GSMA Intelligence

Satellite 2.0: going direct to device

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Contents

Executive summary

The growing momentum of telco-satellite partnerships has resulted in leaps in innovation with regard to non-terrestrial-network (NTN) technology and deployment economics. Despite advancements in terrestrial network coverage, a large section of the world's population remains out of range of mobile and internet access. Combining those living out of network coverage with those living on the 'edge' of coverage (who receive limited or weak signals), this amounts to 570 million people, or 8.7% of the adult population. Similarly, a number of businesses from a range of industries, such as automotive and manufacturing, remain out of range of mobile and internet access. Reaching these people and businesses with conventional mobile networks is limited by fundamental constraints in network economics due to geographic challenges. Other means are therefore required.

Our focus in this report is on direct-to-device (D2D) satellite technology that seeks to help telcos chip away at the coverage barrier. Compared with other satellite services, D2D offers the following changes:

- The main difference compared to geostationary orbit (GEO) and low Earth orbit (LEO) constellations (such as Starlink, OneWeb and Amazon's Kuiper) that need a dish or other large receiving equipment is that connectivity is provided direct to someone's mobile phone or any standard mobile device. This allows people to be 'mobile' while using the service and in some cases, the end user may be seamlessly connected to a satellite and not even realise they are connecting through space.
- D2D also enables improved cost and operational efficiency to mobile operators by eliminating costs associated with cell site deployment, network integration and the receiving equipment (dishes) required of most other satellite services, in addition to facilitating faster time to market for expanding the footprint for service.

D2D is not new. However, an important change has come about with the 5G new radio (NR) standard from 3GPP that incorporates integration for NTN. This means that, where commercial partnerships are in place, standard smartphones and IoT devices will be able to connect seamlessly with traditional cellular base stations and satellite systems (effectively 'satellite base stations') when out of range of terrestrial connectivity. This significantly increases the addressable audience for mobile operators. D2D is likely to offer 3G-like speeds (approximately 3-5 Mbps), although the speeds could be slightly higher in scenarios where the economics and technology provide the right mix.

D2D satellite offers mobile operators access to new customer segments and the ability to provide connectivity for existing customers when roaming out of range of a terrestrial signal. In most cases the business model would be a wholesale partnership. Our modelling suggests a total incremental connectivity revenue opportunity of over $30 billion by 2035.[1] The consumer segment accounts for nearly two thirds of this ($20 billion), enterprise IoT one third ($10 billion) and government applications the remaining portion ($2 billion). To put this into context, the total satellite-enabled market equates to 3% of total telecoms industry revenues, most of which would be incremental (i.e. additional). The yield is actually higher for IoT if one considers that IoT connectivity is worth around $45 billion globally, meaning the $10 billion IoT addressable revenue (by 2035) for D2D satellite offers an uplift potential of nearly 25%.

[1] Revenue associated with ancillaries and services (such as managed services) is not included in this projection.

Spectrum considerations are, and will continue to be, the primary regulatory issue to navigate for satellite groups. The outlook is, however, positive in this instance given ITU-based allocations and the aforementioned NR standard change that is likely to lead to more countries coming on board given the economies of scale and clear benefits in expanding connectivity to a wider group of people and businesses. D2D technology does not currently rely on reusing terrestrial spectrum (although some companies plan to do this), a practice which courts risk and significant operational complexities to avoid interference. Field proof points from commercial trials will be important, as will carefully considered marketing from operators aiming to use extended coverage as a competitive differentiator. There is also a potential competitive challenge in that the service is unlikely to be widely available before 2025, with some satellite constellations likely to come online sooner in search of the same (or at least some of the same) revenue. Finally, would-be partnerships will need to incorporate planning of NTN into roaming systems and billing software – an area where efficiency improvements have been made but where meticulous detail is still demanded. But overall, D2D is an interesting play that merits consideration given the clear and scaled benefits in expanding coverage and revenue streams.

1. Further efforts to close the coverage gap

Terminology preface

Non-terrestrial networks (NTN) refer to communication networks above the earth at different heights depending on the system. While satellite networks comprise the majority of these, others such as high altitude platform stations (HAPS) and balloons also exist. The underlying technology, maturity, deployment model and commercial timelines of a given NTN will vary.

The growing appeal of satellite as a complementary means of reaching unconnected populations and businesses is pragmatic. The expansion of mobile networks in the last 10 years has been extensive. In 2014, 3G networks reached 77% of the population worldwide, while LTE – at the time still in its relative infancy – covered 40% (5G, of course, was non-existent). Regional variation in these numbers was pronounced, with Sub-Saharan Africa (50% and 8% respectively), India (56% and 22%) and swathes of Southeast Asia well below the coverage levels of the US or Europe. Coverage gaps have been reduced as a result of improved economics from network sharing between competing carriers and tower asset offloads to third parties (mostly tower companies) that can take advantage of operational efficiency by hosting multiple operator tenants on one base station mast, mitigating the risk of expansion to lower-density areas.

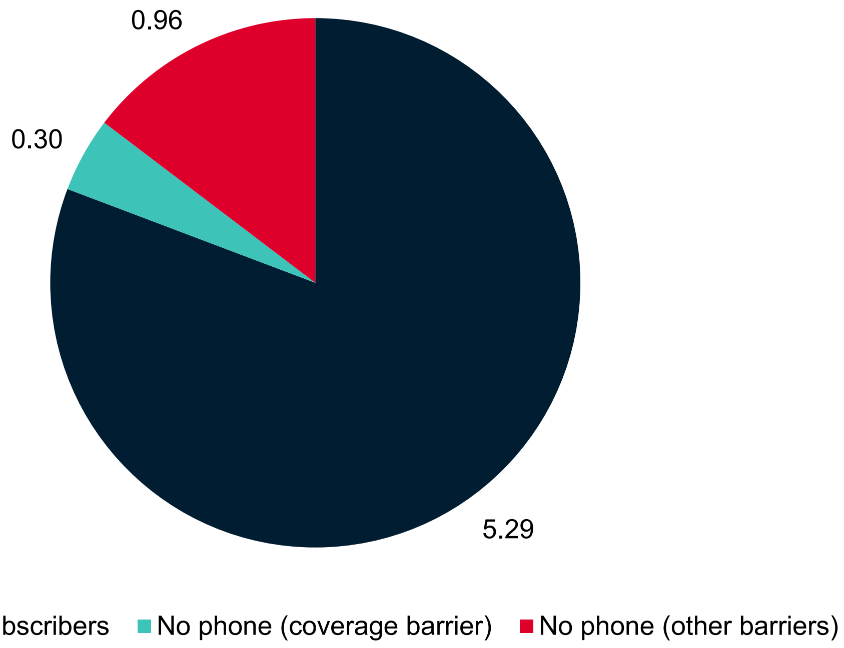
However, even with 80% of adults now having an active mobile phone, stubborn gaps remain:

- 1.3 billion people don't have a mobile phone.
- Only 60% of the global adult population actively uses the internet.
- For the non-internet population, a large majority of people are constrained by price and, to some extent, literacy and relevance. This is described as the 'usage gap', a major barrier to social mobility.
- There is a persistent coverage gap of over 300 million adults who live outside the range of a 3G, 4G or 5G network (i.e. no access to mobile broadband).[2] This has declined from around 550 million in 2018, but further gains will be more difficult given challenging economics (explained below). Taking into account people on the 'edge' of coverage as well – those technically within range but with limited or very weak signal – the 'effective coverage gap' extends to 570 million adults.

[2] Mobile broadband is defined as 3G, 4G or 5G. Note that our calculation excludes people under the age of 10. If people under the age of 10 were included, the coverage gap would be approximately 385 million.

Figure 1: Of the 1.3 billion people without a phone, 25% still face a network coverage barrier

Billion



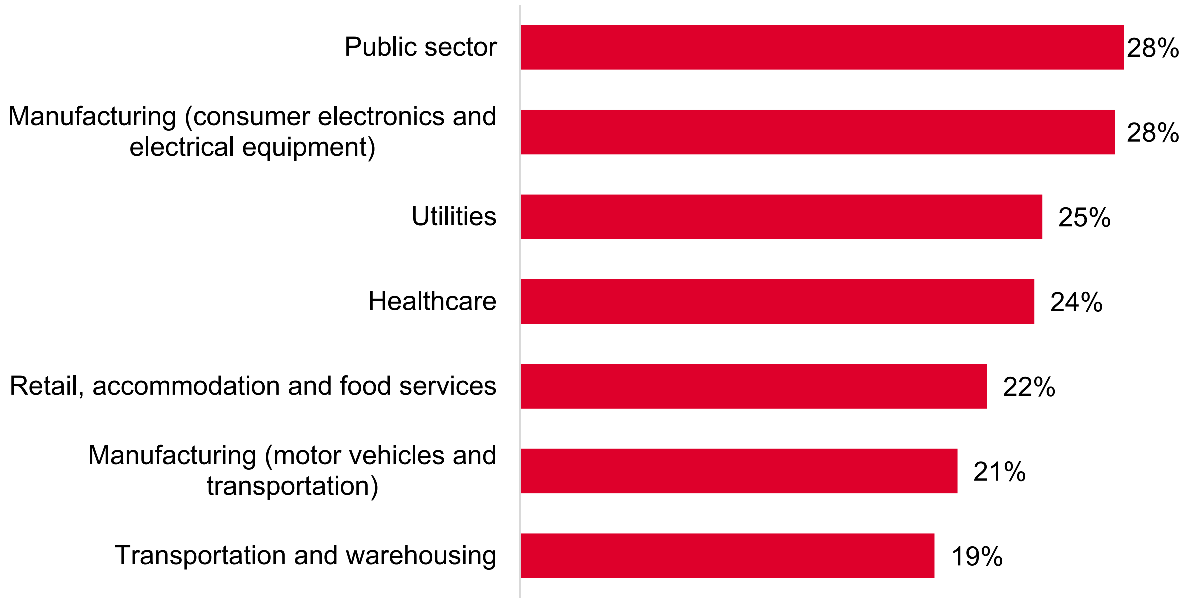
Note: Data as of 2021

Source: GSMA Intelligence

The last point is significant when one considers that 300 million people is 25% of the adult population who do not have a mobile phone. This coverage gap has, of course, come down as terrestrial networks have expanded; but this is unlikely to decrease further by a significant amount. The main reason is that the populations yet to be reached by mobile networks are generally those in rural and remote areas with low population densities and consequently highly unfavourable network economics, even with small cells and existing backhaul solutions. There is also the challenge of providing service to people as they transit through parts of a country where no network coverage exists, such as mountains and valleys. Combining public information and our modelling estimates, backhaul costs for telcos rise disproportionately with distance in rural areas, making fibre, Ethernet and even microwave – the mainstays of mobile backhaul – very expensive. These costs can be as much as 5–10× in city or suburban environments.

The same is true for reaching businesses, whether they have operations in one place (such as a factory) or have assets that are transient (such as a trucking firm or connected car integrator). On average, 20–30% of enterprises would consider using satellite connectivity to service part of their operations (see Figure 2). Although this is based on survey data and is imperfect, it is apparent that there is an upwards trend, reflecting a drop in costs for satellite access and, separately, an easier onboarding path in industrial settings.

Figure 2: Businesses that would consider using satellite connectivity



N=2,900

Source: GSMA Intelligence Enterprise in Focus Survey 2021

Even by 2025, a significant proportion of the world's population will still be limited from access to modern communications and the internet due to the coverage gap. We show the breakdown of this by region in Table 1. The 243 million people outside of mobile coverage in 2025 would represent a drop of 20% from the 300 million in 2021. Expressed as the share of the adult population, the coverage gap will be 3.6% (0.24bn / 6.8bn) by 2025, down slightly from 4.6% now. However, economic constraints in remote areas mean it would come down only a further 7% to around 230 million by 2030. In practice, the true gap is greater because of the proportion of people who technically live in range but for whom the signal is patchy and unreliable, or for those transiting through non-coverage areas – we refer to this group as on the 'edge' of coverage. When combined with those totally out of range, the effective coverage gap will be around 7.7% of the population in 2025, or 520 million people. This is higher in under-penetrated regions, with Sub-Saharan Africa most exposed at 12.1% of the population.

Table 1: Even by 2025, the world will still have a mobile and internet coverage gap

			Usage gap		Coverage gap		
	Adult population (m)	**Mobile internet subscribers (m)**	**Total (m)**	**Usage gap (% of population)**	**No coverage (m)**	**Edge of coverage (m)**	**Effective coverage gap (% of population)***
East Asia & the Pacific	2,126	1,786	278	13%	62	83	6.9%
Europe & Central Asia	729	657	46	6%	25	28	7.3%
Latin America & the Caribbean	575	435	131	23%	10	24	5.8%
Middle East & North Africa	453	307	132	29%	14	20	7.3%
North America	336	309	26	8%	0	13	4.1%
South Asia	1,682	933	682	41%	66	70	8.1%
Sub-Saharan Africa	888	415	408	46%	66	42	12.1%
Global	6,788	4,841	1,704	25%	243	279	7.7%

**In this table, the coverage gap is calculated as the sum of people that lack, or are on the edge of, mobile network coverage and expressed as a share of the adult population. For example, for Sub-Saharan Africa the calculation is as follows: (66m + 42m) / 888m = 12.1%*

Note: Table shows projections for 2025

Source: GSMA Intelligence

Pragmatic partnerships between telecoms and satellite network operators are purpose-built to address this gap through aerial ‘extensions’ to land-based networks. The wave of momentum catalysed by LEO constellations from SpaceX, OneWeb, Telesat and Amazon’s Kuiper initiative is well established. Following regulatory approvals (most crucially from the Federal Communications Commission) and pre-commercial trials, service availability is planned to start coming online in late 2022. We have written extensively on new LEO models, most recently in Radar: Connectivity from the sky.

The satellite communications industry is not, however, singular. Our focus in this report is on a different emerging satellite technology in the form of direct to device (D2D). Compared with other satellite services, D2D offers the following changes:

- The main differentiator from the companies mentioned above is that connectivity is provided direct to someone’s mobile phone, or any standard mobile device, obviating the need for a dish or other receiving equipment.
- This provides a cost and operational efficiency to mobile operators by reducing – or eliminating – the need to deploy and operate remote cell sites, and avoiding installation and operating costs for satellite backhaul equipment. It also speeds time to market for expanding the footprint for service.
- If those savings are passed on to consumers, service costs may also be less than what would otherwise be the case. All else being equal, this could help consumers for whom affordability is also a barrier, alongside a lack of network access, and accelerate the closing of the connectivity and digital divide for consumers and businesses.

- Finally, there is a regulatory dimension in potentially assisting with universal service funds (USFs) faced by telcos in certain countries – an expensive and inefficient use of tax revenue. A partnership with D2D satellite that extends coverage to substantially 100% of the population and geographic area could reasonably provide an argument for a mitigation or potentially exemption from USF levies.

To support the strategic rationale and deployment options, we have modelled an addressable revenue opportunity at a regional level in the consumer and B2B/IoT segments (see Chapter 3). Most of the accessible revenue is incremental, which, combined with cost efficiencies, makes D2D a potentially attractive option for telcos seeking an expansion route to new subscribers.

2. Tech shop: how D2D works

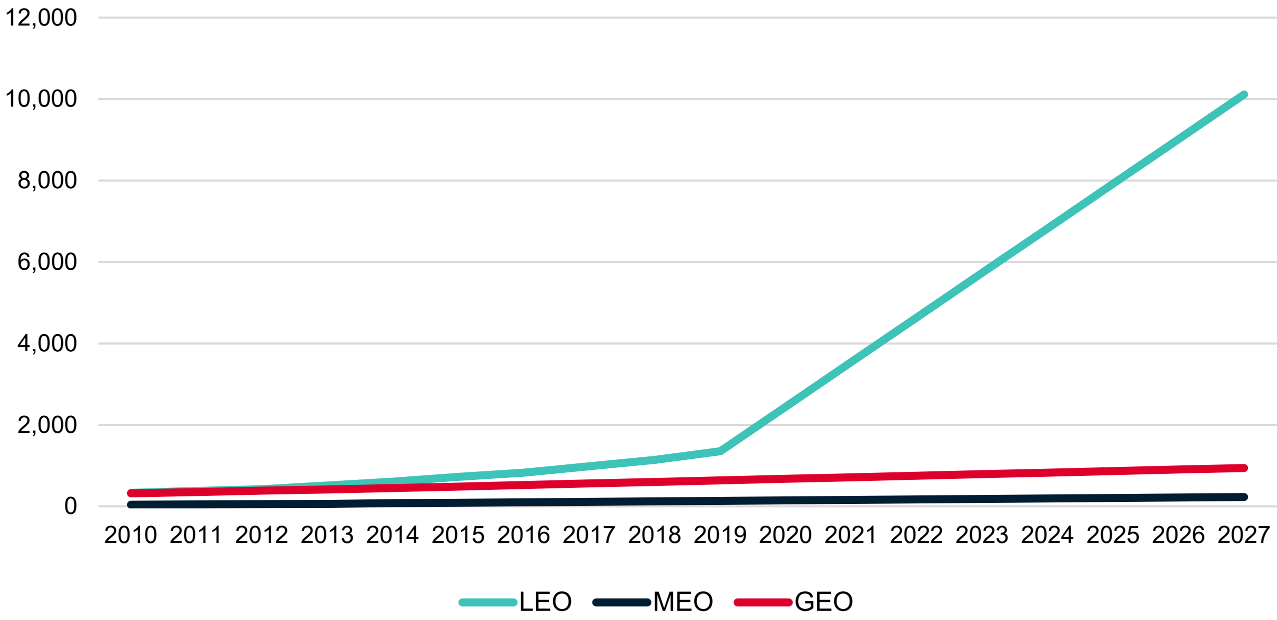
Before overviewing the technology aspect of D2D satellite, it is worth exploring the industry context behind the growth in overall satellite capacity and the physics at play with regard to the different options.

Revisiting the broader sector context

Announced launch plans and constellation sizes from new satellite groups have fundamentally changed the game in terms of available capacity. Prior to 2020, deployed satellite volumes increased at only a modest rate for LEO altitudes, and even less for medium Earth orbit (MEO) and GEO. This is because most of the satellites from existing operators were already in place, with expansions carrying high costs. If existing plans are carried through, overall volumes will reach an order of magnitude far higher than anything seen before (see Figure 3).

Figure 3: Space is becoming a more crowded place

Number of communication satellites in orbit



Source: UCS Satellite Database, GSMA Intelligence

Satellites are generally differentiated based on two main criteria:

- Altitude:
    - The key trade-off between altitude and connection strength is that as altitude increases, ground coverage is increased but with a consequent increase in latency.
    - LEO satellites are nearest relative to Earth, at roughly 400–1,500 km above sea level (for context, commercial aeroplanes fly at an altitude of 10 km) and circumnavigate the globe around 16 times each day. Lower altitudes mean that 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, which is that the orbital period matches the Earth's rotation (24 hours). This means that 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), a potential limitation for rapid turnaround use cases in industrial settings.

- Density:
  - Density is the number of satellites operated by a company within a given orbital plane. LEO constellations generally involve a significantly increased density to expand coverage area and throughput levels, and allow for more seamless signal transmission between satellites.
  - Technology advancements, improved manufacturing capabilities and the expansion of ride-share launch options have all helped enable the implementation of large-scale commercial constellations.
  - Because LEO satellites move quickly across the sky (typically orbiting the earth every 90 minutes) a full, continuous coverage constellation requires hundreds of satellites (versus three or four GEO satellites for global coverage).
  - Satellite networks typically employ a 'shared bandwidth' solution, so the satellites' 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 ultimately service quality will be dictated by the density of users and the throughput of the network.
  - Densifying the constellation by increasing the number of satellites (through increasing the number of orbital planes, the number of satellites per plane or both) can be expensive and will disproportionately add capacity in oceanic or remote regions. Financing, designing and deploying such systems is not a job for amateurs.

Direct to device: an expanded market via 5G NR

The concept of bringing a satellite signal directly to a mobile handset, or IoT device, is not new. The strategic rationale has always been to streamline the connectivity access requirements for people by obviating the need for a receiving dish. For most satellite services, dishes are mounted to a household or community/business premises (such as a hospital or office), which then relay a signal to end users through short range hops such as Wi-Fi. The problem is the satellite consumer-premises equipment (CPE) costs are usually borne by the customer, which increases the cost of ownership when taken together with the mobile device and data plan tariff costs. Customers also need to be in close physical proximity to the CPE, making it hard to receive a signal while travelling throughout a local area such as a village, constraining the concept of mobility. For these reasons, while the size of the addressable population has been in the hundreds of millions for years, the realistic market has been much smaller.

The crucial change is that the new 5G NR standard from 3GPP incorporates integration for non-terrestrial networks (NTN). This means that standard mobile devices – feature phones or smartphones – will be able to connect seamlessly with traditional cellular base stations and satellite systems (effectively ‘satellite base stations’) when out of range of terrestrial connectivity. This will likely come at 3G-like speeds (approximately 3–5 Mbps), although the speeds could be slightly higher in some scenarios where economics and technology provide the right mix. D2D satellite offers mobile operators access to new customer segments and the ability to provide connectivity for existing customers when roaming out of range of a terrestrial signal.

This has several significant implications:

- First and foremost, it vastly increases the addressable universe of devices in play for satellite connectivity. The standards change means that the vast majority of the 570 million people currently not covered would be able to access satellite services direct to the device, provided their operator had a commercial partnership in place.
- Second, it should extend roaming capability to remote areas not previously available to terrestrial networks (e.g. mountainous terrain), which could be tapped into by customers transiting through such regions.
- Third, it scales the supplier ecosystem – principally chipset makers and handset OEMs – to optimise devices for this service. As higher volumes are manufactured, costs will come down through economies of scale, which should trickle down to the consumer in the form of a lower total cost of ownership.
- Fourth, it offers cost efficiencies in integration between ground and satellite networks because, in most cases, no new infrastructure is required of telcos.

Finally, it provides a grounded basis for telecoms operators to consider partnerships with companies that can offer this technology and service. Large swathes of the unconnected population (as well as some existing subscribers) would be accessible, and the services would be interoperable with LTE, 5G and Wi-Fi connectivity, adding up to a seamless experience for customers wherever they are.

3. How much could it be worth?

The logical next question from talking about an enlarged potential consumer and business audience is to estimate the addressable revenue opportunity.

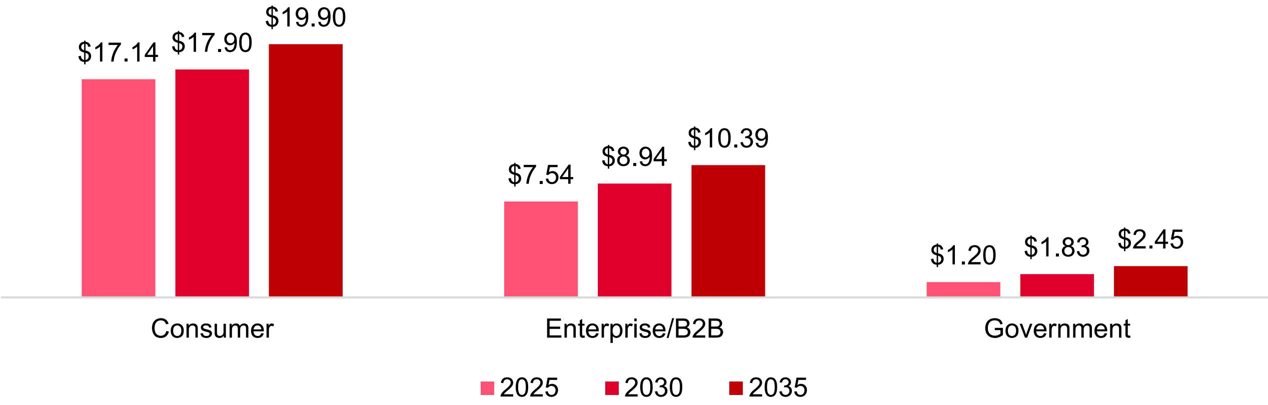
One of the major incentives of network expansion is to access incremental revenues provided by new customers, or through upselling of existing ones. To help put this in context, we have modelled an addressable revenue opportunity in the consumer, business/enterprise and government segments available to telecoms operators through coverage extensions with D2D satellite. Before interpreting the numbers, there are some important notes to qualify these findings:

- These are indicative projections designed to illustrate the broad market size available to mobile operators. They are not, however, revenue forecasts or predictions of what will happen.
- Revenues in the IoT section are those associated with connectivity. In practice, connectivity is a relatively small share of overall revenue (5%), with professional services (28%) and platforms and analytics (67%) accounting for a much larger share. Telcos and other participants could, of course, seek to access a portion of these other revenues as well, but those are outside the purview of this analysis.
- The projections are market-level aggregates. Actual revenues available to telecoms operators and would-be satellite partners via wholesale agreements would come down to commercial arrangements in each individual circumstance. In this sense, an implied ARPU of $7 per month for connecting an individual in East Asia from our model may well vary between, say, Vietnam and Thailand – it depends on the commercial strategy of a given telco.
- There will be a degree of overlap in the revenue opportunity available to telcos from D2D satellite partnerships compared to that accessible through other NTN partners, such as those using LEO models that require a receiving dish in a private residence, school or business premises. This comes down to the partner choice of the mobile operator, and the different services can be complementary.
  Commercial timelines for D2D satellite are generally for service availability from the middle of the decade in 2024–2025. Our addressable revenue figures begin from this period and go out to 2035.

The headline figures are shown below, with a total incremental revenue opportunity of over $30 billion by 2035. The consumer segment accounts for two thirds of this, and enterprise one third. To put this into context, the total addressable figure equates to 3% of total telecoms industry revenues, most of which would be incremental (i.e. additional). While the total coverage gap is a higher share of the adult population in 2035 at around 7%, the addressable revenue enabled by D2D satellite is lower as a share of total telecoms industry revenue because of other consumer barriers to phone and internet access beyond network coverage, such as cost and relevance.

Figure 4: D2D satellite offers access to new revenue for telcos, which will be worth over $30 billion by 2035

Revenue per year (billion)



Source: GSMA Intelligence

Consumer

The consumer segment is broadly comprised of two parts:

- People in the coverage gap:
    - People who live outside of the range of a 3G, 4G or 5G network. Coverage expansion over the last 10 years in 3G and 4G standards has largely narrowed this gap. However, last-mile economics for the final frontier (roughly the last 10% of households and premises) constrain further expansion without alternative solutions.
    - Globally, we estimate this group to reach around 240 million in 2025 and reduce to 227 million by 2035 as LTE infrastructure expands and 2G/3G customers are migrated upwards.
- People on the 'edge' of coverage:
    - An oft-overlooked but significant slice of the population is those who may live within range of a 3G, 4G or 5G signal – and have an active mobile phone – but experience patchy service at home or in transit around a given country for work or travel.
    - We estimate this group to reach 280 million in 2025, with a marginal rise to around 305 million by 2035.

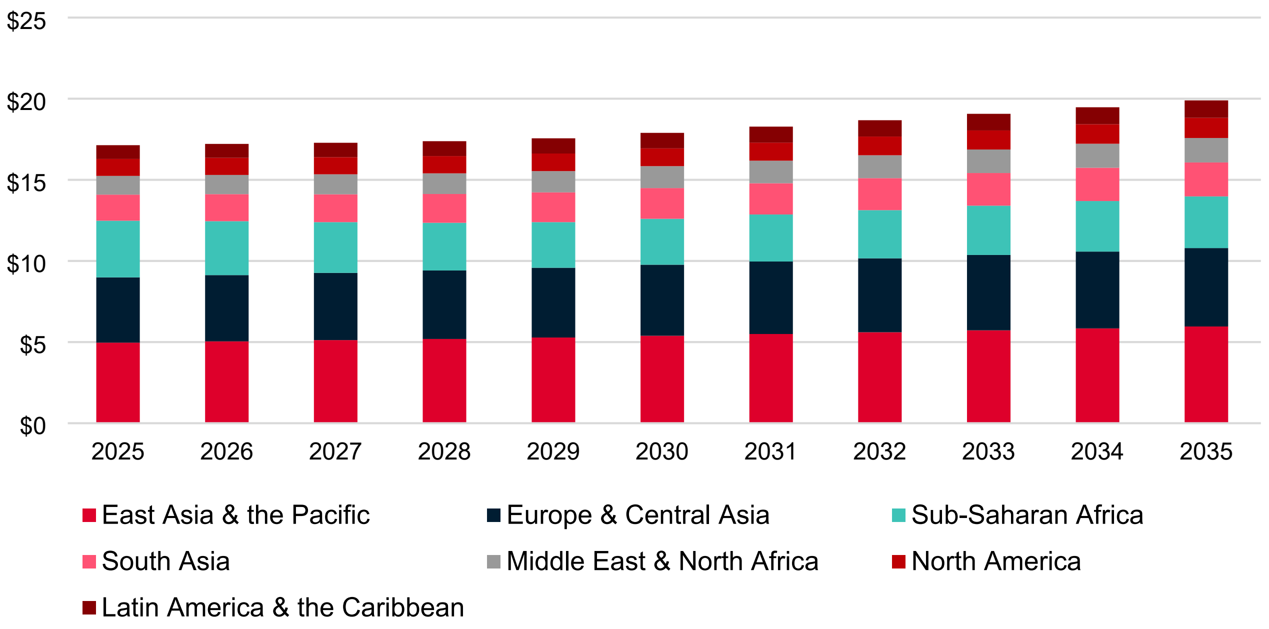
Affordability and other barriers – such as literacy – will persist over time, which means the actual addressable consumer base for satellite is around 75% of the total effective coverage gap. Taking these into account, the total addressable market for D2D satellite is around 400 million subscribers by 2035. Our survey findings indicate that, for people who do not own a mobile phone, cost is typically the largest barrier (i.e. people cannot afford a mobile phone even if they live within a covered area). This holds true for 40% of non-phone owners in Sub-Saharan Africa, 20% in Asia and around 25% in Latin America. Relevance and digital literacy (knowing how to use a phone or the internet) are, however, also persistent issues.[3]

[3] See The State of Mobile Internet Connectivity 2021 for an in-depth analysis of these issues.

Regional variation in the numbers beneath the overall $20 billion addressable revenue is correlated with the size of the coverage gap, per capita income, propensity to pay and prevailing mobile ARPU levels. East Asia and the Pacific (which includes Southeast Asia) accounts for the largest share at $5.9 billion. Europe and Central Asia ($4.9 billion) and Sub-Saharan Africa ($3.1 billion) round out the largest regions (see Figure 5). While China is the largest population in East Asia, traction for this service is more likely to be gained in countries with disparate rural populations or those comprised of islands (notably Indonesia), where network economics are unfavourable. The opportunity in Africa involves these factors as well, but there is also the added dimension of 3G or 4G coverage simply having not expanded as much as in other regions, meaning the coverage gap is wider.

Figure 5: D2D consumer revenue opportunity to reach $20 billion per year (2% of the total telco topline) by 2035

Revenue opportunity (billion)

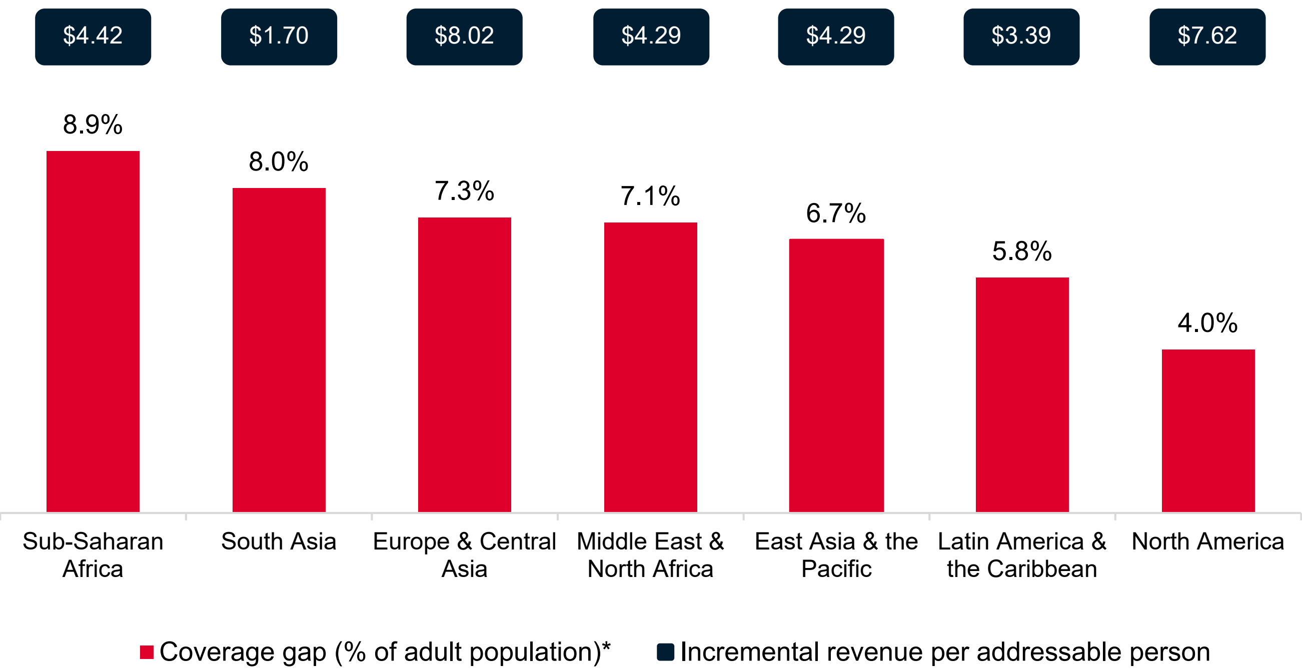


Source: GSMA Intelligence

We can also express the revenue figures per head of the addressable population (see Figure 6). This is arguably more relevant for prospective carriers because the incremental ARPU must be weighed against any capital investments and ongoing opex to justify the business case. On this basis, the average uplift is around $4–5 per person per month, with the figure being lower in Africa and the Indian subcontinent, and highest in Europe (where incomes are higher). These are (roughly) in line with prevailing weighted ARPU rates in the countries within each region. LTE premiums (15–20%) are not applied, as most of the incremental base would likely come onto 3G-level speeds, although there would be the opportunity to migrate these customers to LTE as legacy networks are sunset.

Figure 6: How much incremental revenue would that equate to per person in the unconnected base?

Percentage of adult population



**Calculated as the sum of people outside of, or on the 'edge' of, 3G, 4G or 5G coverage as a share of the adult population.*

Note: Table shows projections for 2035

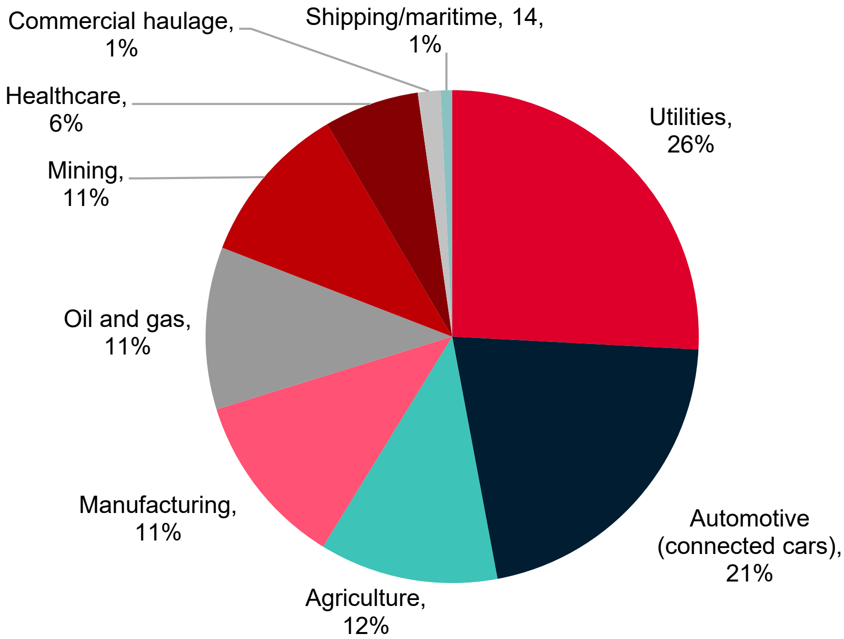
Source: GSMA Intelligence

B2B and enterprise IoT

The business and enterprise segment is based on providing connectivity for IoT devices across a variety of sectors. IoT devices may be distributed, such as for solar and wind installations, or concentrated on industrial campuses or premises, such as for manufacturing groups. The premise for our estimates is based on our IoT connection forecasts on a vertical industry and regional level. We then adjusted the top level forecast based on data from our global enterprise survey on the share of companies in each industry that have network coverage requirements where they would consider using satellite (typically 15–25%). Further filters are applied for propensity to adopt (such as whether an owner of a connected car carries forward a paid tariff for infotainment and mapping following a free trial period). This provides an IoT connections base for each industry that would be addressable for telcos via satellite partnerships.

In total, there are nine sectors of interest, which add to an addressable base of around 1.9 billion devices by 2035 (see Figure 7).

Figure 7: 1.9 billion devices (8% of the IoT market) across nine sectors are addressable for D2D satellite by 2035



Note: Percentages represent the share of total IoT devices addressable for D2D satellite in 2035. Note this is not the same as the share of total addressable revenue.

Source: GSMA Intelligence

There are a number of observations to make:

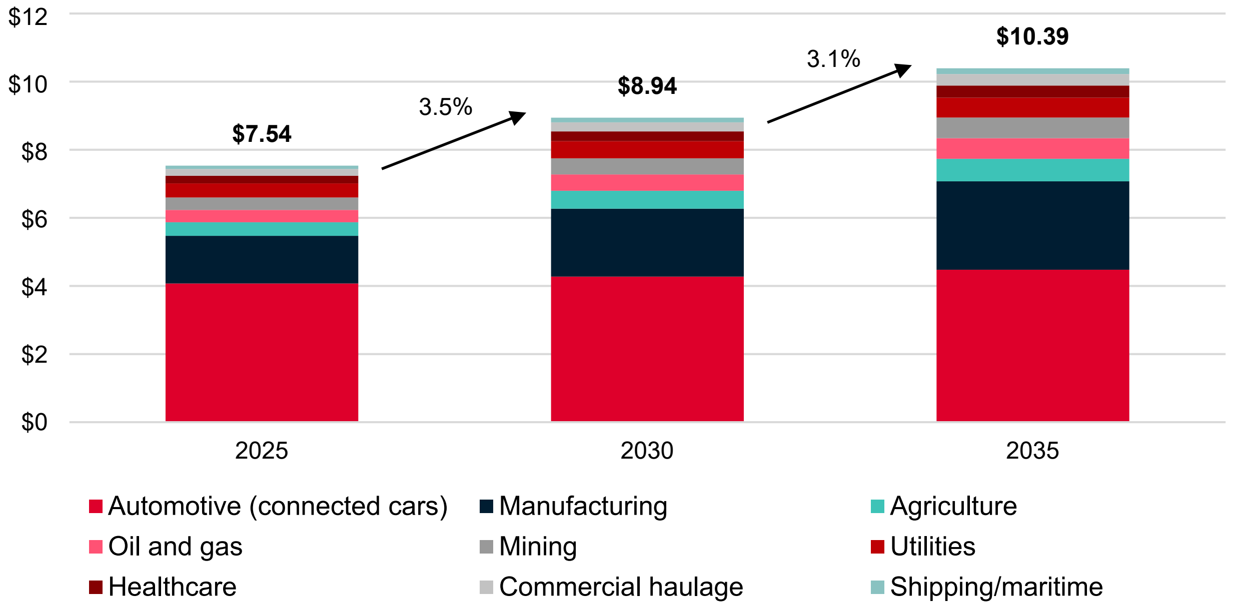
- The two biggest sectors by volume are automotive (connected cars) and utilities, albeit for different reasons.
- Automotive (approximately 400 million devices) is driven by the rising share of connectivity embedded in new vehicles through telematics, infotainment and mapping that will feed through from new car sales, particularly electric vehicles (EVs) from Tesla and other major manufacturers. The revenue opportunity in cars comes from both service fees paid by car manufacturers for embedded telematics and, separately, consumers who elect to carry forward data plans for infotainment and/or mapping services. The same is true of commercial haulage, a separate category that also requires location services, routing optimisation and the monitoring of driver performance, fuel efficiency and cargo assets (temperature control).
- The utilities base (just under 490 million devices) comes from the proliferation of smart meters and energy grids, including solar and wind farms, which are increasingly being equipped with IoT sensors to monitor operations and link to consumers and main grid operators. These are generally high volume/low value connections (utilities is a comparatively low share of addressable revenue).
- Healthcare (around 120 million devices) is addressable from remote clinics, hospitals and diagnostics equipment – again, particularly in Africa and Asia.
- Agriculture (around 220 million devices) involves use cases such as irrigation and soil management, and precision techniques. The actual IoT base for agriculture would be larger, but we have excluded high-volume applications in cattle management and forestry from this analysis.

- The heavy industry sectors (oil and gas and mining) have a higher likelihood of using satellite connectivity by virtue of managing high-net-worth equipment and operations in remote areas.

Converting these IoT volumes to revenues provides a total yield of around $10.4 billion available to telcos by 2035, a rise of 3% per year starting from deployments in 2025. As with connection volumes, connected cars are the largest portion of the opportunity at $4.5 billion per year by 2035, or around 45% of the total. The rest of the pie is roughly evenly split between utilities (high volume but lower ARPU), manufacturing (volumes will rise over time with digitisation/industry 4.0, but satellite is only equipped to handle lower throughput use cases in outdoor settings), heavy industry (oil and gas, mining) and agriculture (driven by precision agriculture and a growing use of connected technology for soil management and irrigation).

Figure 8: D2D satellite IoT addressable revenues will reach $10.4 billion by 2035, mainly due to connected cars

Revenue (billion per year)



Note: Percentages represent the five-year compound annual growth rates (CAGR) for the addressable B2B revenue pot for D2D satellite over each respective period

Source: GSMA Intelligence

To put this in perspective, $10.4 billion is minimal as a share of the total telecoms revenue base ($1 trillion) and even in relation to the SME/B2B portion of that (around $200 billion). However, it is more apt to compare this to total IoT connectivity revenues, which we estimate at around $45 billion. On this basis, D2D satellite offers an uplift potential of over 20% to the connectivity portion of the IoT value chain, an attractive play considering that many groups now have full service offerings that also include platform management and analytics.

Government

Government applications from satellite technology come from handset mobility and IoT segments. The handset market includes military and defence for devices on the move – sometimes referred to as comms on the move (COTM) – and in remote areas. Tactical communications in remote, or at times hostile, areas require precision coverage that may be out of the range of terrestrial networks. IoT deployments could include weather monitoring stations, parks and forestry, and traffic and road management (certain settings), among others. Governments may have their own satellites in orbit in support of these purposes, although there is an uneven distribution, with a large share of satellites controlled by a relatively small number of countries.

The addressable revenue base among government clients for D2D satellite is material, although smaller than both the consumer and B2B segments. We estimate this to be approximately $1.2 billion in 2025, growing at 10% and 6% per year over the subsequent five year periods to reach a value of $2.4 billion by 2035.

4. Addressing the needs of MNOs and MVNOs

Wholesale partnerships between telecoms and satellite operators will likely be the most common revenue model for D2D service. While Starlink is seeking to compete at the retail level against existing broadband and mobile network operators (though not using D2D), most other satellite groups operate at the wholesale level as telco partners rather than competitors – a rising tide lifts all boats. Beyond the market context, addressable audience and revenue availability, there are of course practical considerations for telcos interested in working with satellite operators for coverage expansion, infill or roaming. We have outlined the key technology and financial considerations in Tables 2 and 3 respectively. The same considerations broadly apply for MVNOs.

Table 2: A 'what's what' of working with D2D satellite: technology

	How D2D can work	Implications
Network coverage extension	• Coverage would be available in areas beyond the footprint of telcos' terrestrial network (3G, 4G or 5G). • This is anticipated to cover substantially 100% of landmass in countries where operations are permitted at non-polar latitudes (+/- 65 degrees).	• Extends the reach of mobile network access to previously unreachable populations (570 million people worldwide) and geographic areas. • Enables roaming coverage for operators in areas where terrestrial options do not exist, or where current solutions are available but not cost effective.
Spectrum	• 3GPP has standardised NTN compatibility as part of the 5G NR standard. • Where permissible by individual countries, mobile satellite spectrum typically operates in the S-band (2–4 GHz).	• Higher addressable device base (as noted below). • Most countries have maintained separate allocations in S-band and mid-band for mobile and mobile-satellite use, a key enabler for deployment. In countries that have not provided this allocation, commercial delays may occur
Handset compatibility	• 5G NR NTN standards mean that D2D satellite services would be compatible with most mobile handsets and IoT devices.	• This is the main game changer. NR standards mean that mobile satellite can now address a device volume orders of magnitude higher than before. • As this technology is deployed, chipset manufacturers and handset OEMs will factor NTN performance optimisation into new equipment designs.
Interoperability and roaming	• Service would be interoperable with any 3GPP-standard service, including 3G, 4G, 5G and Wi-Fi. In practice this means a customer would seamlessly shift between land-based and satellite networks – when out of range of a terrestrial signal – potentially without even knowing it.	• NTN networks would need to be incorporated into cellular roaming standards, including VoLTE and 5G.

Source: GSMA Intelligence

Table 3: A 'what's what' of working with D2D satellite: business and revenue model

	How D2D can work	Implications
Deployment	• Seamless integration with terrestrial networks. • Because D2D does not require receiving equipment (i.e. a dish), there should be limited, or no, capex for operators to integrate the satellite service with their network. • D2D also replaces, or limits, the need for fibre or microwave backhaul, which can become very expensive over long distances in rural areas.	• Lowers costs for telcos by reducing capital investments from network expansion and ongoing maintenance opex. • Financial savings may be used for onward investment or passed on to consumers via lower tariffs, which could accelerate mobile service adoption. • In countries that still apply USOs, having substantively 100% geographic coverage may provide leverage for operators in reducing these fees.
Revenue (consumer)	• Consumer revenues could come from people outside of 3G coverage (non-mobile population), implying a full incremental ARPU, or from price premiums associated with roaming tariffs for existing customers. • Most partnerships would likely involve a wholesale access deal in which telcos own the customer relationship, while satellite operators receive a fee for connectivity. • We estimate a total addressable market of $19.9 billion by 2035.	• Provides a revenue upside to the existing base. This is particularly the case in countries most exposed to the coverage gap and with lower network coverage (e.g. Africa, India, parts of Southeast Asia). • Better coverage may also reduce churn. Our survey evidence indicates that in many countries, the quality of network coverage is the number one or two purchasing criterion.
Revenue (B2B/IoT)	• Business/enterprise revenues would come primarily from connecting IoT devices in out-of-coverage areas. • We modelled nine sectors: consumer automotive (connected cars); utilities and energy grids; healthcare; manufacturing; commercial haulage (logistics); shipping; oil and gas; mining; and agriculture. • We estimate a total addressable market of $10.4 billion by 2035 for connectivity only. Additional revenues would accrue to other associated value chain elements such as professional services and platform analytics.	• Lower total addressable market compared to consumer mobile but higher upside as a share of existing IoT revenues (i.e. $10.4 billion is approximately 23% of the $45 billion in connectivity revenues for IoT worldwide). • Provides an entry route into businesses that can be upsold with other services as part of managed service contracts.

Source: GSMA Intelligence

5. Outlook, regulatory implications and open questions

Underpinned by 5G NR standards opening an enlarged addressable audience in the consumer and B2B segments, the D2D satellite opportunity is clear. The rationale is bridging coverage gaps and extending roaming service to previously uncovered areas in a more economically efficient way. The 3GPP's move to include NTN in the 5G standards has direct implications for the telco supplier ecosystem of chipset makers, handset OEMs and equipment vendors such as Nokia and Ericsson. Global standards drive global supply and distribution, which lowers costs overall. This is a good thing for all parts of the value chain.

Regulatory questions are generally surmountable but nevertheless important to be aware of, in part to distinguish D2D from other satellite approaches to spectrum use and partnerships. Mobile Satellite Services (MSS) use via D2D would generally operate in the S-band spectrum range, in which the satellite operator transmits with its own holdings, integrating into the terrestrial network of any would-be commercial telco partner. The decision on whether the use of a given spectrum band is permitted for a given application is country-dependent. Europe, Africa and parts of the Americas are generally accommodative to MSS, albeit with some countries having stipulations in place. In countries with less permissibility (such as South Korea and Japan), commercial operations would be delayed or not possible pending changes to spectrum allocations.

Spectral capacity is unlikely to be a major stumbling block overall given that the NR standards confer strong incentive for countries to align with the global consensus, but it may preclude partnerships in certain countries or delay them even if commercial service could be made available. It also puts a spotlight on spectrum management practice, including scheduling and minimising interference with adjacent bands, which, in the event of things going wrong, can shift sentiments negatively.

There is an important connection here to address concerning satellite models that seek to reuse terrestrial spectrum – a practice that courts much risk in several forms. Terrestrial licensed spectrum is acquired at significant cost 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 were only used by customers of telco partners in the specific geographic areas where said bands are operational. This challenge is compounded in situations where satellite constellations are dynamic (i.e. they move continuously), meaning boundaries would need to be adjusted in real time to avoid signals unwittingly moving into areas where their operation is not permitted.

Shifting gears, there is also the question of converting theory into practice – essentially, will it work? Or, more to the point, will services perform at a good enough level? Despite vast improvements to satellite technology in the last 10 years, including smaller form factors, beam forming and increased ground infrastructure scale, NTNs face fundamental throughput challenges because of the altitude and spectrum channel sizes available (how much data can be put through the pipe). D2D is styled as a '5G-enabled' service because of the 3GPP standardisation. In practice, however, speeds are likely to be more akin to 3G at 3–5 Mbps, perhaps slightly higher in some circumstances. The ability to provide continuous coverage in rural and remote areas is the trade-off to the speed deficit with LTE. Operators will need to carefully consider how the service is marketed and the competitive differentiation that can be offered.

Finally, potential implementation and operational issues may creep into the fold. Willing telcos need to review their network sites to ensure smooth integration with any MSS to minimise the risk of service outages (or patchiness) to customers. This is heightened if an operator is in the middle of a 2G or 3G network sunset, which requires meticulous planning in the timing to get right. Integration of D2D satellite services into the telco billing systems is also key to avoid bill shock. Roaming is perhaps the thorniest issue. Even among terrestrial mobile networks, testing, validation and settlement can be a time-consuming process, albeit one that has improved as hub providers now oversee many of these functions under one roof. There is a strategic trade-off here for operators: while having more roaming partners provides better coverage, it also implies more time and effort needed to interconnect with partners.

We cite these questions not to temper the viability of D2D but to be candid on any complexities or obstacles that need to be negotiated in the course of forming commercial partnerships.

In the main, D2D satellite offers telcos a bridge to connect unconnected people, increase roaming coverage and improve capacity for businesses. The consumer segment has a total coverage gap of 570 million people – a number that will come down somewhat but remain materially large given fundamental network and geographical constraints. Even after adjusting for affordability limitations, the coverage gap contains 400 million people who could be reached with mobile connectivity. The sell-in to vertical industries in providing IoT connectivity addresses long-running pain points, particularly in rural areas. The combined addressable revenue base to telecoms operators of nearly $33 billion by 2035 is mostly incremental, an attractive proposition given that it is equivalent to 3% of the total telecoms industry revenues as of now (and higher in regions with a larger coverage gap, such as Africa). 5G NR standards to incorporate NTNs provide a natural basis for scale. Taken together, the clear change in the addressable market, lower costs and fast route to market are all factors that should drive momentum.

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