct-to-Handset application.

a. Satellite altitude

Satellites can be classified based on their altitude or distance from the Earth's surface. As the distance to the satellite increases, so does latency. This is due to the longer time it takes for the signal to reach the satellite. However, the satellite's coverage area also expands with altitude. Geostationary Orbit (GEO) satellites operate at an altitude of around 36,000 km. To put this in perspective, a constellation of approximately three GEO satellites can provide global coverage.

On the other hand, NGSO satellites operate at altitudes ranging from 400 to 20,000 km. These are further divided into Medium Earth Orbit (MEO) satellites, which operate at altitudes between 2,000 and 20,000 km, and Low Earth Orbit (LEO) satellites, operating at altitudes between 400 and 2,000 km[2]. Depending on their orbit altitude and required visibility period, hundreds of NGSO satellites might be necessary to achieve global coverage.

b. Link latency

Link latency has a significant impact on interactive services, as it refers to the duration of a signal's round trip between the user and the satellite. This determines the speed at which data can be sent and received. A common example is the noticeable delay experienced during conversations on some satellite phones. Due to their higher altitudes, GEO satellite links have a latency of about 600 ms, a value nearly 20 times higher than the 30-40 ms latency experienced by LEO satellite links[3].

GEO satellites maintain a fixed position relative to the Earth's surface, offering greater stability and more extensive coverage areas. In contrast, NGSO satellites, which include LEO and MEO satellites, orbit the Earth at lower altitudes, providing lower latency and higher data rates.

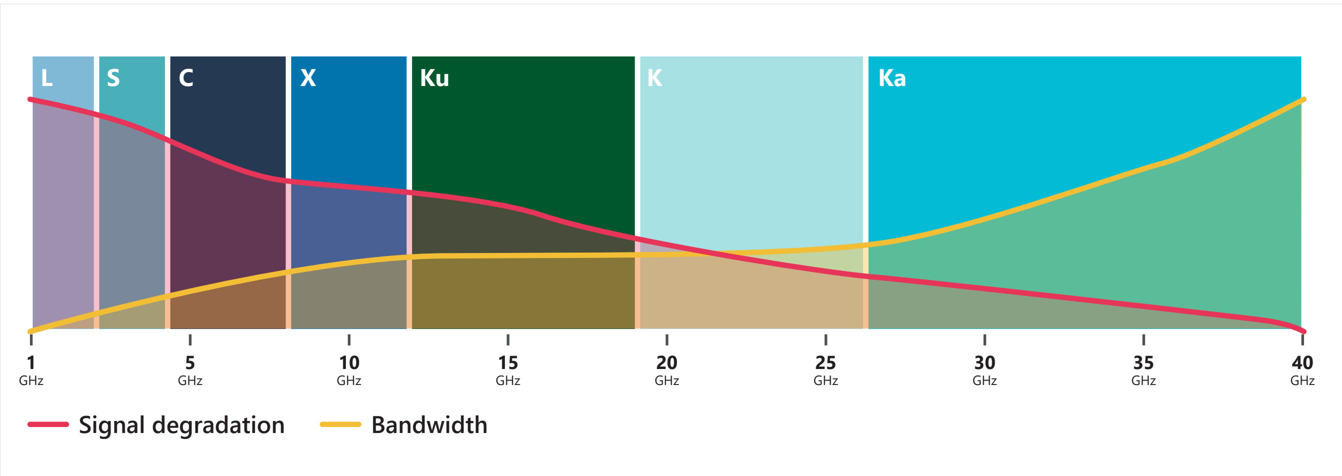


Figure 2: The frequency spectrum bands[4].

c. Network design

Satellites are equipped with transponders that receive and transmit radio frequency (RF) signals between handsets and ground stations. These ground stations act as feeder links to the satellite network and may also be employed for satellite tracking, telemetry, and command purposes[5]. Additionally, ground stations can connect to gateways, serving as intermediaries between the satellite and other terrestrial networks (Figure 3). The satellites and their associated ground stations work together to ensure accurate signal processing, call routing, and strict compliance with spectrum management regulations.

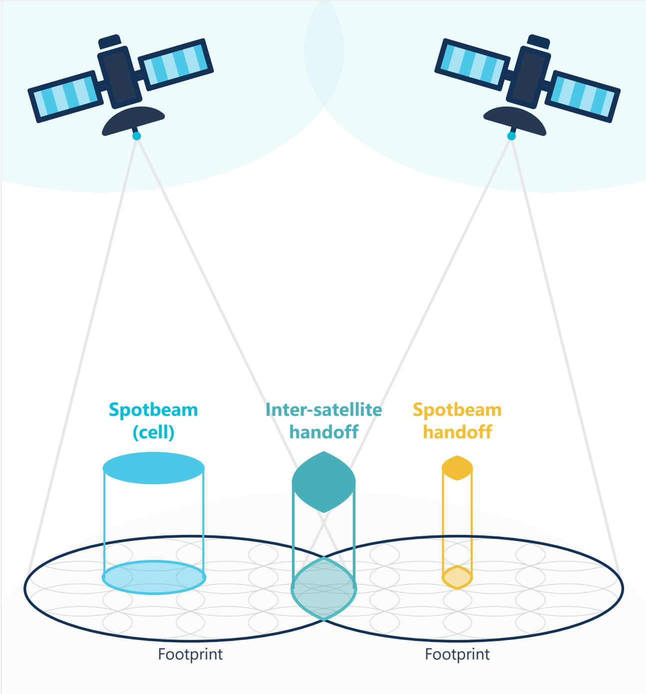


Figure 3: Satellite cells and handoffs.

d. Satellite cells

Handover, or handoff, refers to the transfer of voice or data transmission as a user moves from one cell to another without losing connectivity. Terrestrial base stations and GEO satellites provide radio coverage in cells, which have the distinct characteristic of always maintaining a relatively fixed geographical location. However, as shown in Figure 5, NGSO satellite cells (i.e., beam footprint) move in relation to the user, creating the 'moving cells' problem in these networks. This issue primarily arises from the significant increase in the number of potential handovers during a single transmission, introducing considerable negative impacts on the Quality of Service (QoS).

Efforts are underway to find solutions that will enable seamless handovers in NGSO satellite DTH networks. The aim is to provide a QoS and user experience comparable to terrestrial networks.

3.2 Constellation options

A satellite DTH network can be designed in various configurations depending on the components involved, as described below:

GEO satellite network: GEO satellites that successfully deliver DTH services typically retransmit signals received from a phone to a ground station, which then relays the signal to its target destination and vice versa. However, due to the satellites' distance of 36,000 km, phones need to transmit signals with a relatively high power to reach the satellite and consequently receive very faint signals from it. Long propagation delays are also expected. These factors affect the size of the phone's power supply unit and the speed and capacity of the DTH service that can be delivered. Increasing the phone's size could make it less appealing to users, and there are power limits due to spectrum regulations. Nevertheless, design trade-offs can be made to enable the DTH service, such as limiting the service to messaging, which has a high tolerance for delays and the lowest power requirements.

NGSO network design: By using NGSO satellites, which are closer to the Earth's surface, the signal travel time from the user is reduced, decreasing propagation delays and transmission power requirements for the DTH service. NGSO satellites have been developed that can not only retransmit or relay signals but also process and retransmit them directly to another phone, mimicking a terrestrial base station. This allows for smaller phones and more margin to adhere to power limits.

Multi-orbit network design: While LEO satellites are best suited for DTH service delivery, other factors must be considered during network planning. To optimise DTH networks, some entities explore using multiple orbits. A multi-orbit approach enables the concurrent use of satellites in different orbits to design the most cost-effective network solution. A prime example of the benefits of a multi-orbit approach is using LEO satellites to overcome uplink power limits and leverage the larger coverage offered by MEO satellites for downlink within the same network. As the technology matures, other combinations may emerge, capitalising on the advantages of each orbit.

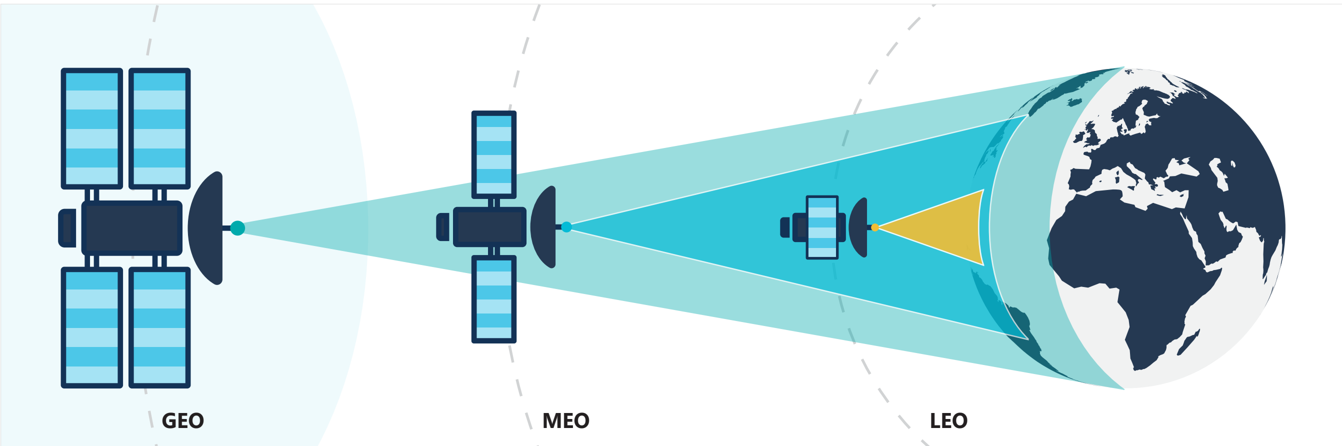


Figure 4: Satellite altitudes coverage and latency[6].

Satellite altitudes	GEO 36,000 Km	MEO 2,000-20,000 Km	LEO 2,000-400 Km
Latency	High	Medium	Low
Global coverage	3 satellites	6 satellites	100+ satellites

3.3 Smartphone components

Chipset

The chipset, or System on Chip (SoC), serves as a smartphone's brain, comprising the processor, memory, modems, interface controller, and other essential hardware. A smartphone chipset forms the foundation that supports communication, storage, power management, interface management, and other core functions[7]. A DTH-enabled phone will need a chipset with additional capacity to handle direct-to-satellite communications. However, due to recent technological advancements, some satellites can run the 5G core network functions onboard, eliminating the need for modifications to conventional mobile handsets. The 5G network's core functions are exceptional in managing access, sessions, mobility, and authentication. Satellites can transmit signals to mobile devices for secure communication registration, data packet security, and authentication. With advanced technology and adherence to 3GPP standards, like the 5G core network, some satellite networks can provide reliable protection against potential threats while facilitating secure information exchange between external applications and the network. Despite this, most phone hardware manufacturers are still working on developing chipsets that will be compatible with any approach.

Antenna

Developing antennas for satellite DTH services presents a significant challenge, as they must be small enough to fit into smartphones. In the past, large and bulky antennas were necessary due to the increased antenna sensitivity required to receive signals from the satellite. Also, the DTH services operating on frequency bands different from the ones used for terrestrial communication require antennas with different characteristics. The challenge is to extend the phone’s antenna capabilities to enable connectivity using both satellite and terrestrial frequency bands. However, recent technological advancements in design and manufacturing, such as phased

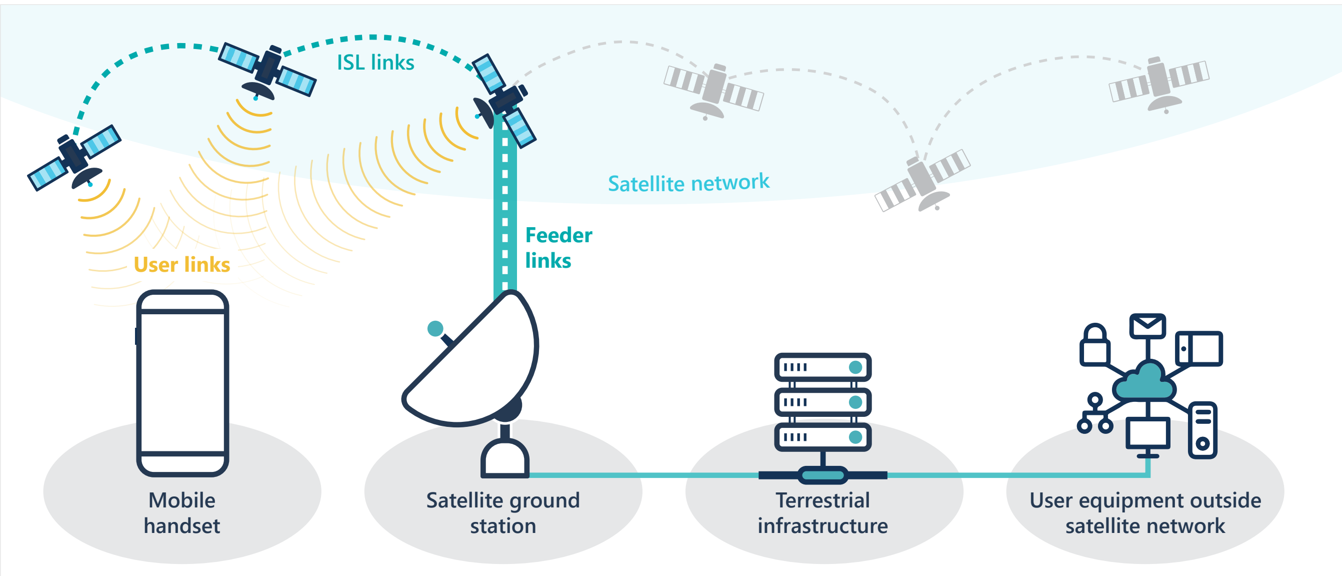


Figure 5: Satellite D2D service components.

array antennas, metamaterials, and software-defined radios (SDR), have made it possible to create small and lightweight antennas that can communicate with the satellite while fitting nicely into a conventional smartphone.

Thanks to constant technological advancements and the increasing accessibility of cost-effective silicon devices, antenna devices have become more compact and smaller. Phased array antennas, for instance, have become so tiny that they are barely visible. Moreover, the latest technological breakthroughs have enabled the use of shorter wavelengths, allowing for the use of smaller antennas without compromising precision. This will be particularly beneficial in the development of DTH antennas.

Network access

Currently, users can achieve satellite DTH network access where there is little or no disruption to the line of sight (LOS) between the satellite and the user terminal. Alternatively, users can use accessories consisting of outdoor antennas that can receive satellite signals and indoor repeaters which boost the signal between the user terminal and the satellite.

For indoor user terminals, it is difficult to achieve satellite connectivity because signals from satellites are received with a considerably lower power compared to signals from terrestrial networks. Indoor coverage by satellite DTH services is particularly challenging as the signals will have to overcome both free space path loss (outdoor environmental factors) and other obstacles, such as walls, windows, and furniture. To resolve these issues, the satellite's altitude will need to be as low as possible and have improved antennas as well as transmission power. Meanwhile, the user terminals will need antennas that are significantly more sensitive in order to receive weaker signals and increased transmission power, as well as sophisticated error correction algorithms to accurately recreate the signal at the receiver.

However, due to improvements in satellite and receiver technologies, the possibility of receiving satellite signals indoors increases, albeit, with other challenges in preventing harmful interference to other networks and devices. The test was carried out using a user terminal in an office building and a conventional omnidirectional antenna[8].

3.4 Standardisation of DTH

The 3rd Generation Partnership Project (3GPP), which unites seven telecommunications standard development organisations (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC), works on standards for expanding 5G wireless technology to support non-terrestrial satellite networks (NTNs) by addressing the issues of topology, integration of NTN and terrestrial services, propagation delays, Doppler effect, and moving cells from Release-17 onwards. Some companies have capitalised on these advancements to propose the extension of connectivity to areas not covered by terrestrial networks via satellite DTH using spectrum allocated to the terrestrial mobile service. While this approach offers more bandwidth, it necessitates new regulatory policies regarding satellite usage of spectrum allocated to terrestrial mobile services and a new MSS allocation in mobile service (MS) bands. The latter can be achieved at the WRC-27, scheduled for 2027 at the earliest.

3.5 Spectrum dilemma

The International Telecommunication Union (ITU) defines MSS as a telecommunication service between mobile earth stations and one or more space stations or between space stations used by this service. In simpler terms, MSS refers to using satellites to provide communication services to mobile users. The ITU regulates MSS through radio frequency spectrum allocation, satellite orbital slots, and technical standards and regulations development, ensuring the interoperability and compatibility of MSS systems worldwide. DTH satellite communication services fall within the scope of MSS; therefore, spectrum bands allocated to MSS should be utilised for this service.

Some mobile handset and chip manufacturers have partnered with existing MSS satellite operators to provide DTH services using frequency bands allocated to MSS, known as the 'by-the-book' approach. The 'alternative' approach extends terrestrial 5G cellular communications using satellites as cell towers or base stations in space and utilising the MS spectrum allocation. However, using frequency bands allocated to MS for DTH satellite communications may not comply with the ITU's Frequency Allocation Table (Article 5 of ITU Radio Regulations), potentially raising regulatory and coexistence concerns that need careful examination.

Spectrum availability is challenging because most allocations are made alongside existing services that can claim protection from new services. For example, the ITU's Frequency Allocation Table reveals that the single MSS-only primary allocation within the L and S spectrum bands (1,535-1,559 MHz) has restrictions due to priority being given to aeronautical mobile-satellite services and limitations on specific bands for distress and safety communications. Other allocations for MSS are shared with other services, requiring coordination to avoid harmful interference.

Other approaches under development, but not yet commercially viable, include atmospheric laser communication technology (which is potentially 1,000 times faster than current communication technologies) and efforts to integrate satellites and High-Altitude Platforms (HAPS) to address the challenge of providing ubiquitous connectivity.

With this understanding of MSS and MS, let us explore how these services are applied in the two main approaches to satellite DTH communication.

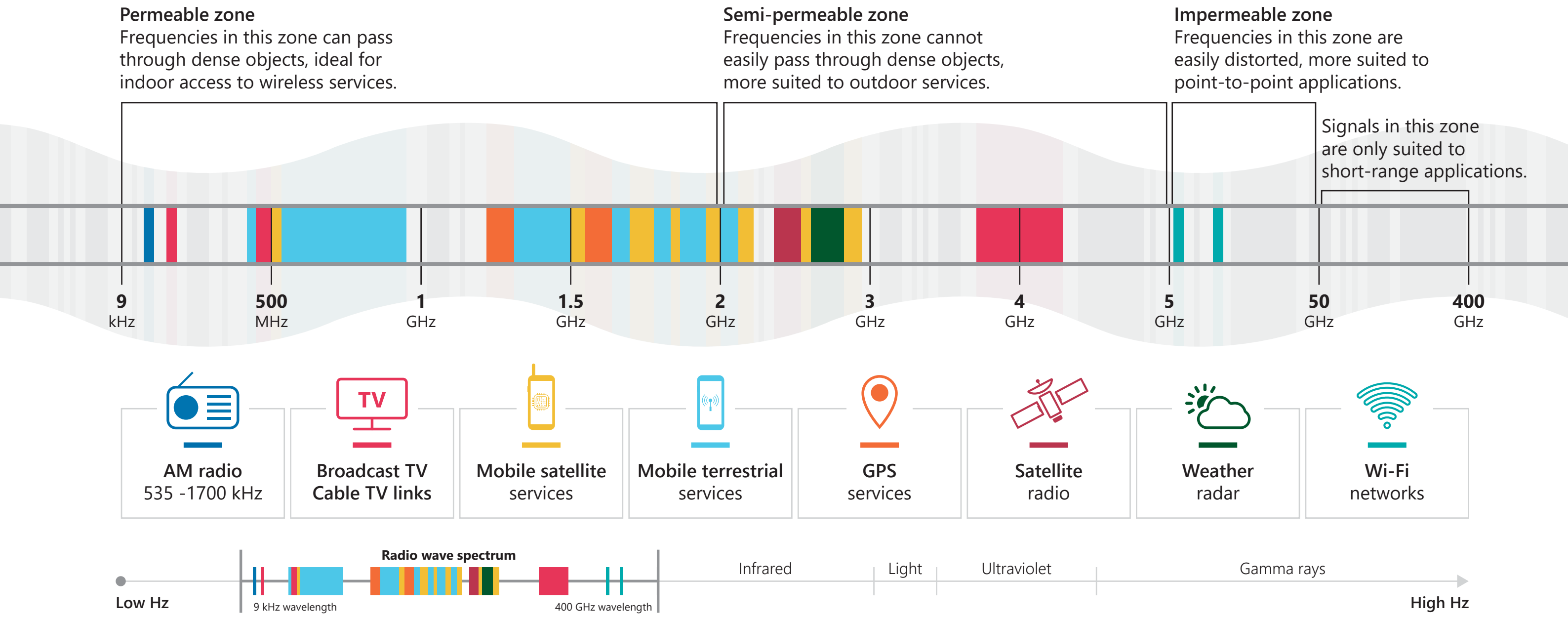


Figure 6: The nature of frequency spectrum usage.

4. Implementation of DTH

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Now, we'll explore the two main approaches to implementing DTH services - the 'by-the-book' approach and the 'alternative' approach.

4.1 The by-the-book approach

A by-the-book approach provides expanded satellite functionality to conventional mobile handsets when outside the coverage of terrestrial networks. This is achieved through modifying the hardware and software of handsets to enable satellite communications by addressing the change in power, frequency, propagation delays, and communication protocols.

Satellite DTH service providers using this approach take advantage of an established service with a global spectrum allocation from the ITU. This means that existing international and national spectrum usage rights could be used to deliver the new service, significantly shortening the time it would take to start from scratch. This helps existing licence holders, but also impedes new entrants significantly. The spectrum availability for MSS is also a challenge, as many global operators share limited bandwidth allocated to the service.

4.2 The alternative approach

Considering the lack of and complexities of accessing existing MSS bands, some companies decided to team up with MNOs to provide MSS service using the MNO's licensed MS bands which are generally licensed for terrestrial International Mobile Telecommunications (IMT) – hence, this would be a non-confirming use of spectrum. This issue might be a viable solution in some countries, but also raises concerns and objections from regulators and industry. Below is a list of the pro and cons of this approach.

4.3 Rise of different business models

A number of companies are currently competing to provide an emerging new satellite service directly to mobile phones. Some of these companies have decided to use the allocated MSS spectrum for this service – a 'by-the-book' approach. Due to the lack of available MSS spectrum and the high complexity of satellite filing coordination, companies betting on MSS spectrum – namely, Qualcomm and Huawei – have decided to partner with existing satellite operators that have access to the MSS bands; i.e., Iridium and Beidou, respectively. On the other hand, some companies (SpaceX, AST SpaceMobile, Link, and others) have favoured an 'alternative' approach of using terrestrial mobile spectrum, which is not in line with the ITU's Frequency Allocation Table (Appendix 5 of ITU RR). To access the terrestrial mobile spectrum, these companies need to partner with MNOs in each country of interest to use their licensed spectrum for satellite service, and this should also be approved by the local regulator. This section analyses these two approaches in more detail to assess the pros and cons of each.

The "by the book" approach

- Certainty of using existing MSS allocation regionally/globally.
- Existing licences of the satellite operators can be used for this service.
- Limited amount of currently allocated spectrum.

The "alternative" approach

- Upon agreement from MNO and regulator, access to the terrestrial IMT spectrum.
- No hardware changes in the handset will be required to support satellite connectivity and service can be provided to all types of handsets.
- Such non-confirming use of MS spectrum can only happen on a per country basis.
- Since this is a non-confirming use of MS spectrum, there is a possibility of interfering with, and being interfered with, other existing users in-band and in the adjacent bands. Moreover, IMT spectrum can be auctioned on a partial economic area (PEA) geographic basis. That means MSS operation in IMT bands may interfere with another MNO's operation within the country.
- Even if this use is agreed locally, there is a possibility of cross border interference to the IMT networks and other users of spectrum in the neighbouring countries.
- Allocating MSS in the MS bands would require a global decision which may only be agreed in a World Radiocommunication Conference.

4.4 The feasibility of DTH

Bandwidth and speed capabilities: Current use and future demand

Most satellite DTH service providers have unique value propositions, leading to various implementation techniques. Consequently, it is quite difficult to gauge the capability of potential DTH services that are yet to be commercially deployed. Even though there are variations in the implementation of the DTH service, the first few attempts at full deployment provide smartphone users with the ability to send and receive messages via satellite using smartphones when outside terrestrial network coverage. A notable example is the use of a satellite DTH service in contacting emergency services by signalling a satellite in areas outside terrestrial coverage, which allows users to send location and distress messages via the by-the-book approach.

This highlights the speed of deployment for the by-the-book approach, albeit with bandwidth and power limitations restricting the service to the transmission and reception of text messages only. The existing satellite DTH systems are only capable of providing low data rate and throughput DTH services, as they were not initially designed to provide such services. However, with improved satellite constellations, larger bandwidth, and higher transmission power, more sophisticated DTH services could potentially be provided.

Numerous laboratory and field tests demonstrating the potential of the DTH service have been carried out by satellite operators, equipment manufacturers, and MNOs globally. These tests usually focus on the utilisation of the alternative approach, which is yet to be fully authorised by regulators.

Regarding capacity and speed, the most optimistic service providers have proposed a 2-4 Mbps capacity for each satellite cell, covering an area usually more than 100 km in diameter. This could allow users to make about 2,000 concurrent voice calls and thousands of concurrent text messages. Such an outcome would be made possible by implementing the alternative approach through a partnership between a satellite operator and an MNO sharing satellite resources and spectrum assets to provide their customers with out-of-network coverage worldwide. The proposed services intend to use NGSO satellites with large phased-array antennas, 5G core network functions running onboard, and the MNO's licensed spectrum assets.

Currently, the DTH and other services provided by satellites in the mobile satellite service (MSS) are using low-frequency bands between 1-3 GHz. The bandwidth available for these services is relatively low, ranging from a few KHz to a few hundred KHz. This bandwidth limitation restricts the data rates that can be used to less than 1 Mbit/s in a single channel. The use of higher frequencies may be necessary for high-speed connections to increase capacity due to more bandwidth availability. Calls for more MSS allocations below 7 GHz by the ITU are increasing as a means of solving the problem of bandwidth availability for the satellite DTH service.

The implementation of satellite DTH services is hampered by bandwidth availability, which is currently limiting it to mostly text messaging. Although voice calls have been demonstrated to work during field tests, satellite DTH services are yet to go beyond text messaging in commercial deployments. However, the range of services could improve with continued advancement in technology, bandwidth availability, and regulatory policies.

Both approaches to the implementation of satellite DTH leverage the advantages of communication satellites, offering broader and more flexible coverage than terrestrial networks. Some satellites can steer beams and change orbital inclination, effectively changing their service areas to fit business goals. Many satellite DTH providers plan worldwide deployment, while others only aim to cover specific regions. These decisions will primarily be determined by their level of funding and ability to gain market access.

Smartphone limitations

Satellite DTH also grapples with the limitations associated with satellite phone communications. The most noticeable issue with the service is that it is only available outdoors, whereas the phone has a clear LOS to the satellite. Some devices may even require users to aim the phone towards the satellite, which could be arduous.

Additionally, the need to increase the phone's transmission power could substantially reduce battery life or enlarge the size of the device. Some trade-offs must be made to accommodate the size of the phones, limiting the amount of energy that can be used. This consequently restricts the transmission power of the satellite DTH-enabled devices. Increasing the power could also elevate the heating effect and other potential health risks associated with mobile phone usage[9].

Interference

The L and S frequency bands are congested due to various terrestrial and satellite communication service allocations. Similar signals received by communication equipment could interfere with each other, confusing the receiver and degrading the system's performance. Fortunately, both international (ITU and regional organisations) and national regulators play a vital role in regulating these services to foster coexistence free of interference. Each service requires authorisation before deployment and must adhere to technical as well as geographical limits to avoid disrupting other authorised services.

The potential for interference in areas outside terrestrial network coverage is relatively low because satellite services are well-regulated. However, due to the size of a satellite coverage area, an overlapping of satellite and terrestrial coverage is inevitable. A satellite typically

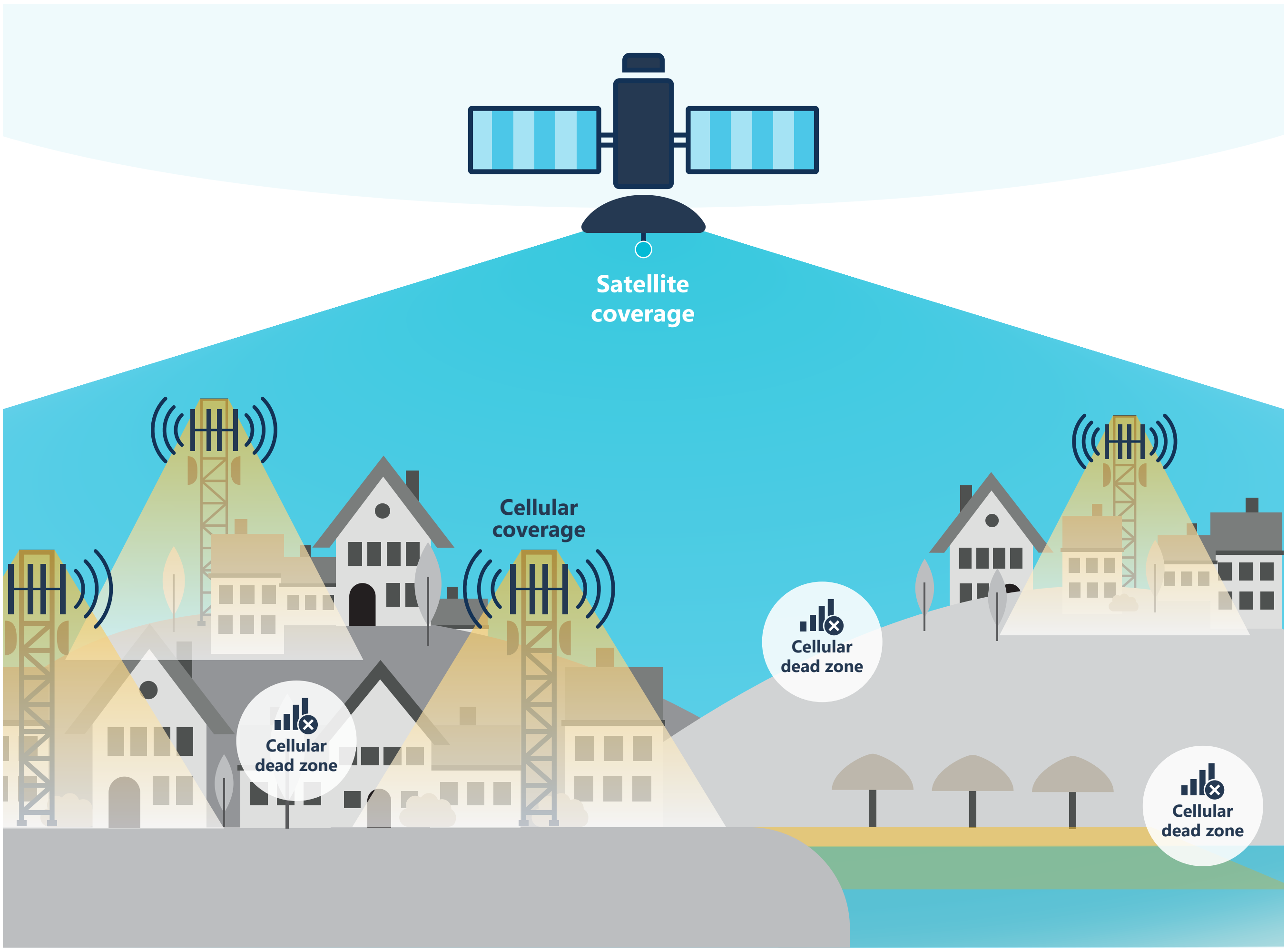


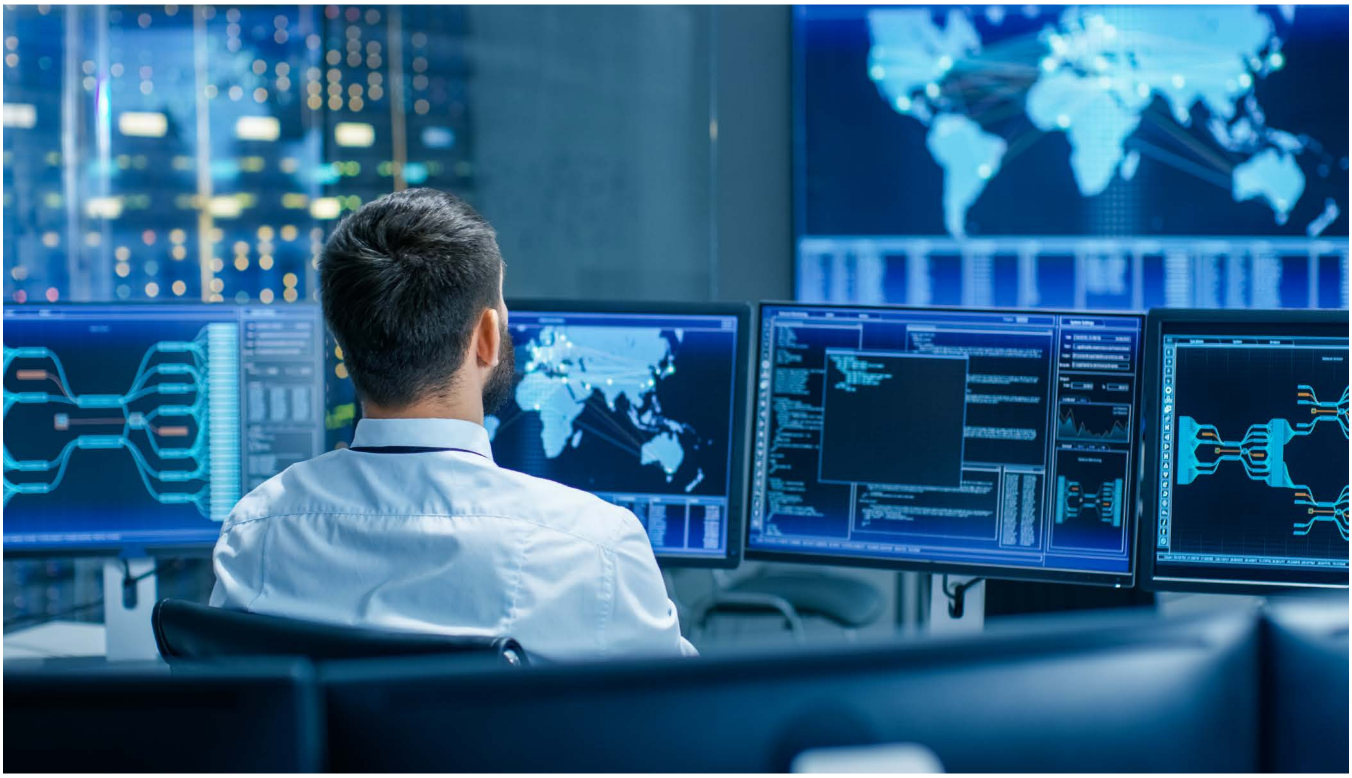
Figure 7: Using satellites to cover cellular dead zones.

has beams covering areas of 100-3,500 km in diameter, while terrestrial cells generally have a diameter of about 5 km. Hence, using satellite DTH to cover dead zones left unserved by terrestrial networks could lead to interference due to the overlap of terrestrial and satellite coverage.

Furthermore, in terrestrial networks, performance typically decreases towards the edge of cellular coverage. This could lead to possible interference at the edge of terrestrial cells, where the signals are at their weakest and closer to the power level of the satellite signals; the handsets could find it challenging to differentiate between the two, resulting in poor performance. Additionally, even if an operator is authorised to operate in an area and can prevent causing harmful interference within that area, the size of the satellite beams and the constant motion of NGSO satellites can create overlapping coverage in neighbouring areas where the operator lacks authorisation. This could make it challenging for satellite DTH providers to ensure compliance with different regulatory regimes across various geographical areas, especially along international borders.

Effective coordination of radiofrequency spectrum usage across borders is crucial to prevent harmful interference. While each country manages its own spectrum, it is vital to conduct a technical analysis before using a satellite DTH service in neighbouring countries where it is not authorised. This analysis helps to identify potential interference and safeguard in-band services.

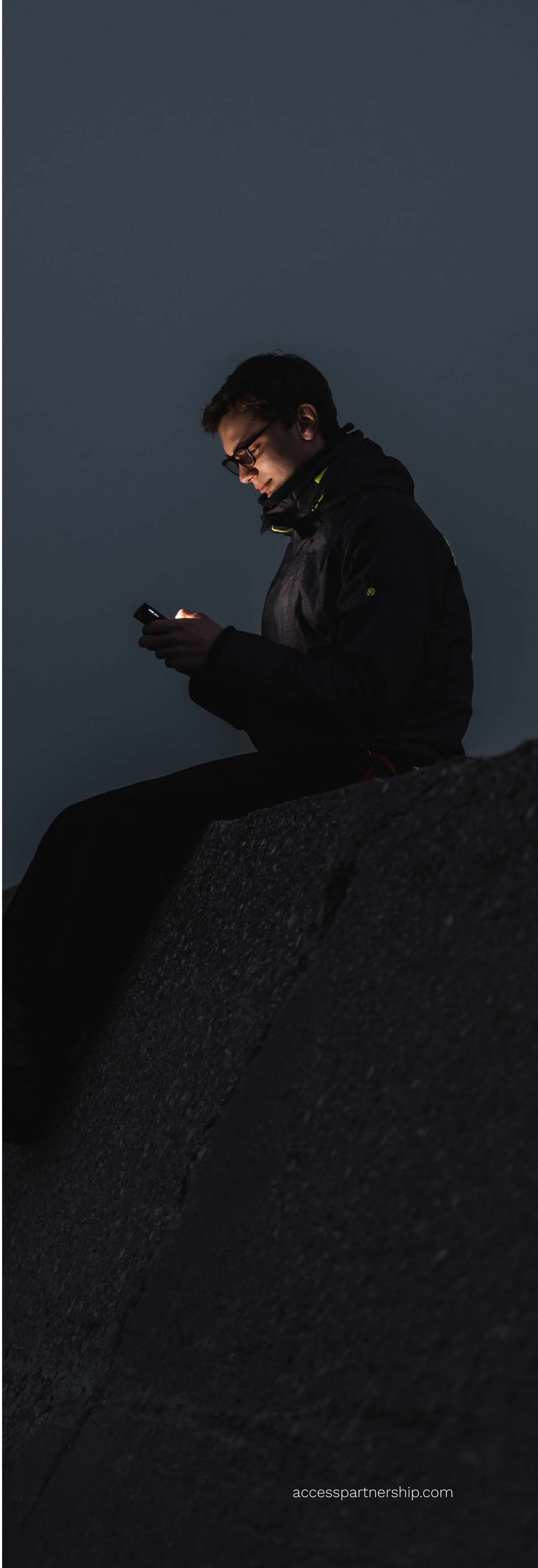
The technical analysis will consider various factors, including frequency bands, channels, power levels, transmission characteristics, EIRP, signal polarisation, and directionality used by the service. It will also consider neighbouring countries' in-band services, frequency bands, power levels, and transmission characteristics. By modelling satellite and in-band signal propagation



in relevant frequency bands, the analysis assesses potential interference based on factors such as distance, power levels, and propagation conditions.
Based on the results of the technical analysis, necessary measures can be taken to protect in-band services. These measures may include adjusting the satellite DTH service's power levels or transmission characteristics or implementing technical solutions like filtering or directional antennas. However, regulatory authorities in different countries may need to coordinate and cooperate to effectively implement necessary technical measures and regulations.

The increase in satellite DTH services would inevitably lead to an additional burden on the existing frequency allocations and necessitate special precautions to protect existing services, such as the Global Positioning System (GPS) and other critical services in similar or adjacent frequency bands. GPS operators in the United States (US) have already reported concerns about harmful interference from the operations of an MSS satellite DTH provider. However, as these services mature, regulators must create sharing mechanisms to prevent harmful interference between new and existing services. Mechanisms such as spectrum sharing could prevent interference through frequency allocations. A paired spectrum approach is also being considered in the US, allowing MNOs to pair up with a satellite provider in delivering satellite DTH through the MNO’s spectrum assets.

However, due to improvements in satellite and receiver technologies, the possibility of receiving satellite signals indoors increases, albeit, with other challenges in preventing harmful interference to other networks and devices. Interestingly, a satellite IoT provider recently announced the successful indoor



operation of their DTH IoT solution based on a proprietary technology, demonstrating bidirectional communication between their chipset and a LEO satellite. The test was carried out using a user terminal in an office building and a conventional omnidirectional antenna[10]. The IoT test is a step in the right direction, but real-time services like voice and video requiring higher data rates will be significantly more difficult to deploy indoors.

Currently, users can achieve satellite DTH network access near windows and in cars where there is little or no disruption to the LOS between the satellite and the user terminal. However, it should be noted that moving cars could challenge the network's capability of maintaining connection in a fast-moving vehicle. Alternatively, users can use accessories consisting of outdoor antennas that can receive satellite signals and indoor repeaters boosting the signal between the user terminal and the satellite.

Interoperability

A global debate has culminated in the consensus that integrating terrestrial networks and NTNs is critical to achieving continuous connectivity. Integrated NTN-terrestrial networks stand to benefit from wide-area coverage, extensive LOS, low-loss, and high-throughput transmissions.

NTNs convergence with terrestrial networks has sparked numerous conversations in the ITU and studies that will guide the technology's adoption by telecommunication administrators worldwide. The ITU-R WP5D is currently studying the integration of NTN with terrestrial networks as a part of IMT-2030, a recommendation defining the framework and overall objectives for the development of International Mobile Telecommunications for 2030 and beyond[11].

The ITU-T study groups 13[12],11[13], and 20[14] are currently studying the QoS, bandwidth requirements, and latencies that will help prevent interference between the NTNs and terrestrial networks. These recommendations will define the QoS assurance for mobile and satellite convergence supported by IMT-2020 and beyond, as well as the requirements, framework, mechanisms, procedures, security considerations, and use cases of satellite DTH[15]. 3GPP Release 16 outlines the temporary and pre-existing conditions that necessitate a satellite component to be connected to a 5G network and regulatory requirements when transitioning to or from satellite-terrestrial networks[16]. TS 22.261[17] describes the service requirements for next-generation new services and markets that require the 5G system to be able to provide services using satellite access. It further specifies the configuration requirements and interactions between terrestrial 5G access and satellite-based access networks owned by the same operator or by an agreement between operators, providing examples of the use cases for the provision of services when considering the integration of terrestrial services with satellite-based access components.

3GPP Release 17[18] delves further into the improvements related to the critical areas of the previous releases. Moreover, this release also studies several network functionalities that have been enhanced, such as slicing, traffic steering, and edge computing. The 'Integration of satellite components in the 5G architecture' work item enhances features in the 5G Core architecture to support NTNs for several use cases, including coverage extension, IoT, disaster communication, global roaming, and broadcasting.

Technical challenges

Many technological questions still need to be addressed for this technology to be fully realised and utilised. Regulators will pose questions on:

1

Bandwidth. Given that millions of end-users will benefit from DTH satellite connectivity service, the lack of spectrum allocated to MSS, and that existing MSS allocations are already heavily utilised for various applications, more radio spectrum will be required to address the needs of DTH MSS. Several countries have already submitted contributions to the Conference Preparatory Meeting (CPM23-2) asking to conduct technical studies to allocate more spectrum to MSS in the frequency bands below 7 GHz at WRC-27, which would be used for the satellite component of IMT. The FCC's newly released NPR for a Single Network Future indicated consideration for a US national MSS allocation on a co-primary basis in the bands 614-652 MHz and 663-758 MHz; 775 MHz-788 MHz and 805-806 MHz; 824-849 MHz and 869-894 MHz; 1,850-1,920 MHz and 1,930-2,000 MHz; and 2,305-2,320 MHz and 2,345-2,360 MHz. Every administration has the right to allocate any service in any band within its borders, but cross-border interference issues might arise from such national allocations. Given the global nature of MSS, new global MSS allocation needs to be considered at the ITU level to carefully study the coexistence of MSS with other in-band and adjacent band services before such allocations can be made at WRC-27.

2

Traffic characteristics. Satellite DTH involves routing information from the user equipment to the satellite and then back to another user equipment within the same satellite network, a different satellite network, or a terrestrial cellular network. It is worth noting that these networks have different network protocols, meaning different routing and switching methodologies. Handset chipsets must factor in the changes in signalling due to the addition of NTNs. The MSS approach requires greater modification of the chipsets as the satellites are not configured to act as a cellular base station; rather, they act as repeaters sending the signal to a ground station, which performs the necessary routing functions. Hence, handset chipsets have to be modified to enable satellite DTH due to changes in power, frequency, propagation delays, and communication protocols.

3

Access network-related issues where satellite operators operate without a local MNO or across borders of various sovereignties. For example, what happens when the satellite operator has a licence to operate in one country and needs the same band of frequency to operate in another area? How will the administrations deal with cross-border interference due to a larger satellite footprint?

4

Spectrum-related issues regarding the availability of new frequency bands (i.e., mm-Wave) and the 5G NR scalable numerology introduce new challenges in managing the radio spectrum in NTN systems. Different numerologies (i.e., different subcarrier spacings) may coexist in each frequency band, generating new types of interference, known as inter-numerology interference (INI).

5

The radio interfaces will interact with each other; i.e., in cases where the chipset is connected directly to the satellite system or using a local terrestrial network (Cellular Network) and its interoperability between various systems. This might lead to discussions of whether the equipment to be developed should have the same EIRP and RF capabilities. However, the biggest question is whether satellite and mobile equipment should adhere to the same standards to promote interoperability.

5.
Economic impact of DTH

5. Economic impact of DTH

5.1 An upcoming market

The emergence of DTH services is anticipated to grow into a significant market opportunity for the telecommunications industry due to the vast economic and social value to be materialised for prospective end-users.

The value is anticipated to roll out in three phases *(Figure 8)*, mediated by the speed of technological development, the presence of facilitative regulatory mechanisms, and consumer adoption. In the initial phase, demand from end-users will come from specialised users (e.g., current holders of satellite phones and gadgets), and the market will expand to non-specialised cellular smartphone users.

The initial embryonic phase will be predominated by the provision of limited DTH services, with a focus on mainly emergency messaging. Data and voice services will still be limited due to the risk of interruptions, where the satellite dish lacks a clear view of the sky and thus visibility of fast-moving LEO satellites. Service providers will also be testing out various business and pricing models, with largely free or nominal prices potentially baked into existing plans. Emergency messaging will help to manage roaming data costs while providing initial data points on what consumers are willing to pay for added services, charting the path for the next stage of growth. Early adopters will include heavy users of satellite phones and satellite-powered gadgets, such as hikers and mountaineers who can't access cellular connectivity through their mobile devices. Handhelds such as inReach (Garmin) and Spot X (GlobalStar) have traditionally served this proven remote satellite communications market, which is worth approximately USD 400 million annually[19]. These consumers will possess a high willingness to pay and the likelihood to switch to an all-in-one DTH offering featuring regular monthly payments, offering a cannibalisation opportunity for MNOs.

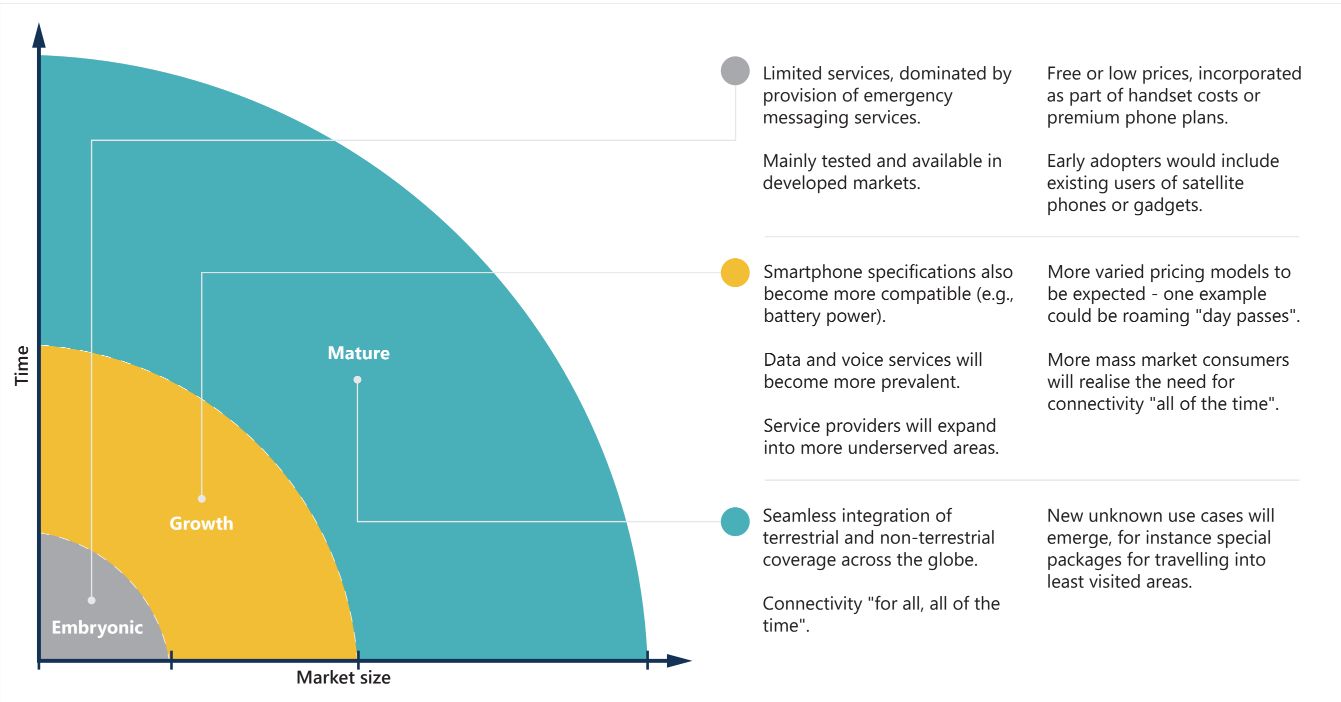


Figure 8: Increasing maturity of the DTH market

Source: Access Partnership analysis

The growth phase is expected to be marked by significantly enhanced DTH capabilities, such as a full suite of person-to-person communication across messaging, data, and voice services. Though most mass market smartphone users may not originally have paid for messaging in the embryonic phase, at this point, DTH services may be able to deliver an enhanced value proposition for the non-specialised smartphone user who wants to maintain off-the-grid connectivity while roaming outside of terrestrial coverage. Due to a less frequent need for non-cellular connectivity, pay-as-you-use 'day passes', where customers would sign up for satellite services only during periods when they might be travelling outside terrestrial cellular coverage areas, may become more popular than monthly payments. Also, populations that lack any terrestrial coverage could become paying mobile subscribers once DTH connectivity offerings become available. In the Americas, 22% of the rural population is not covered by a mobile broadband network. In Africa, the corresponding figure is 15% *(Figure 9)*. With more established business models, service providers will race to expand the breadth and coverage of services to underserved regions.

In the maturity phase, seamless integration of terrestrial and non-terrestrial coverage may be realised through DTH, supported by an evolution of industry and regulatory practices. In a bid to reduce duplication of infrastructure coverage and increase profitability, operators may coordinate with the support of regulatory agencies to sign national roaming agreements and jointly fill in coverage gaps efficiently. The

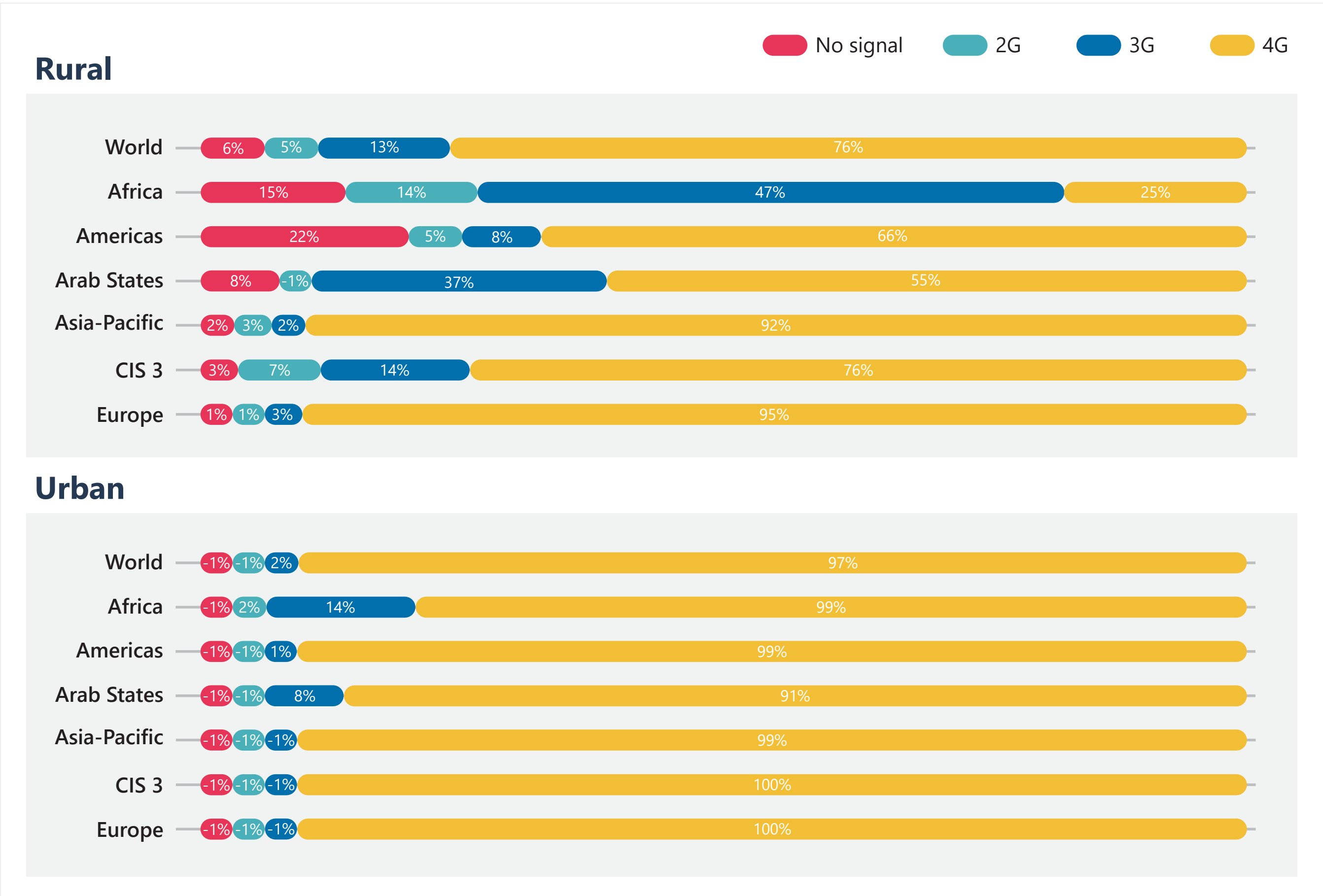


Figure 9: Population coverage by type of mobile network and area, 2022 - Share of total (%)

Source: ITU[20]

The values for 2G and 3G networks show the incremental percentage of the population that is not covered by a more advanced technology network
CIS refers to the Commonwealth of Independent States.

scope of disbursement for Universal Service or Access Funds, for the purposes of building broadband and digital infrastructure in rural and remote areas, may instead be expanded to support the buildout of satellite DTH infrastructure as a replacement for terrestrial coverage.

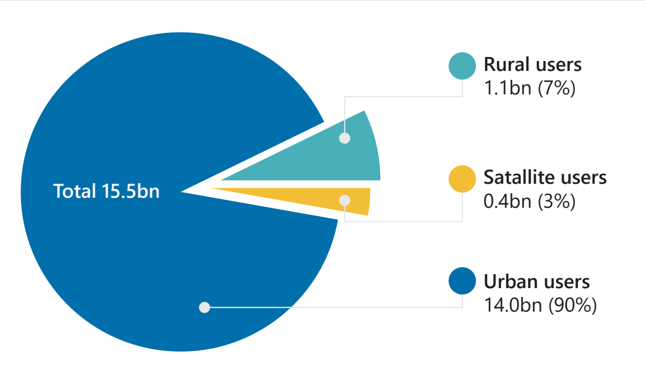


Figure 10: Global addressable market opportunity by type of end-user demand - USS billion, 2035

Source: Access Partnership analysis

This could be coupled with other specific digital divide programmes coordinated at the national and regional levels, while new unanticipated use cases may also develop. For instance, the provision of connectivity services for previously uninhabitable regions, such as outer space or beneath the Earth's geological surface, may become economically viable. Connectivity and communication services may also expand beyond messaging, data, and voice services to include other formats of information storage and transfer.

In total, this could contribute to a USD 15.5bn addressable market opportunity by 2035 *(Figure 10)*. Urban mobile subscribers will eventually constitute a large part of this revenue potential as DTH services expand beyond basic messaging into complementary data and voice services. Other core segments include specialised satellite communication users switching over to DTH services, as well as rural populations not under terrestrial coverage eventually getting coverage through DTH services.

5.2 Consumer behaviour and trends

With an addressable market of 400 million subscribers by 2035, the mass consumer market represents a key end market for DTH services. As the DTH rollout intensifies, multiple cellular and satellite industry partnerships have been announced, with various pricing models and strategies to attract users. At this point, it is still unclear how much consumers are willing to pay for DTH messaging, voice, and data services beyond emergency situations, which tend to be free. At first, simple messaging will be the first DTH offering. While messaging is not expected to constitute a major piece of the eventual DTH revenue opportunity[21], initial operator strategies may provide a first look into future business models and their eventual impact on consumer choices and prices.

As elucidated previously, DTH providers can expect two main archetypes of users. The specialised user already owning satellite phones or satellite-powered gadgets can be expected to be willing to pay a premium for complementary DTH satellite connectivity on their handset for incremental convenience. Android rugged satellite smartphone maker Bullitt is charging around USD 5 per month for two-way satellite-based messaging on its new phones[22].

There is also a non-specialised smartphone user, who can be assumed to be more reluctant to hand over additional cash for complementary DTH satellite connectivity. Operators will have to be sensitive in initial pricing and expend more effort in encouraging and educating consumers to appreciate its value. For instance, Apple is not yet charging for messaging, offering two years of emergency messaging for free. Other Android smartphone makers are poised to offer similar offers via Qualcomm's deal with satellite operator Iridium, and may charge a monthly fee for users to send and receive messages outside of their cellular operator's terrestrial coverage area or recoup such service expenses by increasing handset prices[23]. As a potential data point, analysts at Raymond James estimated that roughly 200,000 Android phone users will spend around USD 3 per month for satellite messaging by the end of 2023, growing to 4.5 million by 2026[24]. As for MNOs, one potentially popular model is to bundle DTH services into premium price plans. T-Mobile indicated that the operator would likely include satellite connections via SpaceX's Starlink satellites in its more expensive service plans[25]. A different model, more akin to a pay-as-you-use structure, might see MNOs sell DTH 'day passes', where customers would sign up for satellite services only during periods where they might be travelling outside terrestrial cellular coverage areas, as suggested by AST SpaceMobile's early IPO filings in 2020[26]. Across these models, emergency communications may be kept free while charging for person-to-person communications.

To enable maximum consumer choice and welfare in the long run, fostering innovation through competition in a nascent market is essential. In a seminal paper, 'Competition and Innovation: An Inverted-U Relationship', Aghion et al. (2005) provided empirical evidence across industries that firms competing neck-and-neck would have a high incentive to innovate to escape competition and earn monopoly profits[27]. This was followed up in 2019, where Aghion et al. (2019) further discussed that the change in innovation with respect to competition depends on the initial level of competition[28]. When the initial level of competition is low and there are many untapped markets, the effect supporting innovation dominates *(Figure 11)*[29].

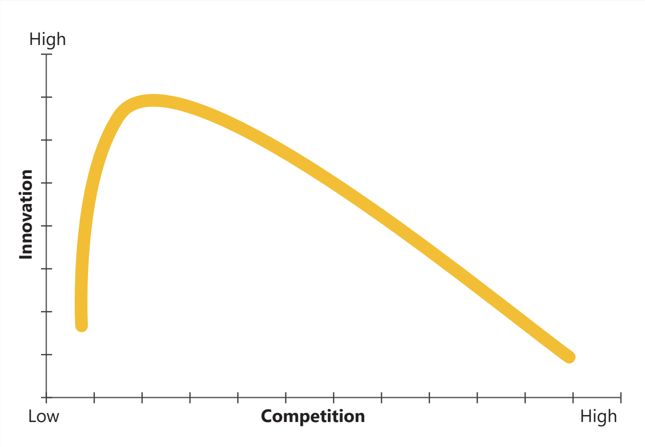


Figure 11: In a nascent untapped growth market where profits from innovation can be substantial, facilitating competition fosters innovation.

This is a stylised model of the relationship between competition and innovation. In the original model, competition is measured by (1-Lerner index) in the industry-year, while innovation is measured by citation-weighted patents..

Source: Access Partnership analysis, Aghion et al. (2019)

In a large untapped market like DTH, increasing the number of firms through competition does not reduce the natural incentive for each firm to innovate, due to the large ex-post profits that can be expected from innovation when compared with the costs of innovation. However, if competitive constraints for the satellite industry were imposed from the outset by channelling regulatory approval through a singular unique deployment model, far fewer willing firms would be able to innovate and freely collaborate to find innovative solutions, which is what initially led the telecommunications industry to its current position. In such a case, the long-term potential economic value of the DTH opportunity for superior product innovation and execution may be significant. In light of this, it is essential that regulators take a light-touch approach to this nascent market to maximise the economic opportunity of DTH services.

5.3 Business viability

Not everyone will be a winner in the DTH market. Despite the large addressable revenue opportunity, sizable financial and operational obstacles require a sensitive business case for DTH rollout. We foresee an eventual industry consolidation into an oligopolistic structure with few major players.

While the technology may be present, high capital requirements have always been a challenge for the industry. Access to capital facilitated by the right partnerships will be a key differentiating factor. Launching and operating satellites in space is costly. Lynk Global is planning to build out 5,000 satellites within two years, and its CEO, Charles Miller, estimates that the company will require several hundred million dollars of additional funding from its Series C funding to make this a reality. Starlink also filed an application with the US Federal Communications Commission at the end of 2022 to include a 'direct-to-cellular'-hosted payload on around 2,000 Gen 2 satellites[31]. The satellite launch costs alone could hit USD 600 million, not including other costs, such as ground stations, research and development, and satellite loss[32].

As DTH services reach the mass consumer segment and customers take time to develop their willingness to pay, material operating cash flow may prove elusive in initial years. In this context, first-mover advantage and strong access to consumers will help players get ahead in the race to establish a new DTH subscriber base.

Additionally, external funding for capital and operating expenditures will still be essential to bridge funding gaps. In a tight credit environment with high costs of capital, certain players may have trouble raising funding, especially if they are still developing proof of capabilities, such as the requisite commercial licences to operate, MNO contracts, regulatory approvals, or technology patents in various jurisdictions. Given this backdrop, the right industry partnership may be critical to providing credibility and loans for the initial constellation buildout.

One source of funds could be MNOs themselves, which may be able to redeploy cash originally meant to build out cell towers. Partner handset manufacturers may also be a vital source of funding. For instance, Apple is loaning its satellite partner Globalstar USD 252 million as a pre-payment to launch a new fleet of satellites, intended to be 95% of the approved spend for the satellites[33].

These initial signs indicate that any firm interested in the DTH play will require extremely deep pockets to fund the significant capital outlay needed to achieve scalability and favourable unit economics. Even then, not all of them will succeed.

5.4 Public value

Achieving universal, affordable Internet access is a key social and economic priority for countries around the world. The 193 member states of the United Nations agreed to work toward achieving this target by 2020 as part of the Sustainable Development Goals. To this end, many countries have established communal funds dedicated to expanding connectivity opportunities to unserved and underserved communities. For instance, Malaysia's Universal Service Provision Fund, launched in 2010, has been very active in promoting mobile broadband by expanding 3G and LTE coverage, contributing to fibre-optic network extensions, providing Internet access to 360,000 people through Internet access centres by 2014. For the most part, universal service funds are used to provide connectivity to rural and remote areas with fundamental constraints in network

economics for operators due to low population densities or geographical challenges, such as island features, which would be underinvested in the absence of any intervention. The advent of DTH and its potential inclusion as a qualifying service under these universal service funds can combat low disbursement rates and increase the effectiveness of funded programmes by helping to direct investment towards the provision of high-speed, reliable broadband to bridge the digital divide.

Alongside key economic benefits that DTH services bring to businesses, governments, and consumers, they offer significant economic potential to the broader society. By expanding the terrestrial coverage of broadband connectivity toward hard-to-reach locations, underserved populations that have difficulties connecting to the Internet would finally be given access to real-time information, facilitating increased economic activity. Increased coverage of higher quality 5G connectivity would also enable underserved populations to gain access to high-speed connectivity, promoting increased productivity among individuals.

Promoting widespread connectivity can mitigate the impacts of disasters by enabling communities in distant locations to receive emergency updates and critical information. While the value of investments required to set up DTH infrastructure will be significant, the potential economic impact that DTH technologies offer to the broader society may mean such investments could be necessary.

With around a quarter of the population across the globe living outside the reach of modern communication systems, there is a significant value of economic potential yet to be captured from this lost connectivity. A study by the ITU in 2018 covering 139 economies across the globe revealed that every percentage point increase in mobile broadband penetration increases an economy's GDP by 0.15%[34]. Thus, connecting the more than two billion

individuals who do not regularly use the Internet today could bring an estimated USD 1.2 trillion to global GDP through various cost savings and productivity improvements. For example, with more reliable mobile Internet infrastructure, consumer costs towards fixed infrastructure with high upfront costs can be redirected toward cheaper DTH services. Individuals would also be able to participate in the digital economy, promoting increased consumption of digital and digitally-enabled goods.

Broader coverage is also essential to tackling emergency situations. In particular, remote communities face disproportionate challenges in receiving updates related to natural disasters. With DTH services offering these underserved locations cheaper alternative access to mobile broadband, such tools can facilitate faster and timelier responses to natural disasters. For example, during the 2020 Cyclone Harold in the Solomon Islands, Vanuatu, Fiji, and Tonga, the reliable communications equipment provided by the ITU and Pacific meant locals affected by the disaster were able to access the community Wi-Fi service and quickly deploy disaster relief assistance, even after local network coverage was wiped out. This has become increasingly pertinent with the frequency of natural disasters expected to rise due to climate change[35]. Given this, analysis by Access Partnership estimates that under a ‘business-as-usual’ scenario, the global cost of natural disasters could reach around USD 320 million per year from 2023 onwards, constituting infrastructure damage, loss of life, and morbidity. However, improvements to communication systems facilitated by DTH services could reduce the impact of natural disasters by up to 38% – meaning around USD 120 million worth of economic impact could be mitigated per year from 2023.

Other societal benefits also illustrate the strong potential of DTH services. For example, promoting access to satellite services enables individuals to access broadcasting services, ensuring they are kept up to date on the latest social, cultural, and economic developments. Increased connectivity also facilitates more accurate navigation, tracking, and transportation systems that can minimise supply chain bottlenecks within remote locations. Finally, DTH infrastructure also provides MNOs backhaul alternatives in times of disruptions, lowering cost, and promoting reliability in times of need.

As of 2023, nearly a quarter of the world's population still lacks access to modern communications[37]. Unfortunately, this is not likely to change soon, and there is only so much that satellite or terrestrial networks can do on their own to address the existing coverage gap. Indeed, according to GSMA's predictions, if we were to rely solely on mobile networks, a significant portion of the world's population would remain unconnected for at least a few more years.

Despite advancements in network coverage over recent years, bridging the global connectivity gap has presented obstacles that traditional networks have so far been unable to overcome. Mobile network access remains out of reach in remote locations with low population densities, as well as in areas where geographic characteristics result in line-of-sight and signal blockage issues. This is due to mobile networks' inherent limitations in reaching remote and rural areas where the terrain is challenging, or where network economics are unfavorable. This isn't unique to terrestrial networks – despite significant changes and technological advancements in recent years, satellite communication also faces challenges that hinder its ability to provide universal access to digital communication.

The positive change we're witnessing today is the realisation that addressing persistent economic or geographic challenges to achieve ubiquitous connectivity may not be possible without innovative, creative solutions that require strong collaboration between different players and technologies. In this vein, we're seeing an increase in announcements of commercial partnerships between mobile and satellite operators to roll out DTH satellite services. Just as satellite operators have recognised that a mixed-orbit model and broader service delivery are necessary strategies to respond to rising competition within the satellite market, both telcos and satellite companies have realised that they can achieve more by working together.

Current DTH satellite services and the long-existing satellite phones differ in the technology used and the equipment required to establish communication links. The fact that the new set of DTH services integrates terrestrial and non-terrestrial networks in the same device – one which most of us already carry in our pockets – can be a game changer and a much-needed step to improve connectivity in areas where traditional communication infrastructure has been unavailable or unreliable for too long.

Benefits of DTH satellite services include not only reaching areas that are otherwise difficult or impossible to reach through traditional networks, but also providing backup connectivity in the wake of a natural disaster where terrestrial communication infrastructure is temporarily damaged and unavailable.

Other benefits include:

1 Disaster response and recovery

During natural disasters or emergencies, terrestrial communication infrastructure may be severely damaged or destroyed. DTH satellite services can provide a reliable means of communication for emergency response teams and affected individuals, helping to coordinate rescue efforts and facilitate recovery.

2 Telemedicine services

DTH communication can enable remote medical consultations and telemedicine services, which can be especially beneficial for patients in remote or underserved areas.

3 Decentralisation

DTH communication can help to overcome barriers to connectivity by providing a low-cost, decentralised means of communication. As DTH communication uses satellites to provide coverage, it can reach areas that are not served by traditional cellular networks. Additionally, DTH communication can be used with existing mobile phones, making it an accessible and affordable option for many.

6. Regulatory challenges

6. Regulatory challenges

The advent of DTH satellite communication technology is transforming the digital landscape, introducing new possibilities for connectivity and data transmission. This field is marked by two primary operational methodologies: the 'by-the-book' and 'alternative' approaches – each with unique regulatory considerations and challenges. The approach that an operator chooses can significantly influence how they fit into the current regulatory environment and the services they can offer.

The 'by-the-book' approach adheres to existing regulatory regimes, operating within the established requirements for both Fixed Satellite Services (FSS) and MSS. Many jurisdictions around the world have these requirements in place, providing a familiar landscape for operators adopting this approach. A notable example of this in action is the provision of additional services on licensed MSS spectrum, such as Apple's iPhone 14's MSS-based emergency service offering on the Globalstar network. However, it is worth noting that these existing MSS licences were not originally designed to encompass the full suite of DTH services. As such, to ensure regulatory certainty and accommodate the burgeoning potential of DTH communications, there is a growing need for regulators to update the licensing regime.

Conversely, the 'alternative' approach had, until recently, faced a barren and uncertain regulatory landscape. This stemmed from the question of how regulators and the industry would respond to a non-traditional approach to satellite communications. Nevertheless, some jurisdictions have started to investigate regulatory regimes that account for DTH.

Perhaps the most noteworthy among these is the FCC of the US. The FCC's Notice of Proposed Rulemaking on Supplemental Coverage from Space (SPS) proposes a regulatory framework to encourage cooperation between satellite operators and terrestrial service providers, aiming to expand the reach of wireless networks. While the proposed framework is still open for comment and subject to evolution, its intent is clear: establishing a collaborative relationship between satellite operators and terrestrial networks. This collaboration is achieved by allowing the FCC to authorise the operation of space stations on flexible-use spectrum currently allocated to terrestrial services, broadening network coverage.

6.1 Licensing

Companies operating direct-to-device satellite communications systems should obtain licences from the regulatory authority. These licences should include conditions that promote fair competition and ensure the maximisation of social and economic well-being but must not make artificial market access barriers or stifle innovation.

Licensing regimes should change to allow technology-neutral service offering and include rules for spectrum lease, quality of service, protection of users etc. DTH operators holding standard telecommunications licences may find that the services they intend to offer are not permitted under the traditional telecommunications licence. To account for the potential regulatory impact of the DTH service, there is need to address several factors. These include, among other contemplated changes, the regulatory status of satellite operators and MNOs implementing DTH servicing, potential changes to spectrum leasing rules, and the appropriate application of the FCC's E911, wireless alert, construction milestone, and spectrum aggregation rules to DTH.

Necessarily, the NPRM also addresses technical rules to protect incumbent terrestrial operations, including out of band emission and power flux density limits, coordination requirements, as well as the mitigation of harmful interference in adjacent spectrum bands and with respect to cross-border operations.

Whilst the questions in these initial stages of the market development are infinite, there are already key considerations we can pin down and explore.

As noted above, the FCC views the current proceeding as an opportunity to develop a framework to facilitate the continued growth of satellite operator and MNO partnerships. To that end, the FCC proposes specific licensing criteria necessary to effectuate these new DTH services.

First, that DTH can only be authorised in areas where:

1. an MNO holds (directly or indirectly) all co-channel licenses on the relevant spectrum band in a Geographically Independent Area ("GIA") and there are no primary, non-flexible-use legacy incumbent operations in the band; and

2. an NGSO operator has an existing Part 25 license (or grant of market access) covering this GIA.

Second, once this baseline criteria is established, a satellite operator may modify its authorisation to add MSS services, if the satellite operator has an application on file to lease the exclusive-use terrestrial spectrum from the MNO, and the MNO partner has applied for a blanket earth station application to allow its subscribers' handsets to receive transmissions from the satellite operator. The foundation of this regime reflects the FCC's expectation of ongoing, close collaboration between a satellite operator and their MNO partner.

Classifying DTH devices brings significant regulatory hurdles and licensing nuances. At the core of this concern is the classification that a DTH device is either a satellite phone with traditional mobile phone capabilities, or a mobile phone with satellite functionality. At present, DTH devices operate, for the most part, in a regulatory vacuum or are subject to two separate regulatory regimes, that of: conventional type approval of mobile devices; as well as the requirements of a satellite operator or service provider – making compliance more arduous and complicated.

6.2 Spectrum management and interference

As the use of both satellite and terrestrial connectivity to provide seamless connectivity to small, every day, transportable personal devices finally become a market reality, the next critical challenge to address in order to allow operations at the domestic level would be related to spectrum management: concretely, the frequencies that could be used and the measures to avoid interference. Likewise, spectrum allocation, assignment, and pricing models shall be adjusted to reflect the complementary network nature of these services. Moreover, to ensure the widespread use and access to DTH services, the conditions that enable the roaming between satellite and terrestrial networks that are expected to operate without being noticed by the user (i.e., automatic roaming) will also pose a challenge to the current rules regarding automatic roaming and network interoperability, presenting the need to revise them.

1. Spectrum allocation: The spectrum allocated to IMT is likely to be the first option for the industry for DTH operations. Spectrum used by MS is usually assigned after conducting public tenders or some form of competitive procedures, where interested parties pay significant value for the exclusivity of its use. Thus, sharing with satellite services would pose the challenge of ensuring that no interference takes place, and in general, that current spectrum holders are not affected in their operations, which also presents a regulatory risk for an administration that could be liable for modifying licensing conditions ex post to their issuance.

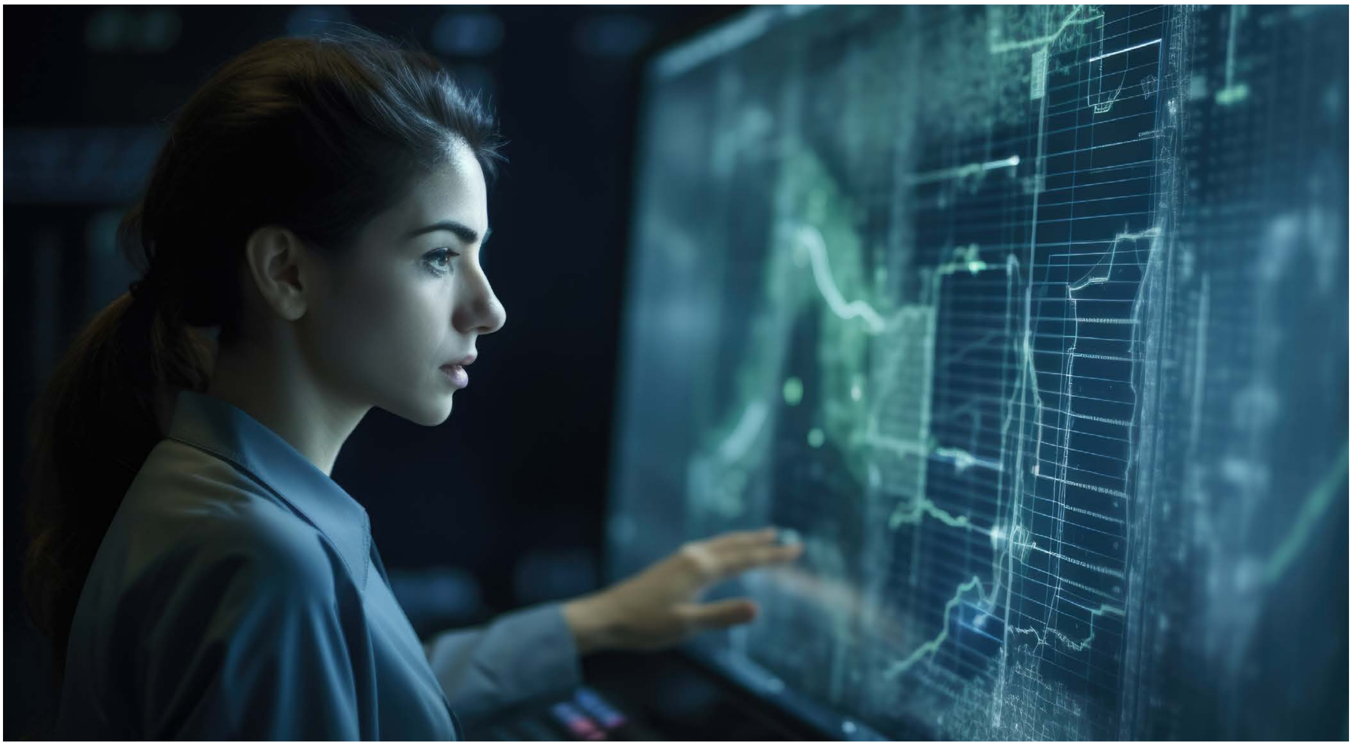
2. Spectrum sharing, reuse, and secondary markets: On the other side, if technical

conditions are met and the industry is able to ensure smooth operations, another challenge that arises is the fact that spectrum secondary markets are not widely developed around the world and that many administrations still impose highly burdensome conditions to enable spectrum licenses to be trade or leased.

3. Interference: The integrity and effectiveness of the radiofrequency spectrum, particularly mobile frequencies, is vital to a multitude of crucial services, from emergency response to data communication. It's imperative that no new service be permitted unless it can absolutely guarantee non-interference. To accomplish this, rigorous testing, validation, and certification protocols must be established. Advanced technologies such as dynamic spectrum sharing, and cooperative spectrum sharing can be explored to avoid potential interference. ITU Radio Regulation 4.4 outlines the principle that administrations implementing new radio systems must take all necessary steps to avoid causing harmful interference to the existing services of other administrations. In essence, it mandates that any new introduction of radio communication service should not detrimentally impact the functioning of the already existing and planned radio services of other countries[38].

6.3 Global allocations

ITU Resolution 212 and Resolution 223 designated the bands 1,980-2,010 MHz and 2,170-2,200 MHz for IMT. These frequencies, also known as the S band, are likely the first to be used for DTH considering the advancement in the technical developments and network deployments for mobile devices. This is also consistent with the international allocation for the mentioned bands, harmonised in the three ITU regions, and their respective international



footnotes. Regional bodies (CITEL, ATU, ATP, CEPT) have also issued recommendations for the use of the 1,980-2,010 MHz and 2,170-2,200 MHz bands for IMT, and their allocation for mobile and MSS. This is a first step towards the required harmonisation and allocation of spectrum for DTH operations.

1. In the Single Network Future: Supplemental Coverage from Space[38] Notice of Proposed Rulemaking GN Docket No. 23-65, the FCC proposed the amendment of the US allocation table to enable the operation of MSS with spectrum frequencies traditionally allocated to MS to remove regulatory obstacles that could be preventing the nascent partnerships between satellite and terrestrial providers to consolidate. The framework focuses on the need to advance coverage in underserved or unserved areas, particularly rural, where terrestrial services are not yet fully deployed. The proposal also considers the eventual need to allow FSS to operate as part of DTH, considering the technical evolution that shall continue. Additional considerations regarding the use of bands where no exclusive service applications are defined, and it is possible to use a 'flexible' approach regarding the intended use of the bands. The absence of potential harmful interferences is also considered within this decision.

2. Spectrum is a scarce resource and, as a general rule, its use should be efficient. This means that hoarding or other situations where one participant holds the rights to spectrum that is not fully exploited is a lack of efficient use of the resource. In addition to effective assignment rules and procedures from administrations, allowing spectrum secondary markets is a tool to achieve efficiency, by enabling the market to provide the optimal outcome in the distribution of the assigned bands, avoiding unused spectrum, and incentivising developments of alternatives for better coexistence and efficiency. Defining regulatory frameworks that clearly state the conditions to conduct spectrum leasing and trading will allow the development of spectrum secondary markets, and thus, create the conditions for a more efficient use[39].

6.4 Roaming and interoperability

Automatic roaming allows the users to access seamless coverage within a jurisdiction through the network components design that allows their devices to connect to the network that is available in their location regardless of the provider that operates it. Usually, roaming is carried out by commercial agreements between providers subjected to private negotiations. However, regulatory intervention is made to ensure agreements are reached, a dominant provider does not impose burdensome anticompetitive conditions, new entrants have opportunities to favour network expansion and coverage, among other policy goals. Thus, while it is not exactly a spectrum element, it is usually a regulatory obligation to provide roaming imposed on spectrum holders to meet to above mentioned objectives. For the operation of DTH, such technical developments and agreements would require the revision of current roaming regulation within administrations, much like the early developments of mobile terrestrial communications, to ensure competition and benefit end-users who are expected to have ubiquitous connectivity.

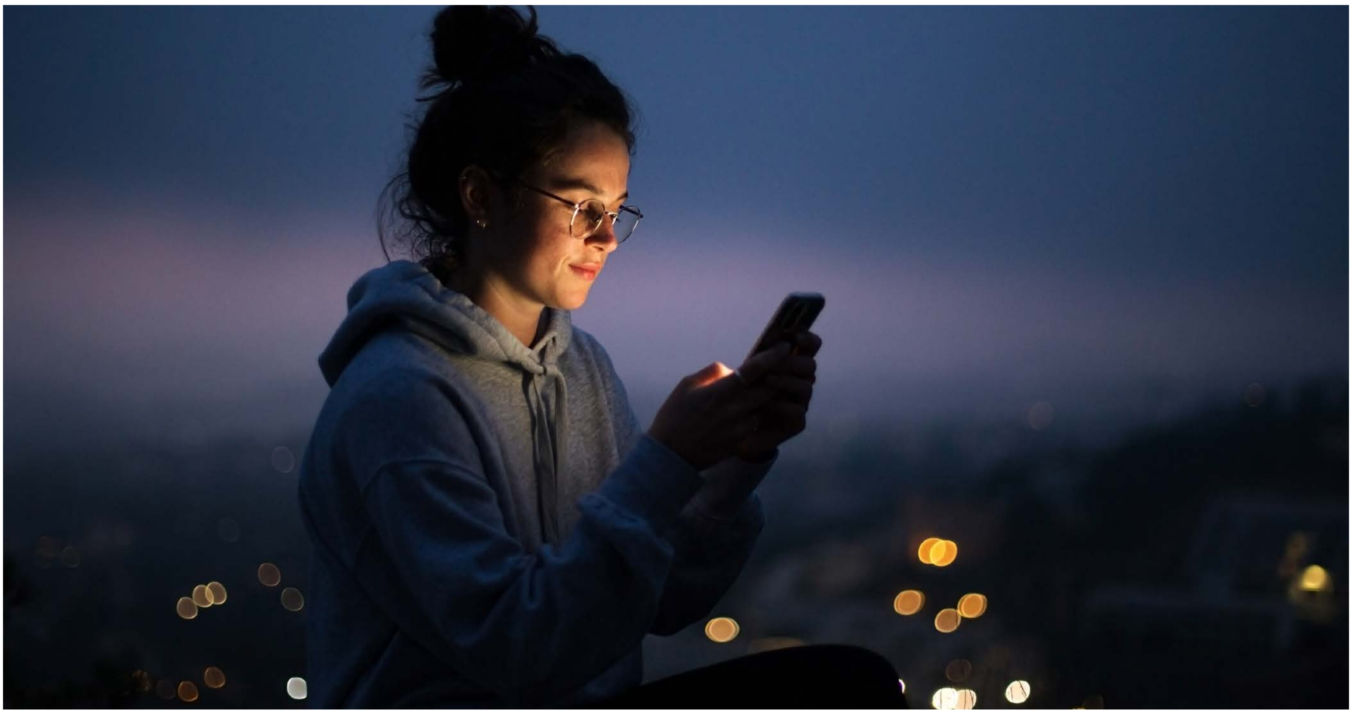
6.5 Universal access

To promote equitable access to DTH satellite communications, the regulatory authorities and policymakers should ensure affordable access to the services by designing the best available alternative for coverage, expansion, and overall contribution to the close of the digital divide. DTH operations provide a solution to the lack of coverage in several areas, particularly rural, by complementing the terrestrial network and filling out the blank spaces of coverage within a region or a nation.

Despite several advancements, around 50% of the global population remains without Internet access[40]. Part of the development goals and targets include access to the Internet and providing connectivity as a goal that enables the realisation of other rights and overall well-being of the population[41]. Maximising the capacity of newer technologies to expand the services and access to connectivity for the entire population is also a challenge deriving from the materialisation of the promise to have ubiquitous connectivity with complementary networks and DTH operations.

The coverage that is not provided by the market due to the lack of a business case that incentivises the deployment of networks and services creates the need for regulatory intervention to ensure all citizens are given access to connectivity. These interventions should encourage the market deployments of additional infrastructure and technologies for better coverage and provision of services, specifically in the segments where the end-users lack the capacity to purchase the services or where there are not enough market incentives for providers to conduct investments and expansions.

Public spending on the provision of connectivity services is technology-neutral[42]. Therefore, regulation shall neither impose nor discriminate in favour of the use of a particular type of technology and only define the desired outcomes or required solutions[43]. In this context, when universal service funds are available, they should be invested in the best available solution for the public policy objectives, mainly for closing the digital divide.



Policymakers' aim should be not to set out specific solutions or technologies, but to provide a flexible and open network architecture to reduce the burden and complexity of remedies imposed that were fixed on specific solutions or technologies.

6.6 Regional harmonisation

To ensure that DTH satellite communications systems can operate seamlessly across borders, administrations could work towards the development of harmonised regulatory frameworks and standards at the international level allowing the expansion of the services without causing harmful interferences.

The need to define spectrum allocations, standards, and parameters will materialise in some countries defining domestic rules for the operation or for testing purposes, with others following their lead. However, given the global nature of the investments and telecommunication operations, as well as the capacity of the spectrum to irradiate beyond geopolitical borders, the pressure to achieve agreements and recommendations at the international level will be hardened in the following years.

Increasingly, administrations are realising the need to analyse and reach international agreements for the streamlined operation of DTH services. In this sense, regulators are including these conversations on their regulatory agendas or defining the need to monitor the developments in the regulatory framework at the national or international level to identify the measures that are beneficial or necessary to enable further development of DTH. International agreements will be required for a worldwide smooth operation and provision of DTH services.

6.7 Other challenges to consider

In addition to the abovementioned challenges, as the market availability of DTH offerings becomes a widespread reality across jurisdictions, there are additional elements that need to be considered by the regulatory authorities to ensure the well-being of customers and end-users, as well as to ensure there are no market failures that could occur from lack of sufficient modernisation of the regulations. Said challenges will imply the monitoring of elements already regulated to determine if specific revisions or new rules are specifically required. The main elements to consider are described below.

1 Electromagnetic exposure concerns

To ensure the safety of DTH communication, it is important to consider potential health issues associated with radiofrequency signals used to transmit data between satellites and ground devices. Although no conclusive evidence has been found, long-term exposure to high levels of RF radiation may cause health problems. Therefore, the International Commission on Non-Ionising Radiation Protection (ICNIRP) should conduct studies and set safety standards for exposure to RF radiation for devices used in DTH communication to mitigate the risk of any potential health issues and ensure users' safety.

2 Quality of services

Service providers should be required to maintain a minimum level of QoS to ensure that users receive reliable and uninterrupted service. The regulatory authority should establish standards for service quality and monitor compliance through regular audits and inspections.

3 Security

DTH satellite communication systems should be designed with security in mind, with measures in place to prevent unauthorised access or interception. Companies should be required to report security breaches to the regulatory authority and take prompt action to remedy any vulnerabilities and abide by internationally agreed laws on security of networks.

4 Privacy

Privacy protections should be built into the design and operation of DTH satellite communications systems. The companies operating these systems should be required to adopt robust data protection measures, and users should be informed about the data that is being collected and how it is being used and handled.

7. Road ahead

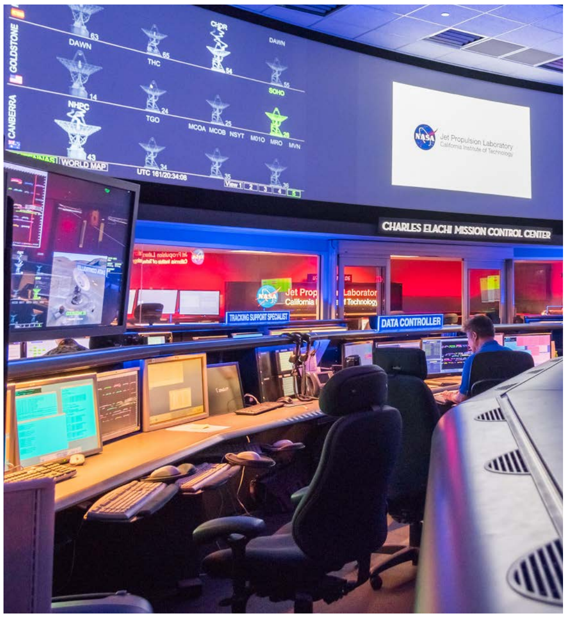
7. Road ahead

As we transition to a new era in DTH satellite communications, the years ahead promise transformative developments in this sector. The potential of DTH to enhance connectivity and bridge digital gaps is more significant than ever, especially in regions where terrestrial networks are limited or absent. We foresee advancements in spectrum management, regulatory consolidation, digital inclusion, data protection, service quality, and universal service, all unfolding within an evolving and adaptive regulatory framework that nurtures innovation while safeguarding user rights.

Spectrum management

Efficient and coordinated spectrum management remains the bedrock of successful DTH communications. With the accelerated pace of technological advancements, pressure on the finite capacity of the spectrum will only increase. As such, we expect global regulatory bodies to intensify their efforts in collaboration with international organisations and industry stakeholders. This collaboration aims to develop a standardised, cohesive framework that can efficiently manage current demands and adapt to future technological shifts, with an emphasis on maximising spectrum usage and minimising potential interference risks.

Data protection, security, and quality of service



With the projected increase in reliance on DTH networks for data transmission, concerns surrounding data integrity and security will be magnified. We expect the establishment of robust data protection frameworks, devised collaboratively by regulatory bodies and industry players. Transparent policies surrounding data collection, usage, and sharing, along with stringent security measures, will become imperative. Alongside data protection, maintaining high standards of service quality and safety will become paramount. Regulatory bodies will be expected to enforce clear guidelines on critical services, such as emergency services, ensuring network reliability even in times of crisis.

Coexistence models

In the upcoming years, we foresee a greater emphasis on coexistence models that allow DTH and other forms of communication to harmoniously operate side by side. The interoperability of DTH services within the 5G and forthcoming 6G ecosystems, along with other terrestrial networks, will become crucial. This integration will ensure seamless service delivery, promote efficient use of network resources and spectrum, and help bridge the digital divide.

Solving spectrum challenges

Solving the spectrum challenges that have been a persistent issue in DTH communications will take centre stage in the coming years. Greater collaboration between industry stakeholders, regulators, and international bodies like the ITU is anticipated. This joint effort may lead to the development of innovative spectrum management methods, such as dynamic spectrum sharing and advanced interference management.

Licensing regime

As regulatory authorities move ahead to consider how best to approach the paradigm shift that DTH represents to the communications sector, any changes must remain technologically neutral. This is to ensure that all DTH approaches are given sufficient room to mature to market changes and regulatory sentiments. Additionally, regulators should consider all the above considerations relevant to the proper functioning of a DTH service.

Assessing tech-readiness

Once again, national authorities have the historic responsibility of pioneering the market, paving the way for its regulation. In the context of the scarce spectrum resources, the full potential of DTH can only be realised when the underlying technologies are fully developed and ready for implementation. Prior to fast-tracking market entrance, careful consideration of the technology readiness for each project is crucial.

Get in touch

Our team is at the forefront of direct-to-handset regulation, and we are constantly monitoring and assessing the impact of this technology globally. To understand the regulatory implications of this important technology, please contact:

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Access Partnership

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