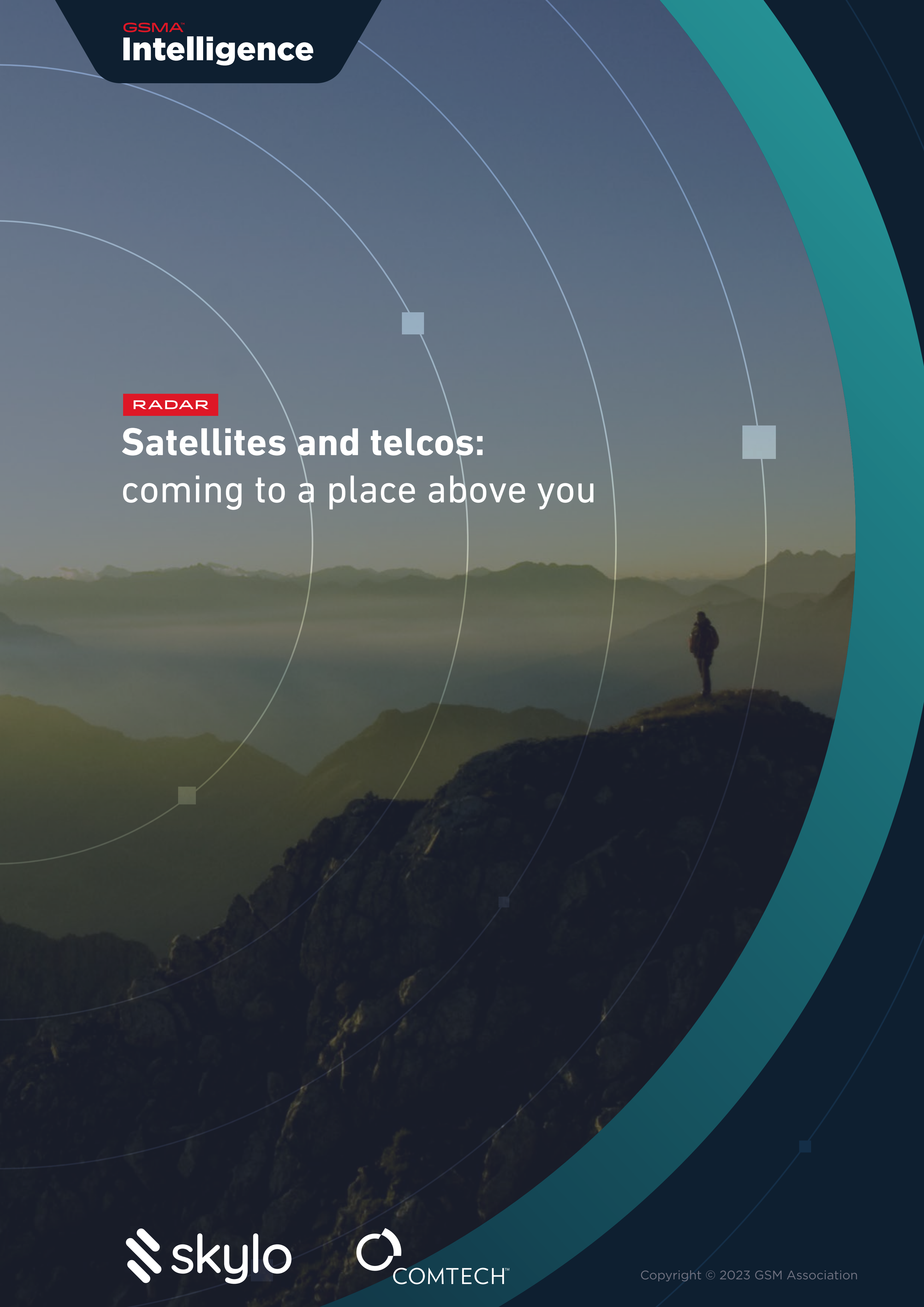

GSMA Intelligence

RADAR

Satellites and telcos:
coming to a place above you

skylo

COMTECH

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Contents

Executive summary

Despite gains in internet penetration levels across much of the world, stubborn gaps remain.

Some 1.2 billion people do not have a mobile phone. Mobile internet take-up is around 55%, but the rate of growth has slowed and continues to slow. While network coverage has expanded to more than 90% of the global population, the coverage gap remains a sticking point. This gap, and the prevailing economics of closing it, is the major driver of telecoms operators in search of satellite partnerships.

The consumer, enterprise and government segments are all in play for operators using satellite-enabled connectivity. While GSMA Intelligence has written extensively on the consumer side, this report explores the business-to-business (B2B) dimension. It reflects growing demand from enterprise groups and a rise in the supply of satellite-capable IoT devices embedded with the requisite chipsets that leverage the new radio (NR) standards from the 3GPP. This means satellite connectivity can be accessed seamlessly on devices updated to Release 17 or later.

A hive of competitive activity has taken root

Skylo has introduced standards-based satellite functionality for consumer smartphones and enterprise IoT devices with a consortium of partners, including chipset makers (MediaTek, Qualcomm, Sony), satellite partners (Viasat), carriers (Deutsche Telekom, Emnify, floLIVE) and eSIM/iSIM provider, Kigen. Skylo's 3GPP standards-based approach doesn't require a change in cellular device hardware, and allows devices to automatically roam between terrestrial and satellite signals – useful for devices with intermittent terrestrial connectivity and those transiting large distances, such as in logistics and maritime. Others are similarly targeting IoT devices with satellite connectivity. They use micro-sats roughly the size of a small home-delivery package, and embed a low-cost, custom modem in IoT devices to receive the connectivity. Meanwhile, Sateliot launched the first of a planned constellation of 250 satellites in April 2023 based on the 3GPP standards. The payloads can support low-power use cases (i.e. messaging) using narrowband IoT, with extensive geographic coverage. The company has also partnered with AWS for cloud and gateway infrastructure.

The potential revenue is $10 billion per year, from enterprises alone

GSMA Intelligence modelling suggests a potential overall uplift in the annual revenues mobile operators earn from B2B clients using satellite by around $4 billion globally, to $10 billion per year by 2035. Manufacturing, automotive and agriculture account for 65% of the addressable revenue opportunity. This speaks to both new demand and upselling existing customers; for example, it applies to vehicle manufacturers as connected infotainment systems and smart mapping continue to rise. In agriculture, the opportunity is driven by precision farming, such as the use of connected drones for soil monitoring and dispensing pesticides.

The potential $10 billion per year from B2B enabled by satellite connectivity may seem small compared to mobile operator revenues of around $1 trillion worldwide now. However, if B2B accounts for 20–25% of total revenues now and rises to 30% by 2035 on average, with 3% operator revenue growth per year, satellite could account for up to 20% of the rise in B2B.

Partnerships are moving from trials to commercial rollouts

There is a growing list of partnerships between operators and satellite groups, spanning several continents and covering direct-to-device (D2D) and other LEO technologies. Bharti Airtel's partnership with OneWeb to provide enhanced coverage in India has the single largest addressable base. Those of Telefónica (Europe and South America) and Veon (Russia, Ukraine, CIS, Pakistan and Bangladesh) are also sizeable.

All three of the national US operators have active satellite partnerships. AT&T has existing agreements with OneWeb and AST SpaceMobile, Verizon with Amazon's Kuiper, and T-Mobile with Starlink. Vodafone and Orange have deals in place with AST SpaceMobile and OneWeb respectively, with an intention to deploy across their footprints once constellations are operational. Vodafone has also now signed with Amazon's Kuiper for coverage across its European and African footprint, though testing will not begin until 2024.

Regulatory questions mostly involve spectrum, again

In terms of regulatory issues, one risk is instances where satellite companies seek to reuse terrestrial spectrum. Terrestrial licensed spectrum is acquired by telecoms operators on the basis of its intended use free from interference. Reuse by satellite groups would require extensive technical systems in place to ensure signals are only used by customers of telecoms partners in the specific geographic areas where those bands are operational.

1

From concept to delivery

Coverage gaps to close

Momentum in partnerships between telecoms operators and satellite companies has continued in 2023, with a shift from pilots to commercial launches implying service availability in late 2023 or early 2024. This new phase of market evolution follows years of planning, testing and commercial negotiations. Coverage has expanded from equatorial towards polar regions as more satellites enter orbit.

The basic premise and attraction of satellite to telecoms operators remains that it offers a means of providing coverage where it would be uneconomical to do so using terrestrial infrastructure alone. Data from the latest State of Mobile Internet Connectivity Report indicates that global internet penetration is now 55%, but with diminishing returns evident in further growth. Within the proportion of the population not online, around 500 million people still live in a coverage gap (outside the range of a 3G, 4G or 5G mobile network). While mobile coverage reaches more than 90% of the population, the final 5–10% (sometimes called the ‘final frontier’) is the most difficult to reach. Support from non-terrestrial systems is a pragmatic means of filling the gap.

Coverage gaps have reduced as a result of voluntary network sharing (passive and active) and tower companies becoming part of the network value chain. Tower companies can operate on improved economics and therefore extend land-based networks further into rural areas, through having multiple tenants.

Despite gains in internet penetration levels across much of the world, stubborn gaps remain, including the following:

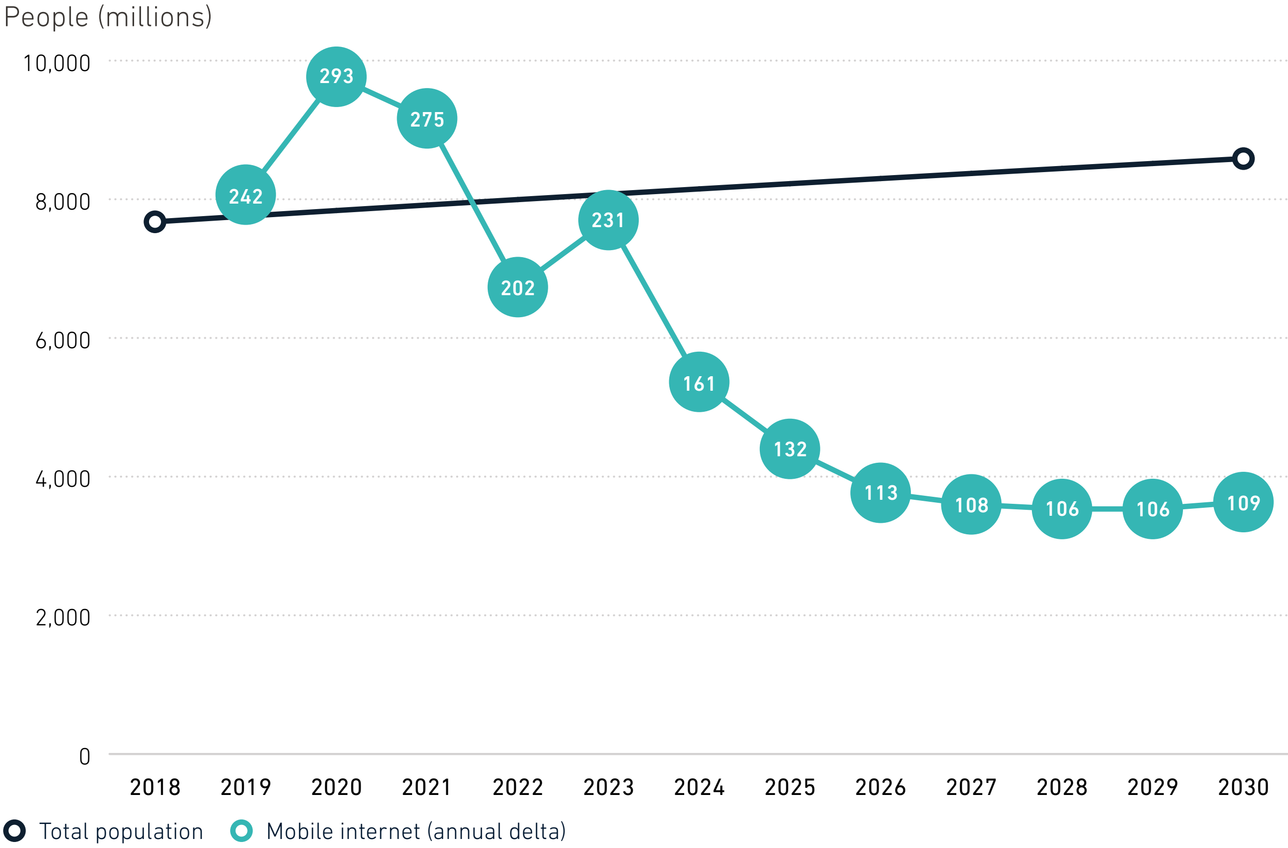
- 1.2 billion people don't have a mobile phone
- 55% of the global population actively use the mobile internet, with further gains in this rate diminishing over time
- Of the offline population, approximately 500 million people (8% of the global population) live outside or on the edge of the range of a 3G/4G/5G network (those capable of delivering the speeds necessary for a meaningful internet experience).

> Despite gains in internet penetration levels across much of the world, stubborn gaps remain

Using only terrestrial network expansion, the gap is unlikely to be closed. Figure 1 shows the forecast to 2030. Mobile subscriber penetration should increase by around 5 percentage points (pp) to 75% by 2030 (over 80% if we only include adults). A similar rise will occur for mobile internet access, which is forecast to grow from 55% to 65% of the population by the end of the decade. However, this masks the fact that mobile internet subscriber growth is decelerating. Before 2020, the net gain in new internet users (the annual delta) was 250–300 million per year. This had fallen to 200 million in 2022 and will decline steadily over the next seven years to an average run rate of 130 million per year. In short, the world is adding new internet subscribers at only half the pace that it has been.

Figure 1

Mobile internet penetration is at nearly 60% worldwide, but growth is slowing



*Number of unique subscribers with an active mobile tariff. This is lower than the total number of SIMs (or connections) in circulation as it excludes multi-SIM ownership and subscriber inactivity.
Source: GSMA Intelligence

Coverage gaps are rooted in economics

The diminishing returns in incremental rises in mobile internet subscribers are a result of several barriers, including lack of coverage, affordability and relevance. The coverage barrier has often been regarded as reducing over time; to a large extent this is true, as mobile networks have expanded from around 75% to more than 90% of the population over the last 10–15 years. However, the final frontier presents fundamentally different economics because of the geographic realities of laying and linking network infrastructure in remote areas. Backhaul costs can rise 5–10× compared to those for suburban or rural areas. There are also increased costs associated with new base station construction, energy and ongoing maintenance. The result is a higher TCO for telecoms operators, which is tough to offset against new revenues as population densities tend to be low and with lower incomes.

The coverage gap figures are shown in Table 1. While the coverage gap is most acute in Africa, South Asia and other emerging markets, it also exists in higher income regions such as Europe and the US. The rural coverage challenge is a global one.

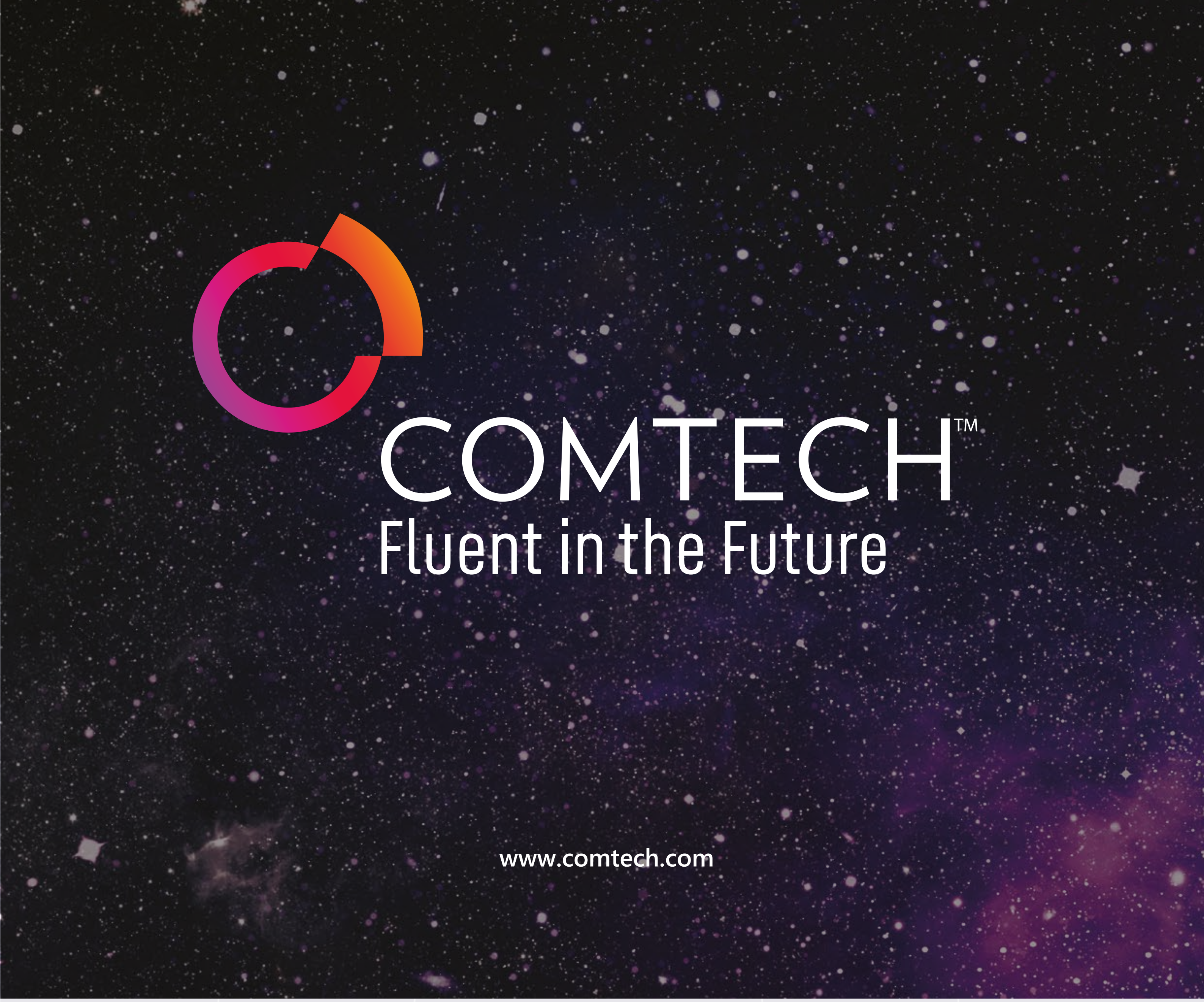
Without satellite support, the coverage gap is unlikely to close at any material scale. GSMA Intelligence projections indicate a gap of around 7% of the global population by 2025 – a sizeable number in absolute terms.

Table 1

Even by 2025, the world will still have a mobile internet coverage gap

2025	**Adult population** (million)	**Mobile internet subscribers** (million)	**Usage gap** (% of population)	**Effective coverage gap** (% of population)*
East Asia and Pacific	2,126	1,786	13%	6.9%
Europe and Central Asia	729	657	6%	7.3%
Latin America and the Caribbean	575	435	23%	5.8%
Middle East and North Africa	453	307	29%	7.3%
North America	336	309	8%	4.1%
South Asia	1,682	933	41%	8.1%
Sub-Saharan Africa	888	415	46%	12.1%
Global	6,788	4,841	25%	7.7%

*Calculated as the sum of people that lack or are on the edge of mobile network coverage. It is expressed as a share of the adult population. For example, for Sub-Saharan Africa, the calculation is: (66 million + 42 million) / 888 million = 12.1%
Source: GSMA Intelligence



With more than 50 years of proven technology leadership across global satellite, space, terrestrial, and wireless markets, Comtech enables ubiquitous, smart-enabled connectivity anywhere, anytime creating new opportunities for industries, businesses, communities, government, and individuals.

Comtech's **Dynamic Cloud Platform** will enable traditionally disparate satellite systems and ground station infrastructures to be easily integrated, creating a new path to introduce cloud-based applications, waveforms, and services.

The company's DCP is designed to be infrastructure, cloud, and application agnostic, allowing satellite customers to easily orchestrate, integrate, and manage a wide variety of applications, waveforms, and services across private, public, and hybrid cloud-based networks.

2

Competitive update

An expanding range of uses, with growing B2B demand

Satellites (sometimes referred to as non-terrestrial networks or NTNs) and the updated D2D model can target multiple market segments.

For the consumer segment this includes:

- backhaul to sites with weak existing capacity (better service for customers in hard-to-reach areas)
- backhaul to areas with no existing coverage (offering a route to new mobile broadband or FWA subscribers)
- roaming service in areas with weak or no coverage. This could be sold to the domestic customers of an operator wanting ubiquitous coverage (e.g. for mountaineering, driving or travelling) or inbound roamers from tourism.

For the B2B segment, it includes cellular or IoT coverage for a range of sectors:

- land-based industries (e.g. mining, oil & gas, rail and logistics, automotive, agriculture)
- aviation
- maritime.

For the government segment, it includes:

- disaster and emergency response
- defence.

While GSMA Intelligence has written extensively on the consumer side, this report focuses on the B2B dimension. This reflects growing demand from enterprise groups and a rise in the supply of satellite-capable IoT devices embedded with the chipsets that leverage the NR standards from the 3GPP.

Starlink, OneWeb, Kuiper and others join the fray

The coverage gap, and the prevailing economics of closing it, is the major driver of telecoms operators in search of satellite partnerships.

A step-change in constellation size was the key development ushered in with LEO constellations, starting with the initial SpaceX (parent of Starlink) approvals in 2016. This was enabled by form-factor size reductions, including the use of nano-sats, and huge falls in the prevailing cost of satellite launches. Starlink had almost 3,600 satellites in orbit as of March 2023, around 30% of its planned initial constellation of 12,000 by 2027.

OneWeb and Amazon are Starlink's nearest competitors, at least in terms of planned constellation size and orbital capacity. OneWeb's constellation is planned to reach almost 650 satellites, with current deployment actually further along as a share of the expected total. Amazon's Kuiper initiative has a sizeable planned footprint of more than 3,000 satellites which recently gained regulatory clearance for launch. Amazon can execute a vertical integration strategy using its AWS infrastructure and edge nodes to support a vast ground station network, with Bezos-owned Blue Origin providing additional support.

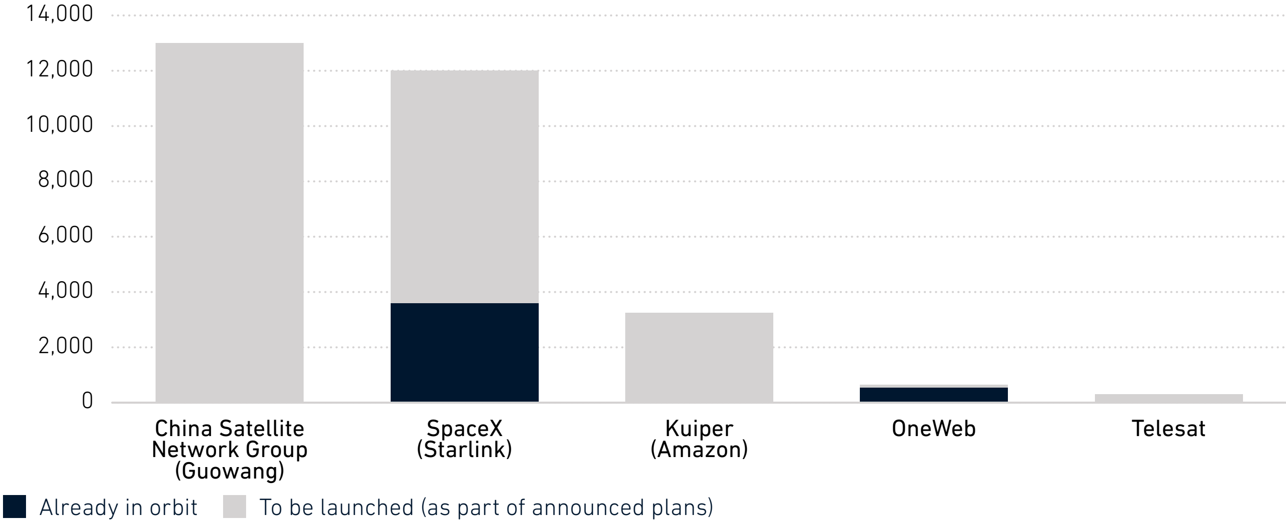
China has a clear strategic interest in satellite capacity, and the advantage of scale and speed. The China Satellite Network Group's planned Guowang constellation would be the world's largest, if it reaches its target of around 13,000 satellites. The deployment would likely have both civilian and military uses. Public disclosure on timelines is limited.

A long list of other firms are also active, including established groups such as SES, Globalstar and Eutelsat, and emerging companies running different models – notably Swarm, now owned by Starlink.

Figure 2

Starlink and OneWeb are global leaders in LEOs deployed, though others are active

Total number of satellites



Source: GSMA Intelligence

Operator partnerships are a global story

The growing list of partnerships between telecoms operators and satellite groups spans several continents and covers D2D and other LEO technologies. Figure 3 shows some prominent examples, along with the mobile customer footprint of the participating operators. Bharti Airtel's partnership with OneWeb to provide enhanced coverage in India has the single largest addressable base. Those of Telefónica (Europe and South America) and Veon (Russia, Ukraine, CIS, Pakistan and Bangladesh) are also sizeable.

All three of the national US operators have active satellite partnerships. AT&T has existing agreements with OneWeb and AST SpaceMobile (in which it is also a strategic investor), Verizon with Amazon's Kuiper, and T-Mobile with Starlink – announced to much fanfare in August 2022, though with no firm deployment timelines.

Vodafone and Orange have deals in place with AST SpaceMobile and OneWeb respectively, with an intention to deploy across their footprints once constellations are operational (in 2023/2024). Vodafone has now also signed with Amazon's Kuiper for coverage across its European and African footprint, though testing will not begin until 2024. This suggests large operators may use multiple satellite partners depending on the required coverage footprint. Alternatively, they are betting on multiple horses to see who will ultimately win the race. The partnerships cover links to unconnected populations, B2B, disaster relief and the potential for enhanced roaming coverage for existing customers. This implies coverage across a total footprint of around 280 million existing mobile customers, or 25–30% of the total African subscriber base. These are just two examples; eventual satellite coverage is likely to extend over a larger customer footprint.

While the last few years have seen various trials, satellite-enabled service is expected to come online in the next 12–18 months. Additional capacity will be added over time, based on take-up, to ensure high performance.

Figure 3

Examples of partnerships between telecoms operators and satellite companies

A) Veon; Starlink – Ukraine: 24 B) BT; OneWeb – UK: 22 C) Rakuten; AST SpaceMobile – Japan: 5 D) Orange; OneWeb – Middle East: 3

Note: numbers indicate mobile subscriber base (million) of telecoms operator across the footprint covered by a satellite partnership. The actual uptake would target a smaller number of customers (those out of coverage), but the chart shows the relative size differences between operator footprints.

Source: GSMA Intelligence, company websites

3

5G and D2D

A complement to terrestrial coverage

The resurgence of direct-to-device (D2D) communications is one of the most notable developments in satellites over the last two to three years. D2D is not new; it has been used to service maritime and other industry clients with remote operations (e.g. oil & gas, mining). The problem was that D2D satellite phones and airtime plans were prohibitively expensive, exacerbated by weak competition. This has, however, changed on account of lower delivery costs and the inclusion of non-terrestrial network (NTN) standards in 3GPP. The first is Release 17, which provides support to integrate satellite connectivity with mobile broadband and IoT devices.

The standards integration increases the addressable base of devices that can use satellite connectivity by an order of magnitude. This is because NTN functionality can now be incorporated as standard into chipsets, smartphones and IoT devices (things like sensors and modules). The pace at which the change happens will depend on factors on the supply side (e.g. when each OEM chooses to incorporate NTN compatibility into their own designs) and the demand side (e.g. whether consumers and businesses will pay for expanded coverage, and how quickly they upgrade a device). We expect a three- to five-year transition, at the end of which a majority of new handsets and IoT devices would include NTN integration.

Performance upgrades will also happen in a staged fashion. Most satellite-enabled connectivity via D2D pilots has focussed on low-power applications such as messaging (e.g. weather monitoring). As capacity is added, voice and ultimately data (i.e. internet) access enter the frame. Added technical support will come with Release 18 in 2024 (also known as 5G-Advanced), which will (for example) permit carrier aggregation and larger band sizes for satellite.

Strategic benefits of D2D

D2D has several strategic points of significance for telecoms operators and their suppliers:

New subscribers
D2D increases the addressable universe of devices available for satellite connectivity because of the NTN integration into 3GPP standards. This means any devices compatible with Release 17 or higher could receive satellite signals. The approximately 600 million people in the coverage gap would be the first port of call and come online in stages as the handset replacement cycle plays out. D2D would be an option for IoT devices (such as weather meters or low-power sensors) that are out of range of terrestrial coverage and often off-grid.

Roaming
D2D extends roaming capabilities to remote areas not previously available to terrestrial networks (e.g. mountainous terrain), which customers could tap into when moving through such regions.

Driving economies of scale
Chipset and handset makers can manufacture on a greater scale to the 3GPP's common standards for 5G, rather than having to cater to specific countries or regions. This should reduce costs (or at least prevent them increasing). However, precisely when each handset maker provides support will vary, as this is a commercial decision.

Enabling cost efficiencies
For operators, D2D reduces the costs (and time) associated with integrating NTN signals into terrestrial base stations. It also does not require new sites to be built if satellite is repurposed for fronthaul as well as backhaul. D2D obviates the need for any receiving dishes that previous satellite technologies require to 'hop' the signal to an end-user device (like using a local community centre as the receiving point for villagers to connect to). This reduces the total cost of the overall service.

4

The pivot to the enterprise segment

Assessing the addressable base

Much of the attention from expanding satellite coverage has understandably been geared towards coverage in-fill for those lacking signal, or for disaster-response scenarios. The enterprise side has garnered relatively less attention. This is starting to change, in recognition of clear demand from SMEs and even larger enterprises for stable connectivity to service IoT installations in hard-to-reach areas or for transiting purposes (such as with logistics).

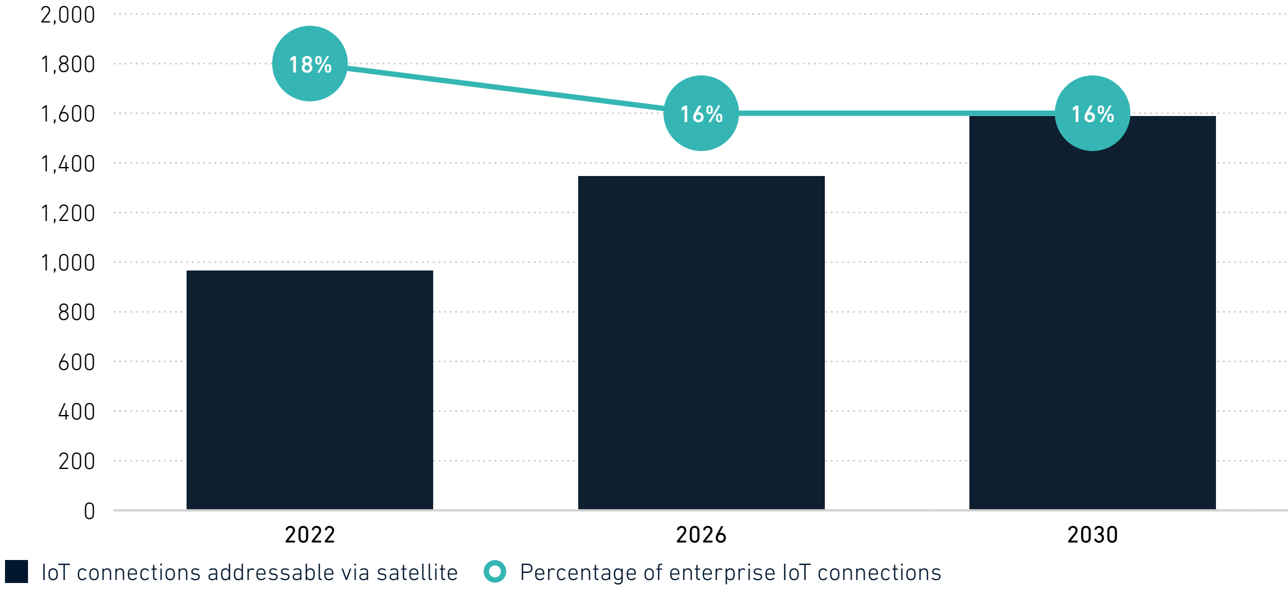
GSMA Intelligence survey data indicates that 15–20% of enterprises already use, or would be interested in using, satellite connectivity. This skews higher for industries with remote operations – oil & gas, and mining – and for logistics/haulage. The 15–20% may at first glance seem high, but it may be reflective of businesses who have terrestrial coverage from a mobile operator on an intermittent basis, making satellite a desired back-up.

When the survey projections are combined with GSMA Intelligence IoT forecasts, an addressable IoT base emerges of around 1.6 billion connections by 2030. This rises to 2 billion by 2035, which is the horizon used to express revenue projections in this chapter. Figure 4 shows that satellite can reach almost a fifth of enterprise IoT connections by 2030.

Figure 4

Around 1.6 billion IoT connections are addressable for satellite by 2030

Millions

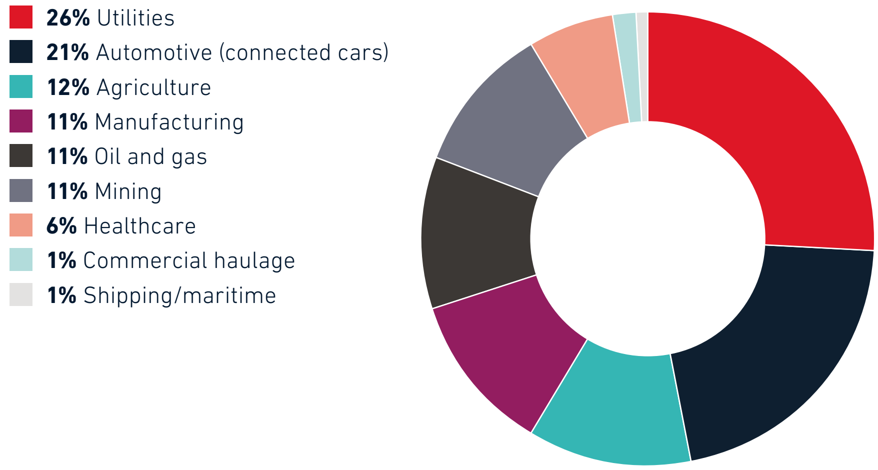


Source: GSMA Intelligence

Figure 5 splits the opportunity between different industries. It shows a wide range of buying industries. Traditional users of satellite connectivity such as shipping and mining will inherently be reflected as terrestrial signals in many cases cannot physically reach their locations. Agriculture, utilities and manufacturing are newer demand segments, driven by the growing need for precision and analytics to adjust production capacity in real time. The B2B demand implies the need for extended sales channel reach from operators and their partners. Meanwhile, the nature of the landscape means some industries will account for a large share of the addressable device base (volumes) but a lower share of revenues because of lower prevailing price rates. Utilities, weather monitors and some large fleet contracts for logistics operators would be examples of this, with ARPU levels of only $0.25–0.50 per connection, per month, compared to higher spend in the manufacturing and consumer automotive industries.

Figure 5

Sector split of the IoT base addressable via satellite, 2035



Source: GSMA Intelligence

Converting the addressable base into revenues

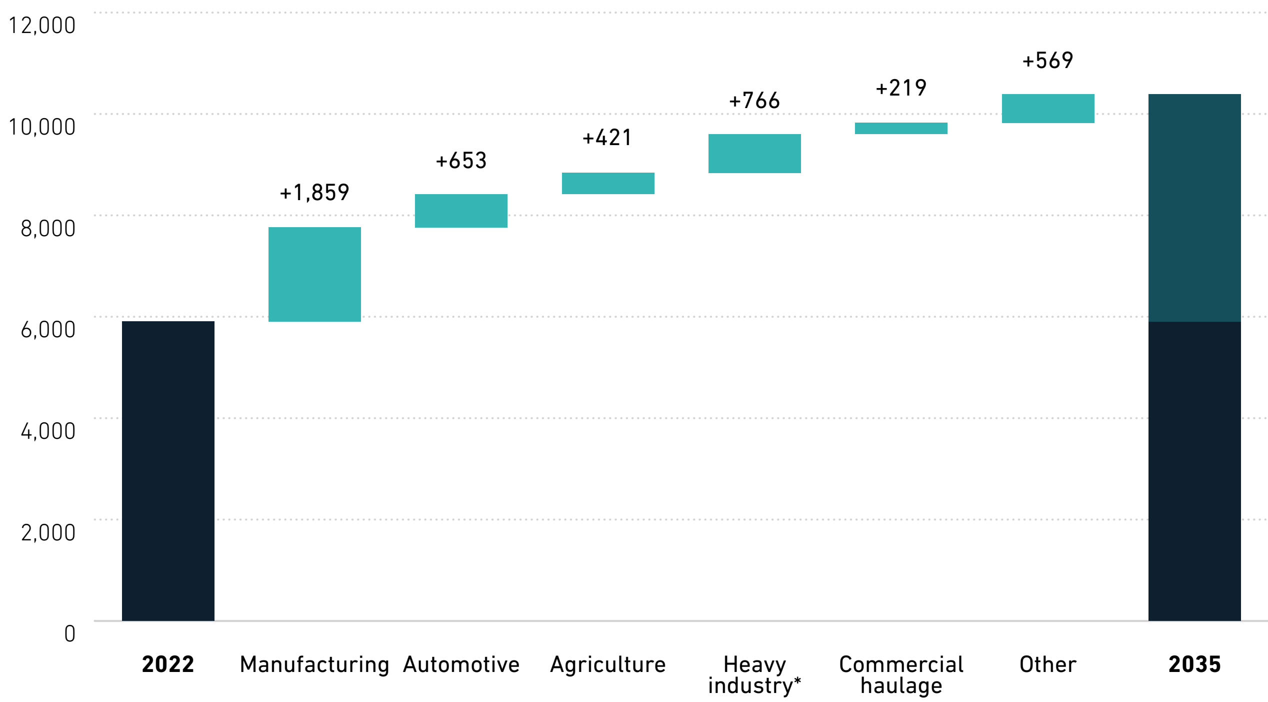
A hive of competitive activity has taken root. Most of this stems from the integration of NTN into the 3GPP's 5G NR standard. NTN integration means satellite connectivity can be accessed seamlessly on devices updated to Release 17 or later. It will take some time for satellite connectivity to percolate through the consumer set of devices (mostly smartphones) because of the handset replacement cycle. However, it is quicker for IoT as much of it is new anyway, and modules are built to be embedded in devices fairly easily. Examples of competitive activity include the following:

- Skylo has introduced satellite functionality for consumer smartphones, wearables and enterprise IoT devices with a 3GPP 5G NB-NTN approach leveraging existing satellite constellations. Skylo presents a standard cellular interface to devices as well as other cellular carriers to automatically roam between terrestrial and satellite signals. This is possible as both use 3GPP standards. MediaTek, Sony and Qualcomm have publicly announced their partnerships with Skylo to support its network in their respective modems, as well as module-makers such as Murata and Quectel, and consumer device makers such as Bullitt and Motorola.
- Sateliot launched the first of a planned 250-satellite constellation in April 2023. The payloads can support low-power use cases (i.e. messaging) using narrowband IoT, with extensive geographic coverage. The company has also partnered with AWS for cloud and gateway infrastructure. It has disclosed a confirmed sales pipeline of €1.2 billion. While Sateliot has not specified a timeframe for the pipeline, it is targeting annual revenues of €1.2 billion by 2026 with an EBTIDA margin of approximately 30% – something that will heavily rely on the vertical integration and lower build/launch cost of satellites

Figure 6

Around $4 billion of incremental B2B revenue is on the table for operators via satellite

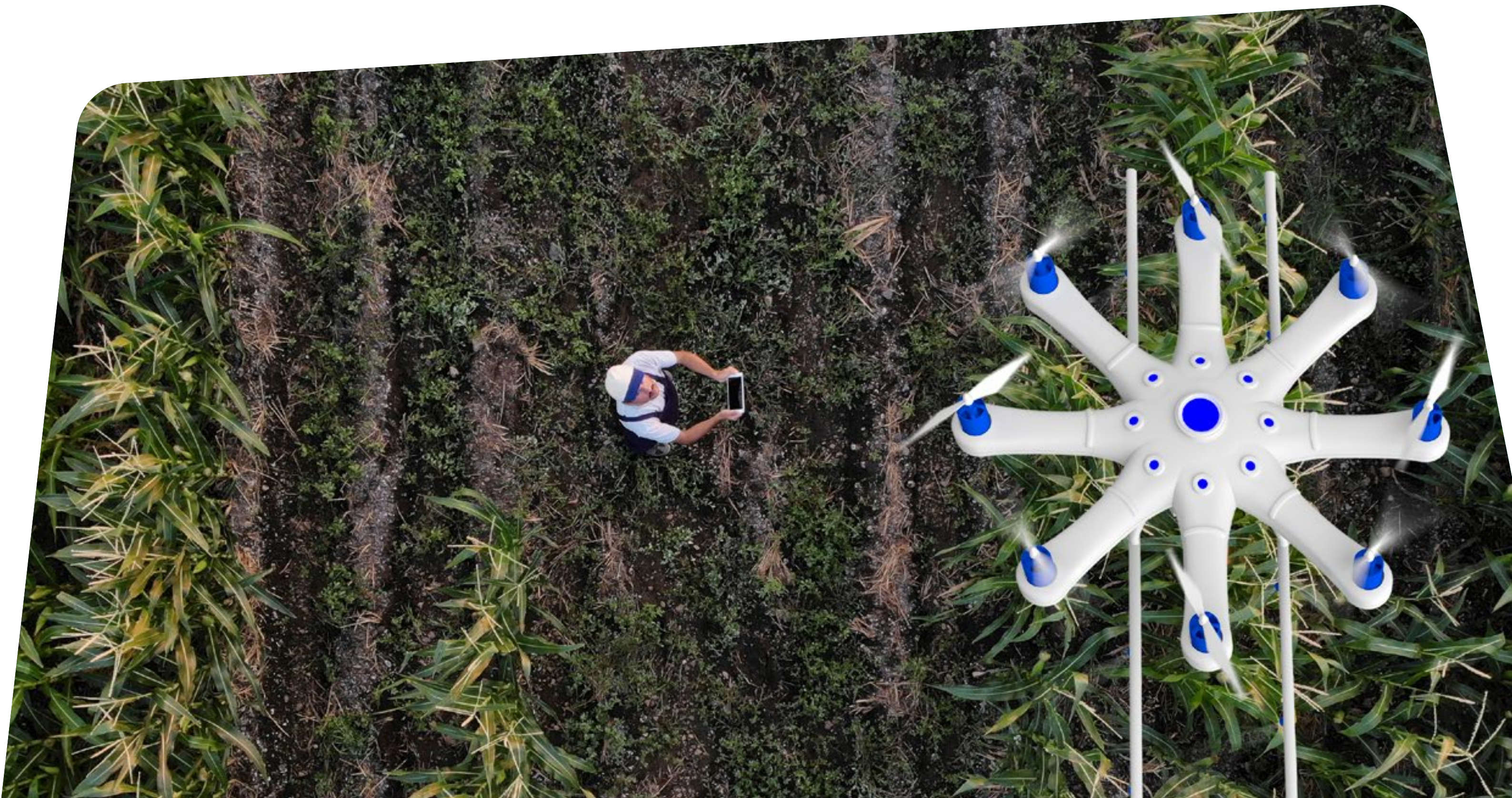
Addressable B2B/IoT revenue from satellite ($ million)



*Includes mining and oil & gas
Source: GSMA Intelligence

GSMA Intelligence modelling suggests a potential overall uplift in the annual revenues operators earn from B2B clients using satellite of around $4 billion globally by 2035. Manufacturing (mostly low-power use cases), automotive and agriculture account for 65% of the addressable opportunity. This speaks to new demand and upselling existing customers; for example, this applies to vehicle manufacturers with the rise of connected infotainment systems and smart mapping. The opportunity in agriculture is driven by precision farming, such as the use of connected drones for soil monitoring and dispensing pesticides. Heavy industry includes offshore oil & gas rigs and mining. The latter is employing drones for site surveys of remote areas.

The potential $10 billion per year from B2B enabled by satellite connectivity may seem small in relation to operator revenues of around $1 trillion worldwide now. However, if B2B currently accounts for 20–25% of total revenues and rises to 30% by 2035 on average, with 3% operator revenue growth per year, satellite could account for up to 20% of the B2B increase.



5

Implications and outlook

Standards and spectrum

Regulation is generally becoming more accommodating of satellite services, but issues and complications remain. Mobile satellite service (MSS) via D2D would generally operate in L-band and S-band spectrum, in which the satellite company transmits with its own holdings, integrating into the terrestrial network of telecoms partners which, in turn, transmit on their own licensed bands.

This is the approach companies such as Skylo have chosen, in partnership with MSS operators such as Inmarsat and Viasat. The decision on whether the use of a spectrum band is permitted for an application is country-dependent. Europe, Africa and parts of the Americas are generally accommodative of MSS, though some countries have stipulations in place. In countries with less permissibility (such as South Korea and Japan), commercial operations could be delayed or not possible pending changes to spectrum allocations.

In bands outside this range, such as the mid-band that T-Mobile wishes to use with Starlink in the US, regulatory permission is still required even if that spectrum is already controlled by a telecoms operator, potentially adding further time. Sub-6 GHz is near capacity and is being targeted for mobile use to accommodate the inevitable rise in data traffic from 5G smartphones, meaning it is unlikely to be used for satellite.

Spectrum management for satellite services will be done on a country and regional basis rather than through a one-size-fits-all global approach. This places an emphasis on coordination between operators, satellite providers and national communication authorities (or other spectrum licensing bodies) to ensure harmonisation for a given frequency range, which adds time and should be factored into any potential partnership.

Chipsets and devices

The device and chipset/modem aspect is mostly about the supply side. Most of the indicators are positive.

NR integration with Release 17 underpins the interlinkage between satellite and cellular connectivity. Modem supply with in-built NTN capability has grown. In addition to the aforementioned examples, Qualcomm's launch of two modems – in partnership with Skylo – specifically designed for NTN access in off-grid, hard-to-reach areas further boosts product availability, again catering to a range of use cases including asset tracking, mining and forestry management.

eSIM capabilities have increasingly become native in IoT devices, offering an easier way to bring IoT devices satellite connectivity than physical SIMs (given that a new device needs to be purchased).

The consumer side will take longer on account of the handset replacement cycle and barriers to phone ownership regardless of whether coverage exists (e.g. cost, literacy). Devices compatible with Release 17 or later will have access, but this will take at least five years to pass 50% of the installed base.

While the overall revenue opportunity is larger from consumers (higher ARPU levels), we expect to see a faster growth rate in NTN-connected IoT devices as supply can come online quicker. In both segments, customer connections should start to come online in meaningful numbers in late 2023 and into 2024 as service is launched, providing a step-change in mobile internet take-up and IoT in a range of verticals.

Appendix

Satellites are typically differentiated based on two main criteria:

- altitude
- density.

Altitude

The key trade-off between altitude and connection strength is that as altitude increases, ground coverage is boosted but with a resultant increase in latency.

LEO satellites are nearest to Earth, at roughly 400–1,500 km above sea level (for context, commercial airplanes fly at an altitude of 10 km). LEO satellites circumnavigate the globe around 16 times per day. Lower altitudes mean it takes less time for signals to make a round trip from satellite to Earth, so many LEO constellations also have the shortest latency, typically 30–40 ms – a prime justification behind their newfound use to support broadband provision.

GEO satellites are furthest away from Earth, occupying an altitude of 35,800 km directly above the equator. This altitude is chosen for a specific purpose: the orbital period matches the Earth's rotation (24 hours). For a person on the ground, the position of a GEO satellite remains the same throughout the day, preserving line of sight and reducing the risk that coverage is lost. However, GEO satellites have a latency 20× longer than LEO (typically 600 ms), which is a potential limitation for rapid turnaround use cases in industrial settings.

Density

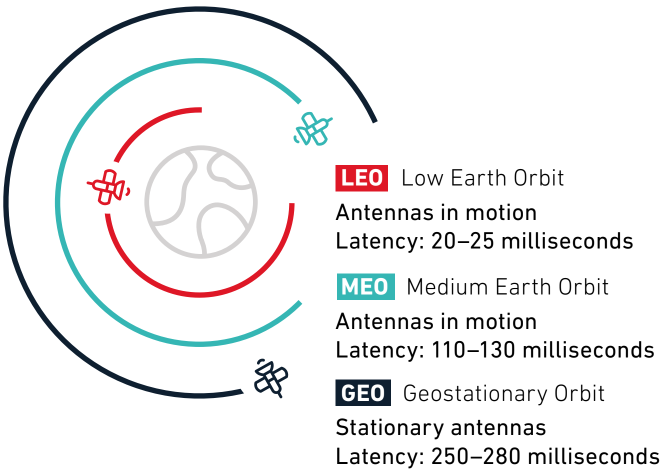
Density refers to the number of satellites operated by a company within an orbital plane. LEO constellations have a higher density relative to MEO or GEO to expand coverage area and throughput levels, and allow for more seamless signal transmission between satellites.

Because LEO satellites move quickly across the sky (typically orbiting the earth every 90 minutes), a full, continuous coverage constellation from pole to pole requires hundreds of satellites (compared to three or four GEO satellites, with a wider ground area covered per satellite).

Satellite networks typically employ a 'shared bandwidth' solution, so the satellite design and coverage area have a significant impact on the types of services that will be available to users. Relatively cheap LEO satellites will only be able to offer users a low throughput solution (2G equivalent or less). Handsets may be capable of higher throughput (4G/5G) performance, but service quality will ultimately be dictated by the density of users and the throughput of the network.

Figure 7

LEO satellites work at lower altitude, with commensurately improved performance set against a lower ground coverage per satellite



Note: Not drawn to scale

Source: GSMA Intelligence based on Harris Caprock gsmaintelligence.com

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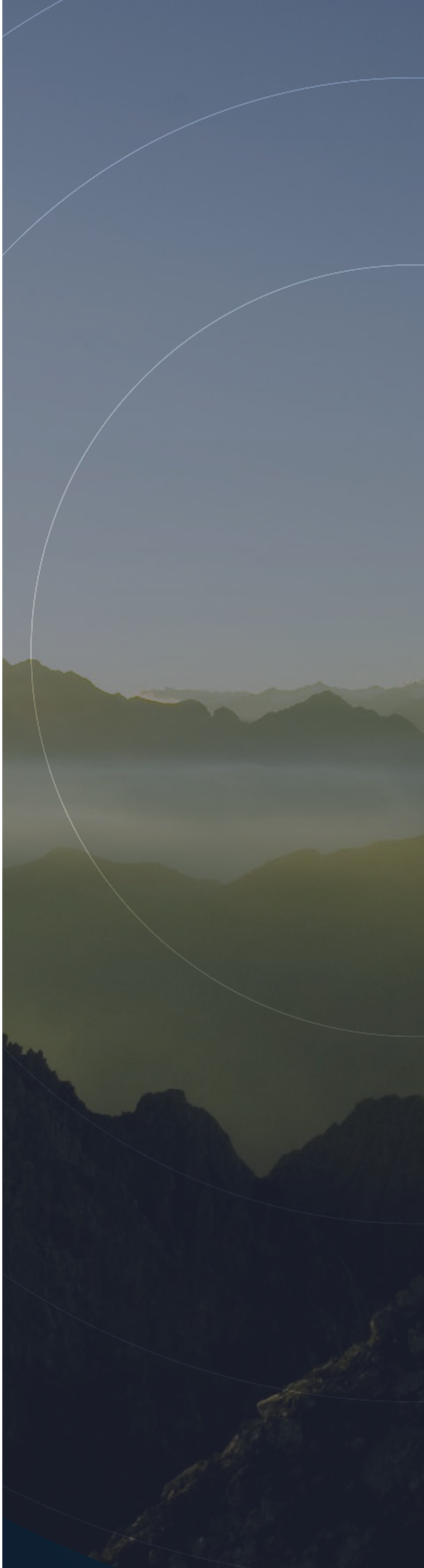

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