Final report

Dedicating 28GHz spectrum band to satellite services

An economic cost-benefit analysis

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NETWORK STRATEGIES

Executive summary

The 28GHz spectrum band (27.5-29.5GHz) is widely used by satellite operators to provide global fixed and mobile satellite broadband services. With the advent of IMT-2020 5G radio technologies, mobile operators are seeking spectrum to meet new technical requirements (including niche applications in mmWave). While the 26GHz band has been globally identified for 5G IMT by the ITU (WRC-19), the 28GHz band has been preserved for satellite services on a global basis by the ITU (WRC-15, WRC-19). Deviating from the globally agreed spectrum allocations by wholly or partially repurposing the 28GHz band for 5G may present adverse impacts (technical and economic), as countries seek to expand ubiquitous broadband access across land, sea and air with investments in Ultra High Throughput Satellites (HTS).

Economic benefits of 5G in mmWave are likely to be representative of the use cases that require localised high-capacity coverage. Few, if any, benefits of 5G mmWave are expected in underserved or unserved areas. This has significant implications for governments seeking to encourage economic growth in some targeted areas or to reduce the digital divide between communities. For Asia-Pacific (APAC) countries, this issue is crucial as most countries have more than 50% population living outside densely populated areas, representing at least two billion people. This study examines the socio-economic case for maintaining the 28GHz spectrum band for satellite services only.

Satellite is the most cost-effective option to address many universal coverage issues

Satellite provides links for mobile and broadband services, and access and satellite-powered connectivity for broadband services in underserved / unserved areas where populations do not have access to the same level of broadband available in urban areas.

Satellite is an affordable option for unserved and underserved communities

For the average data consumption in APAC of 10GB/month per user, hundreds of subscribers per cell in unserved and underserved areas can be brought online at an affordable cost. These scenarios are relevant for most unserved and underserved communities in APAC.

A large proportion of the APAC mobile broadband coverage gap can only be addressed by satellite

APAC has a mobile broadband coverage gap of about 200 million people, the majority being in highly populated countries with large populations beyond urban areas and difficult topography where it is economically unviable to lay terrestrial infrastructure. Assuming a gradual mobile coverage increase over a 10 year period into these unserved communities, we estimate that the demand will exceed 500Gbit/s by 2026 and reach about 2.8Tbit/s by 2030.

Satellite is the only option for enabling high-speed broadband applications for key global transportation sectors in urban and beyond urban areas

There is an increasing demand for high-speed connectivity for aviation and maritime. Implementation of data-centric applications is becoming a necessity in these sectors, as the industries seek to reduce costs through improved efficiency, increase revenues, comply with environmental targets and improve safety. The importance of FSS ESIM (Earth Stations in Motion) is a notable example where uninterrupted, ubiquitous and 'always-on' broadband is powering aircraft (gate-to-gate) and vessels (pier-to-pier) with seamless connectivity across the busiest airports and ports, located in major cities in APAC.

For example, our estimate of the potential direct benefits that could be achieved by shipping companies through high-speed broadband enabled applications on vessels, using a sample of 24 major global shipping companies, is between USD7.4 billion and USD11.6 billion for 2021-2025. Assuming cruise passengers return to pre-COVID-19 levels by 2022 and cruise ship operators ensure that their vessels have the capability for delivering broadband access, potential broadband-enabled revenues could reach USD2 billion by 2024. Global revenues for aviation satellite communications were USD527 million in 2019.

Satellite offers a future-proof solution for connectivity beyond urban areas

Terrestrial microwave links used beyond urban areas typically use frequencies in the range of 5-42GHz as these can support distances between 5-60km. However, these frequencies do not have sufficient capacity to meet the expected throughput of 5G cell sites and consumer data growth. As such, many communities in the APAC region will be left behind with limited network performance due to the terrestrial microwave bottleneck.

Satellite use case for 28GHz spectrum has high economic value

When re-planning spectrum bands international best practice is to examine alternative uses to identify which use maximises the value of that spectrum. The 28GHz spectrum band is currently assigned to satellite services, providing connectivity to ESIM applications and users without, or with insufficient, access to terrestrial services, particularly high-speed broadband services. These users could be in urban and beyond urban areas, on ships or in the air, and without satellite services utilising 28GHz the options for high-speed broadband are limited. Assessing the economic value of 28GHz for 5G must take into account the loss of value associated with removal of the arrangements for satellite services. This loss in value may have implications for national policy objectives as well as efforts to improve global trade. It therefore follows that the similar 26GHz band would have a higher value for 5G services than 28GHz, as it will cause no disruption to current and planned Ka-band satellite services which provide the highest capacity and performance in comparison to lower satellite bands (i.e. L-band, C-band and Ku-band).

Satellite plays a critical role in exploiting the potential of 5G

- Providing supplementary capacity to terrestrial networks to offload traffic in peak traffic times
- Carrying multicast traffic and caching of content on edge servers
- Providing satellite broadband connectivity to moving platforms such as vessels, trains and airplanes and temporary disaster recovery networks.

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1 Introduction

The 28GHz spectrum band (27.5-29.5GHz) is widely used by satellite operators to provide global fixed and mobile satellite broadband services. There are already over 120 Ka-band satellite systems in service, with many more currently under development.

With the advent of IMT-2020 5G radio technologies policy-makers and regulators are facing considerable pressure from terrestrial mobile operators to refarm and repurpose spectrum to meet new technical requirements (including mmWave). To meet these requirements the 26GHz band has been a key focus of mobile operators. Despite an international commitment at WRC-15 to the critical role of satellite in the 28GHz band, it appears that in some cases the 28GHz band is under consideration for either partially or wholly repurposing for 5G.

This study examines the costs and benefits of maintaining the 28GHz spectrum band for satellite services only. While there are many studies on 5G mmWave there is little available on the economic benefits of the allocation of 28GHz spectrum for satellite.

Our assessment considers three issues:

- the use of satellite as a 5G enabler (Section 2)
- comparative demand for satellite versus 5G mmWave (Section 3)
- the cost-effectiveness of satellite (Section 4).

Our conclusions are presented in Section 5.

2 Satellite: extending connectivity to the unserved and underserved

Use cases of satellite connectivity within a 5G context include:

- offering a cost-effective solution for addressing many universal coverage issues
- introducing an affordable option for underserved and unserved communities
- addressing a large proportion of the APAC mobile broadband coverage gap
- providing supplementary capacity to terrestrial networks to offload traffic in peak traffic times
- carrying multicast traffic and caching of content on edge servers
- providing satellite broadband connectivity to moving platforms such as vessels, trains and airplanes and temporary disaster recovery networks.

5G infrastructure is envisioned to be an ecosystem of networks that serves applications with differing requirements and using multiple complementary technologies. As such, many regional and international organisations, including 3GPP and the European Commission, recognise the importance of an integrated satellite and terrestrial infrastructure in the 5G ecosystem.[1] The satellite industry can play a critical role in providing universal coverage and supplementing terrestrial capacity.

2.1 Demand for satellite broadband: current status

As at September 2018, the GSMA reports that 1.9% of global backhaul connections are satellite based.[2] The study reveals a clear contrast between developed and developing countries. In north and north east Asia – which includes Japan, Republic of Korea and China – satellite links represents less than 1% of the backhaul links (Exhibit 2.1). However

1 3GPP (2016), *Technical Specification Group Services and System Aspects; Feasibility Study on New Services and Markets Technology Enablers*, technical report, 3GPP TR 22.891, 3GPP, 2016.

2 GSMA (2018). *Mobile backhaul options: Spectrum analysis and recommendations.* GSMA, September 2018.

these countries are highly fiberised, with fibre representing around 79% of total backhaul links in 2017. In south and south-east Asia, satellite links represents about 1.5% of the total backhaul market. Overall this represents about 30,000–50,000 cell sites connected by satellites in the APAC region. According to the GSMA's report, the total installed base of satellite backhaul links will continue to grow over the forecast period (2017–2024), however with a lower rate than that of fixed microwave and fibre links.

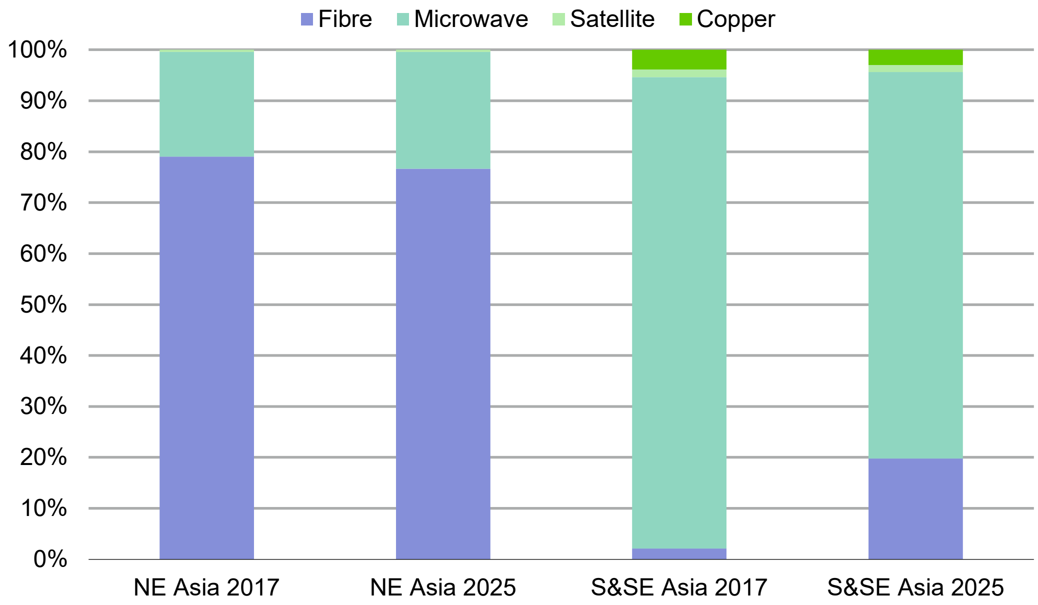

Exhibit 2.1: *Mobile backhaul by technology in north and south-east Asia [Source: GSMA]*

A large number of south-east Asian and Pacific countries have many communities where operators face topographical challenges such as dense forests or remote island populations. In many cases, laying terrestrial backhaul infrastructure is extremely impracticable considering the small user populations.

INDONESIA

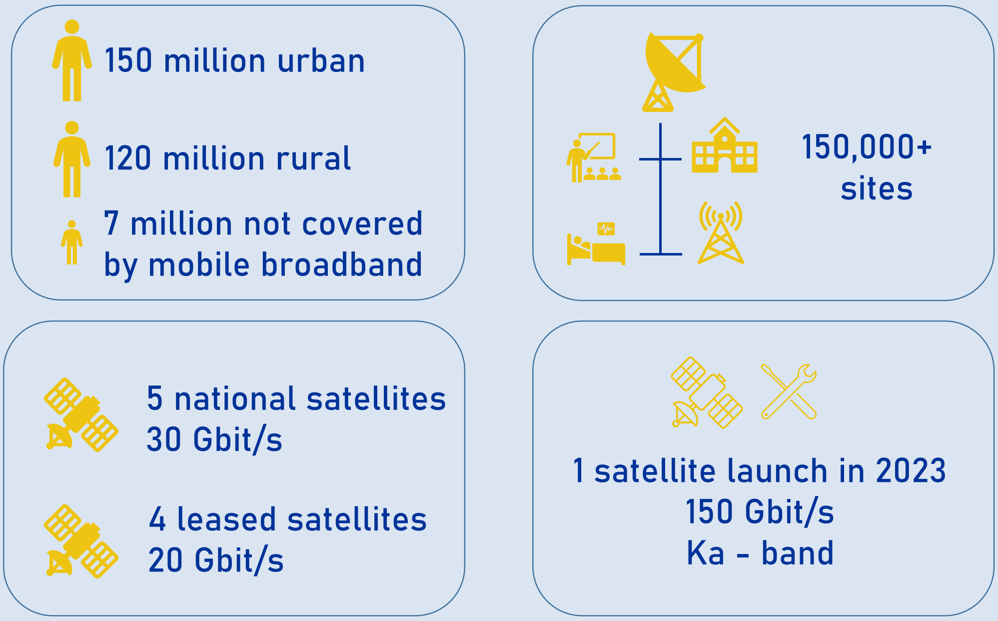

Exhibit 2.2: *Indonesia: satellite use and demand [Source: Network Strategies]*

Topography and demographics

Indonesia has a population of about 270 million. The country consists of an archipelago of 17,000 highly forested islands with challenging topography. Indonesia has about 118 million rural population, with around 7 million citizens with no access to mobile broadband.

Satellite services

Indonesia is heavily reliant on satellite middle mile and backhaul links. The country has five commercial satellites providing a capacity of 30Gbit/s and leases 20Gbit/s capacity from another four international satellite providers.

Indonesia established the Telecommunication and Information Accessibility Agency (BAKTI) in 2006 with the initial aim to facilitate rural connectivity.[3] BAKTI's main mission is to bridge the digital divide and provide ICT infrastructure for the public funded by the universal service obligation of telecommunications operators. BAKTI aims to provide satellite-based broadband and backhaul services to 150,000 isolated rural sites by the end of 2023. The first phase of the project, involving many local and international satellite companies, was completed in 2019. This includes government offices, schools, hospitals and mobile cell sites.

In 2020, the Indonesian government committed to an agreement with Thales Alenia Space to build a new Ka-band VHTS satellite (SATRIA-1) which will provide a capacity of 150Gbit/s for Indonesian operators. The satellite is expected to go into service in 2023. In the long term, the government intends to launch two other satellites, SATRIA-2 by 2024 and SATRIA-3 by 2030, which will provide 300Gbit/s and 500Gbit/s, respectively.[4]

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3 BAKTI, https://www.baktikominfo.id.

4 BAKTI (2020). *How Partnership Boosts BAKTI Contribution to Close the Digital Gap in the Country's Effort to Digitalize the Nation*. Presentation to ITU Presentation. BAKTI, November 2020. Available at https://www.itu.int/en/ITU-D/Regional-Presence/AsiaPacific/Documents/Events/2020/RDF2020/Session%202a/Final%20PPT%20-%20ITU%20RDF%20-%20Anang%20Latif.pdf.

Spectrum arrangements for 5G and satellite

The Indonesian regulator reserves frequencies in the C, Ku and Ka bands for satellite services.[5] While the 26GHz is being considered for 5G deployment and 28GHz is likely to retain satellite services in the band, no millimetre wave spectrum has been licensed to 5G as of September 2021.[6] Initial 5G launches used spectrum in the 1.8GHz and 2.3GHz bands.

Connectivity for unserved and underserved sites: satellites vs terrestrial microwave

The backhaul technology of choice in areas beyond urban is either long range terrestrial microwave (using 6-13GHz bands) or satellite links. Satellite equipment and traffic costs have been decreasing over time. The capital investment of satellite backhaul is typically a fraction of the cost of a terrestrial microwave link (Exhibit 2.3).

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5 Ministry of Communications and Information Technology (2016). *Indonesian Satellite Service Regulator Framework*. ITU International Satellite Symposium, Bali, September 2016. Available at https://www.itu.int/en/ITU-D/Regional-Presence/AsiaPacific/Documents/Events/2016/Sep-ISS2016/Presentation/ITU%20International%20Satellite%20Symposium%202016%20-%20Indonesia.pdf.

6 KOMINFO (2020). *Four Top Priorities for 5G in Indonesia*. Press release, ministry of information and communications technology. September, 2020.

	Terrestrial Microwave (6-13GHz)	*GEO High Throughput Satellites*
Typical capacity (Mbit/s)	270-1,000	100–300
Range (km)	18-35	unlimited
Spectrum fee	yes	no
Capital cost (USD)[7]	25,000–30,000	4,000
Maintenance costs (USD/year)	2,500–3,000	1,000
Traffic cost (USD/Mbit/s/month)	none	50-200[8]

***Exhibit 2.3**:* *Terrestrial microwave vs satellite links costs [Source: Network Strategies]*

Contrary to the historic perception that the capacity cost of satellite will lead to a higher total cost of ownership (TCO) than terrestrial microwave over time, satellite-based links can have a lower cost under many scenarios. The business case for satellite links depends on many factors, including the number of subscribers, data consumption and cost of the alternative technology. For example, if connecting an unserved/underserved site requires more than one microwave hop, terrestrial microwave is often economically unviable, unless it is justified by the need for high capacity.

One main advantage of satellite links is that capacity can be assigned on demand where it can be pooled across many small cell sites which helps the mobile operator to reduce and manage the cost. The introduction of High Throughput Satellites (HTS) and increase in supply within this decade is expected to bring satellite capacity costs below USD4 per Mbit/s per month by 2030, making satellite links more affordable over time and offsetting the cost of increasing data usage.[9]

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7 This includes the cost of a terrestrial microwave hop for the microwave option or, in the case of satellite, the cost of a ground satellite terminal.

8 Cost varies depending on the business model, length of contract and total capacity leased.

9 APSCC (2020). *Are Very High-Throughput Satellite Systems New Game-Changers?*,Asia-Pacific Satellite Communication Council, December 2020. Available at https://apscc.or.kr/2020-3/#Future.

ViaSat-3 and ViaSat- 4: FSS and ESIM services for the Asia-Pacific

Commencing in 2023, the ViaSat-3 UHTS network will deliver broadband globally with end-user speeds of up to 1Gbit/s and throughputs of over 1Tbit/s per satellite. The ViaSat-4 design is expected to increase this throughput five to seven-fold.

Ground infrastructure is under construction in Australia which will support the network across the entire Asia-Pacific region. Viasat's innovative gateway technology is reducing the size of gateway earth stations, and increasing capacity. The Viasat UHTS network is promising to provide ubiquitous fast-broadband services across urban and non-urban areas, as well as direct fast broadband to fixed premises and offering a cost-effective solution through Viasat's Community Wi-Fi (VCI).

Using ESIM services, the Viasat network will facilitate uninterrupted fast-broadband onboard aircraft and ships (gate-to-gate and pier-to-pier), as well as supporting ground transport infrastructure.

The coverage gap: the untapped potential

The Asia-Pacific region has a mobile broadband coverage gap of about 200 million people,[10] the majority being in highly populated countries with many communities located in difficult topography where it is economically unviable to lay terrestrial infrastructure (Exhibit 2.4). However, even highly urbanised countries with developed infrastructure such as Japan, Australia and New Zealand have sizable populations that are beyond the reach of terrestrial mobile broadband.

10 GSMA (2020). *The Mobile Economy: Asia Pacific.* June 2020.

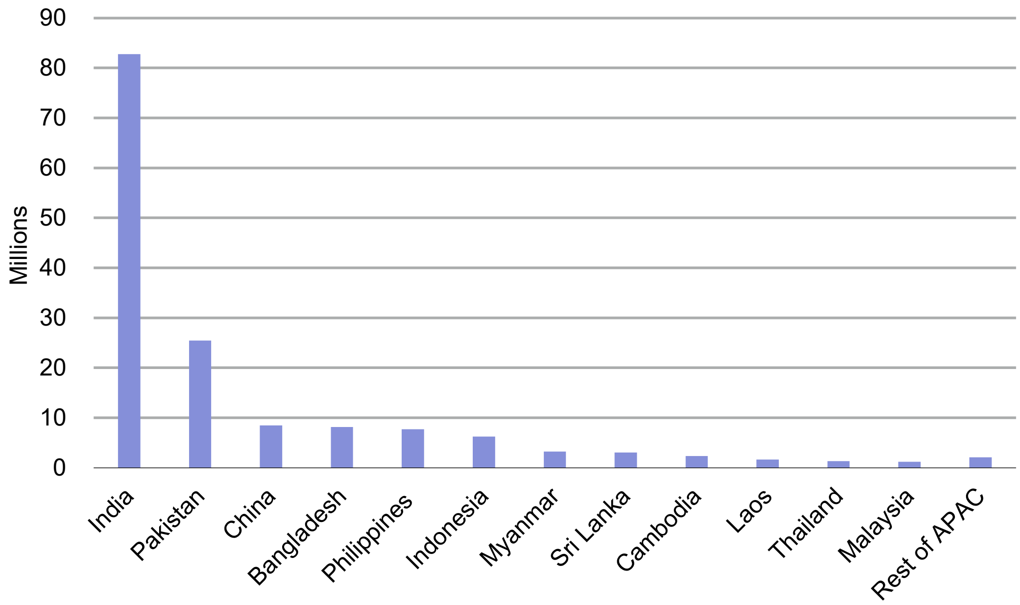

Exhibit 2.4: *Population not covered by either 3G or 4G in the APAC region [Source: ITU]*

Extending the coverage to unserved communities depends on national policy and the economies of deployment. As a large proportion of this gap could only be served with satellites, it is worthwhile to estimate the expected demand of these communities. Assuming a gradual mobile coverage increase over a 10 year period into these unserved communities, we estimate that the demand will exceed 500Gbit/s by 2026 and reach about 2.8Tbit/s by 2030 (Exhibit 2.5).[11] To put things into perspective, this demand exceeds the existing capacity provided by GEO High Throughput Satellites over the APAC region.

11 The forecast is based on the assumption that a user uses 1GB a month in the first year and traffic increases at the same rate as in urban areas.

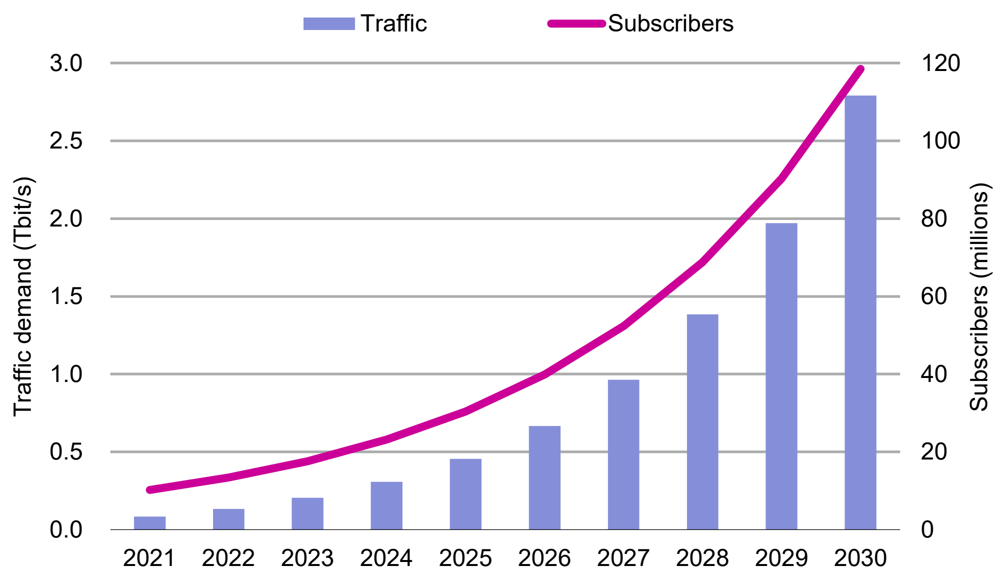

Exhibit 2.5: *Potential traffic demand of unserved communities in the APAC region [Source: Network Strategies]*

2.2 Connectivity for moving platforms across urban areas and beyond

Moving platforms such as airplanes and vessels in busy airports and ports located in APAC major cities represent cases where only satellite connectivity is possible, at least most of the time. For terrestrial transport, satellite can play a supplemental, but critical role for some cases. In this context, satellites can provide stand-alone links to moving platforms or provide connectivity directly to connected devices. Use cases that are envisioned for satellite services include (Exhibit 2.6):[12]

- multicast of traffic to update entertainment content onboard of airplanes (gate-to-gate)
- flight management data (gate-to-gate)
- broadband access for aircraft passengers (gate-to-gate)
- enterprise data transfer for maritime transport (pier-to-pier)

[12] Liolis et al. (2018). 'Use cases and scenarios of 5G integrated satellite-terrestrial networks for enhanced mobile broadband: The SaT5G approach', *International Journal of Satellite Communications and Networking*, Vol. 37, pp.91–112.

- connecting self-driving vehicles in areas beyond urban centres lacking reliable mobile coverage
- emergency 5G networks for public safety and disaster recovery
- government uses.

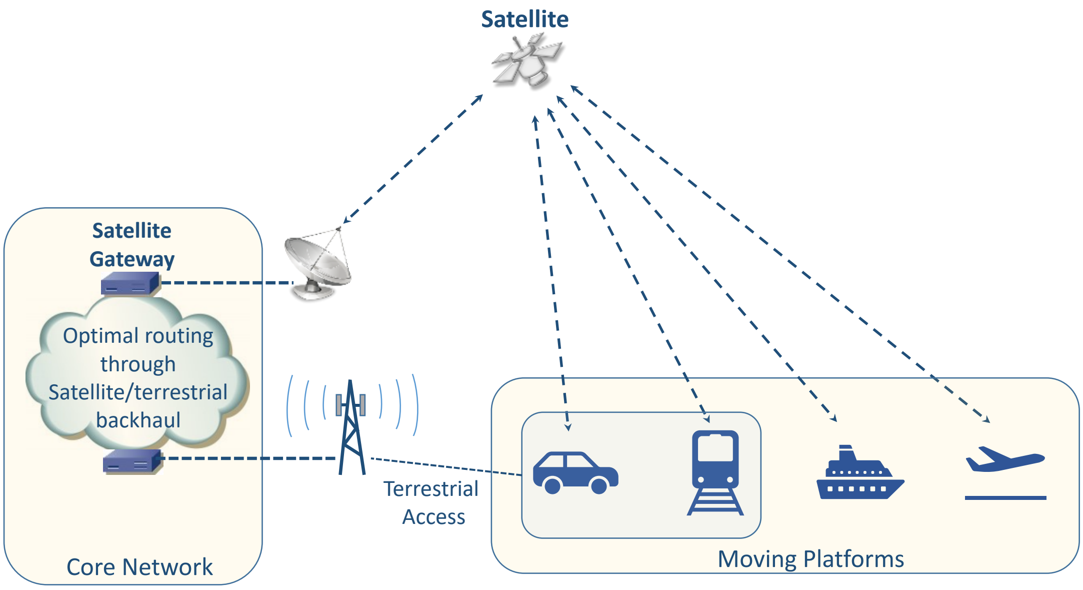

Exhibit 2.6: *Backhaul and broadband access for moving platforms [Source: Network Strategies]*

Satellite broadband connectivity to ships, aircraft and offshore oil and gas facilities is quite common and growing in demand. However, instead of merely connecting Wi-Fi hotspots, concepts are being developed for small 5G cells on moving platforms, as this will provide ubiquitous mobile coverage and seamless user experience.[13]

Moving communications platforms, that can be deployed quickly in case of emergencies, are also essential for public safety and disaster recovery. The APAC region is known to be the most disaster-prone region in the world, with annual economic losses predicted to exceed

13 Völk et al. (2019). 'Satellite Integration into 5G: Accent on First Over-The-Air Tests of an Edge Node Concept with Integrated Satellite Backhaul', *Future Internet*, Vol. 11, pp.1–17.

USD160 billion by 2030. [14,15] Mission critical communications are typically narrowband proprietary systems which do not allow traffic-intensive applications such as video and data transmission. However, 4G and 5G are specified to handle mission critical communications with far more capabilities. Integrating satellites with the terrestrial infrastructure adds resilience and robustness as the 'always-on' infrastructure is mostly located in space. In an event of disaster, emergency networks using satellite connectivity can be rolled out from scratch in a timely manner. 5G mobile base stations on moving platforms using satellite and with so-called Core-Edge Split (CES) have already been demonstrated.[16] The CES concept allows for communications to work within the cell, and between neighbouring cells, even when satellite coverage is temporarily unavailable. This distributed and flexible architecture with integrated satellite-terrestrial networks is likely to be a critical part of the future of Public Protection and Disaster Relief (PPDR) networks.

2.3 Solutions to terrestrial network bottlenecks

A large number of APAC countries have more than 50% population living outside densely populated areas (Exhibit 2.7). This represents more than two billion people across the region. Some communities in less populated areas are completely unserved, while there is a huge proportion of served communities vulnerable to terrestrial network bottlenecks.

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14 United Nations and Social Commission for Asia and the Pacific (2019). *Asia-Pacific disaster report*, August 2019. Available at https://www.unescap.org/publications/asia-pacific-disaster-report-2019.

15 United Nations (2018). *Disasters could cost Asia-Pacific region $160 billion per year by 2030, UN warns*, press release, April 2018. Available at https://news.un.org/en/story/2018/04/1008182.

16 Völk, F., Schwarz, R. T., Lorenz, M., and Knopp, A. (2020). 'Emergency 5G Communication on-the-Move: Concept and field trial of mobile satellite backhaul for public protection and disaster relief', *International Journal of Satellite Communications and Networking*, Vol. 39, pp.417–430.

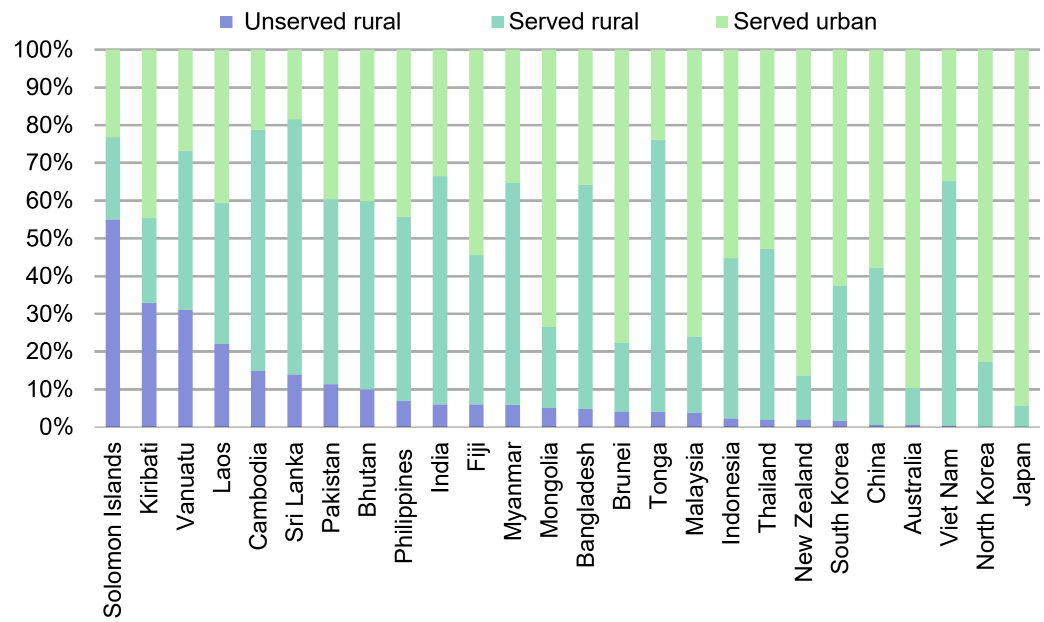

Exhibit 2.7: *The proportion of rural population not covered with 3G/4G (unserved) and rural and urban population covered by 3G/4G in a select number of APAC countries [Source: ITU]*

Mobile backhaul beyond urban areas is typically deployed using terrestrial microwave links. Capacity advancements in terrestrial microwave links have been mainly achieved by using higher frequency bands in the millimetre wave range (Exhibit 2.8). While higher frequencies in the V- and E-bands can provide capacities in excess of 1Gbit/s, they are unsuitable for unserved and underserved areas due to the limited range of 1-2km and increased atmospheric absorption. Microwave links beyond urban areas typically use frequencies in the range of 5-42GHz as these can support distances between 5-60km. However, these frequencies do not have sufficient capacity to meet the expected throughput of 5G cell sites and consumer data growth.[17] As such, communities beyond urban areas in the APAC region will be left behind with limited network performance due to the backhaul bottleneck.

17 A 5G cell site operating using a 40MHz channel at 3.5GHz can have a throughput in excess of 1Gbit/s. Using a 100MHz channel increases the throughput to more than 3Gbit/s.

Microwave frequency bands	*Typical capacity (Mbit/s)*	*Range (km)*
Sub-5GHz licensed	27	60
Sub-5GHz unlicensed	270	60
6GHz	270	35
13-25GHz	378	9-18
26-56GHz	540	1-9
56-71GHz (V-band)	810	1-2
71-86GHz (E-band)	5,400	1-2

Exhibit 2.8: *Typical terrestrial microwave capacities and range [Source: GSMA, Network Strategies]*[18]

Mobile data traffic is expected to grow by 24-39% annually in APAC countries over 2021-2026.[19] As the demand for mobile data grows, many cell sites beyond urban areas may become underserved compared to urban sites using high capacity links (fibre and microwave). We estimate that there are around 1.7 million cell sites serving populations beyond urban areas in the APAC region. Using forecasts of the types of backhaul links developed for north-east, south and south-east Asia by GSMA and the number of cell sites in each country,[20,21] we estimate that about 200,000 sites and 550 million subscribers will be underserved by 2025 and about 975,000 sites and 1.2 billion subscribers will be underserved by 2030 (Exhibit 2.9).[22]

18 GSMA (2021). *Wireless Backhaul Evolution: Delivering next-generation connectivity*. GSMA, February 2021.

19 Ericsson (2021). *Ericsson Mobility Report*. Ericsson, June 2021.

20 GSMA (2021). *Wireless Backhaul Evolution: Delivering next-generation connectivity*. February 2021.

21 The number of cell sites in each APAC country was estimated using data from different sources, including www.opencellid.org, towerco reports and telecommunications news websites.

22 The forecast is based on an annual data traffic growth of 21%, which is significantly less than what is predicted by the Ericsson Mobility Report.

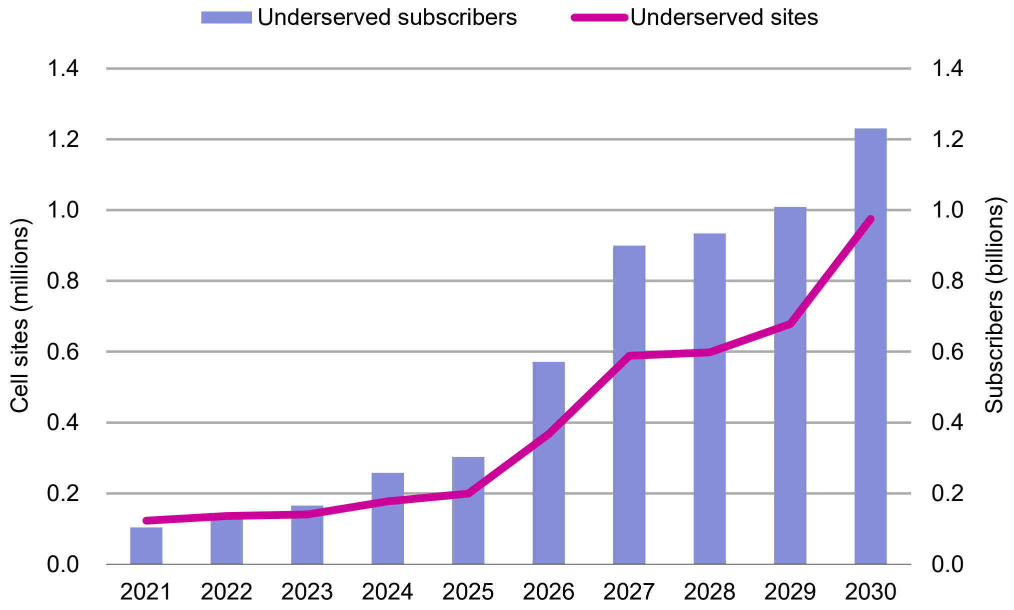

Exhibit 2.9: *Forecast for the number of cell sites and subscribers underserved by terrestrial microwave in APAC countries [Source: Network Strategies]*

The capacity gap between the forecast busy hour traffic of cell sites beyond urban and existing terrestrial microwave backhaul capacity is depicted in Exhibit 2.10. The ability of terrestrial technologies to cover this gap by upgrading existing infrastructure is likely to be limited by cost and topography. As such, this gap represents a sizable market for satellite services to offload traffic from terrestrial microwave links during peak traffic time and enable populations beyond urban areas to experience the full potential of 5G services, without the need for expensive capital investments.

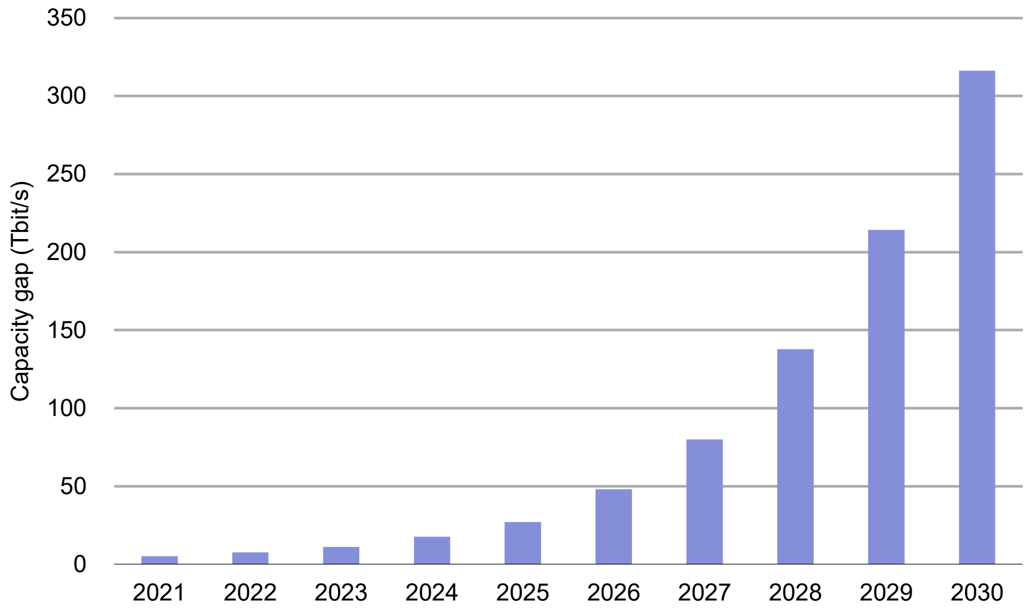

Exhibit 2.10: *Forecast for the gap between busy hour demand of rural cell sites and capacity of existing terrestrial microwave backhaul in the APAC region [Source: Network Strategies]*

AUSTRALIA

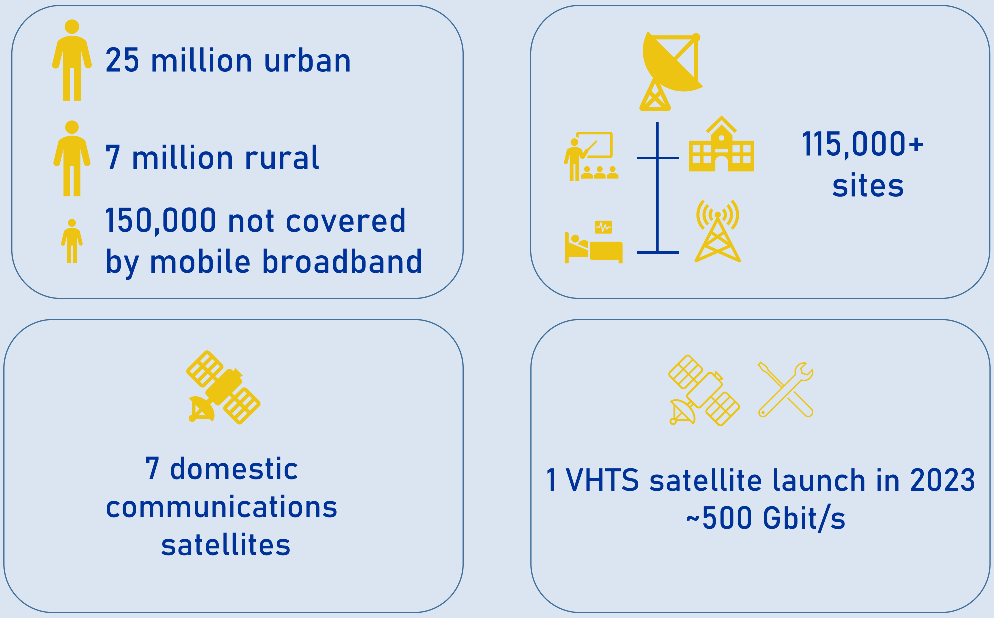

Exhibit 2.11: *Australia: satellite use and demand [Source: Network Strategies]*

Topography and demographics:

Australia encompasses a land area of 7.7 million km^2, including several thousand islands. Two separate coastal regions – in the east/south-east and the south-west – are home to most of the population, largely concentrated in urban centres. More than half the Australian land area has a population density of less than 0.1 person per km^2.

Satellite services

Australia has seven domestic communications satellites to bridge the large distances, and operators also lease capacity from several international satellite service providers. Optus, a telecommunications operator, has five satellites, all operating in Ku-band. NBN Co, the government-owned wholesale broadband provider, has two Ka-band GEO satellites used to deliver broadband services to areas not covered by its terrestrial network. As at July 2021, 111,900 premises were connected with an NBN Co satellite service.[23]

In 2014 the Australian Government implemented a mobile black spot program that aims to improve mobile coverage and competition in rural and remote areas. Funding also covers satellite backhaul in cases where existing fibre or microwave backhaul is not available or readily accessible.[24] As at May 2021, 926 base stations funded through the program had been activated.

The Regional Connectivity Program – also government-funded – has supported 132 projects to deliver broadband services in rural and remote locations. Projects have included several satellite solutions, including satellite backhaul for broadband, 4G satellite small cells and public pay-as-you-go satellite Wi-Fi and VoIP within remote communities.

23 NBN Co (2021), *National Broadband Network – rollout information*, 29 July 2021. Available at https://www.nbnco.com.au/corporate-information/about-nbn-co/corporate-plan/weekly-progress-report.

24 Department of Communications and the Arts (2016), *Mobile black spot programme: round 2 guidelines*, February 2016. Available at https://www.communications.gov.au/documents/mobile-black-spot-programme-round-2-guidelines.

Spectrum arrangements for 5G and satellite

The Australian Communications and Media Authority (ACMA) conducted a detailed review of the 28GHz band over the two-year period from 2018 to 2019. As a result, the ACMA introduced new arrangements for the Fixed Satellite Service (FSS) operating in the entire 28GHz band (including the ubiquitous FSS ESIM). Conditions for the protection of FSS were implemented to cater for the operation of fixed wireless access on secondary (no protection) basis across the band, and on a co-primary basis with apparatus licensed FSS earth stations in large population centres in the 27.5-28.1GHz frequency range.[25]

A key input to the review of the 28GHz band was the ACMA's planning decisions and intentions already made for the 26GHz band. The ACMA believed that sufficient spectrum had already been identified in the 26GHz band for wide-area broadband use (including 5G), and thus options in which such services were also allocated a portion of the spectrum in the 28GHz band were not expected to maximise public benefit and thus were not considered to be an appropriate use of the band.

2.4 Provision of multicast and edge caching

Broadcast and multicast traffic typically use extensive network resources as it travels through many network routes to reach geographically scattered users. Most of this traffic is video traffic, which currently accounts for two-thirds of mobile data traffic and is expected to increase to 77% of traffic by 2026.[26] Meeting quality requirements of video streaming can also be challenging for congested terrestrial networks. Satellites are perfectly suited to address broadcast/multicast traffic, as well as to optimise the content delivery costs, due to their ability to cover large areas in a cost effective manner. In these scenarios, a 5G core

25 Australian Communications and Media Authority (2019), *Future use of the 28 GHz band: Planning decisions and preliminary views*, September 2019. Available at https://www.acma.gov.au/consultations/2019-08/planning-options-28-ghz-band-consultation-092019.

26 Ericsson (2021). *Ericsson Mobility Report*. June 2021.

network can offload some of this traffic to satellites to bypass a congested terrestrial network and optimise resources (Exhibit 2.12). This can include:[27]

- offloading of broadcast/multicast traffic such as live video events
- pre-fetching and caching of content at edge servers where this content is on high demand
- delivery of software updates over the air to edge network nodes
- backhauling of aggregate IoT traffic from multiple sites.

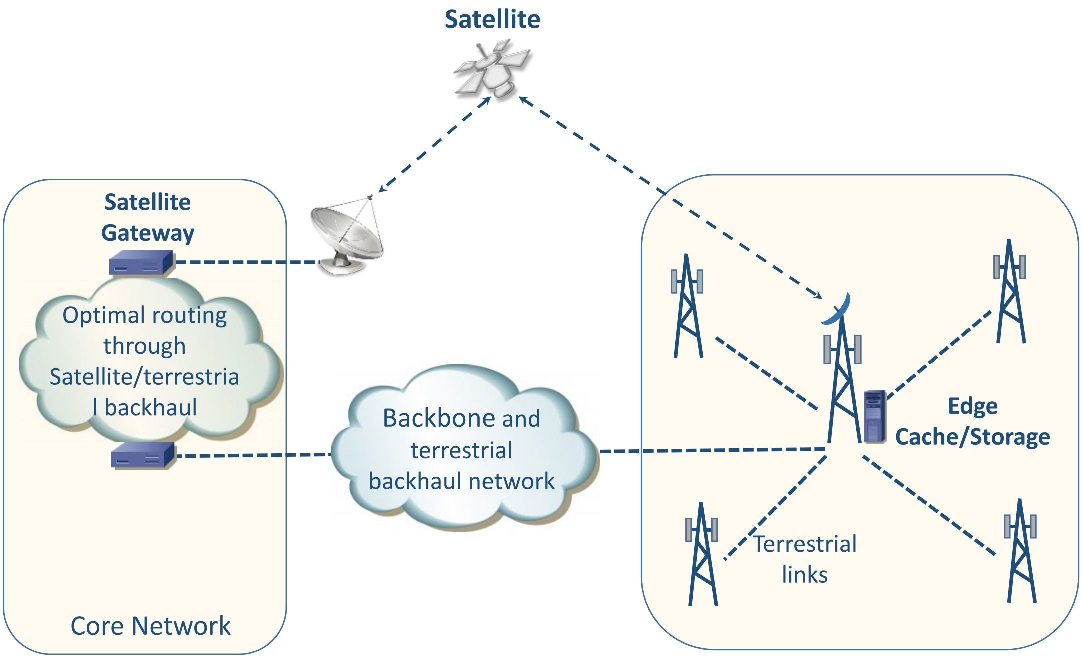

Exhibit 2.12: *Multicast/broadcast traffic to edge network nodes [Source: Network Strategies]*

27 Evans et al. (2020). 'An integrated satellite-terrestrial 5G network and its use to demonstrate 5G use cases', *International Journal of Satellite Communications and Networking*, Vol. 37, pp.358–379.

3 Beyond the reach of 5G mmWave access

Much of the estimated socio-economic benefit of mmWave is generated within urban population centres. The more limited reach of the mmWave bands results in increased costs of deployment in less densely populated areas, serving fewer people, which translates to a reluctance by operators to prioritise mmWave rollout in many areas.

Beyond the reach of terrestrial networks, there is an increasing demand for high-speed connectivity for aviation and maritime. Implementation of data-centric applications is becoming a necessity in these sectors, as the industries seek to reduce costs through improved efficiency, increase revenues, comply with environmental targets and improve safety.

3.1 5G mmWave: winners and losers

As noted by the Australian mobile network operator, Optus:

> While much is unknown about the possible future service made possible through mmWave application, what we can say at this early stage is that mmWave spectrum is unlikely to be used to supply wide area mobile networks; its propagation characteristics simply make this uneconomic. Rather, mmWave will be targeted to specific users and ultra-high bandwidth applications, most likely in the enterprise market.[28]

The GSMA estimated the socio-economic benefit of mmWave, identifying the use cases likely to be the chief beneficiaries of mmWave as requiring "a large amount of data throughput in a small coverage area or face scarcity of spectrum in lower frequency bands"[29]. This clearly excludes many regions, that have population densities much lower than in urban

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28 Optus (2020), *Spectrum allocation limits – 26GHz band*, submission in response to ACCC discussion paper, March 2020, paragraph 4. Available at https://www.accc.gov.au/system/files/Optus_31.pdf.

29 GSMA (2018), *Study on socio-economic benefits of 5G services provided in mmWave bands*, December 2018. Available at https://www.gsma.com/spectrum/wp-content/uploads/2019/10/mmWave-5G-benefits.pdf.

or suburban areas. These locations may have large coverage areas and often more than sufficient spectrum capacity to meet demand.

A second GSMA study[30] examined the economics of 5G mmWave for three notional geographic areas, based on sample locations from urban China, suburban Europe and rural United States (Exhibit 3.1). While the analysis demonstrated that mmWave delivered advantages for cost-effective 5G deployments, it is clear that the scenarios examined would have traffic densities considerably greater than could be achieved in many areas.

Scenario	*Population*	*Area (sq km)*	*Population density (persons per sq km)*
Urban China	2,300,000	112	20,300
Suburban Europe	25,000	5.6	5,000
Rural United States	19,000	17	1,100

Exhibit 3.1: *Characteristics of sample areas in GSMA study [Source: GSMA]*

A 2021 study of 5G 26GHz in Europe found that while the economic benefit of mmWave was significant, the use cases generating those benefits were characterised in interviews with mobile network operators as having multiple targeted locations within a wider network footprint that require "localised high-capacity coverage, and/or to cover specific industrial locations and corporate campuses"[31]. The use cases examined in the study included:

- **industrial**: ports, airports, smart factories
- **fixed wireless access:** macro site upgrades in areas with no fibre to the home (FTTH) but with minimum population density of 300 persons per square kilometre
- **high density urban / suburban locations** – shopping centres, city centres, transport hubs and stadiums.

30 GSMA (2021), *The economics of 5G mmWave*, January 2021.

31 Analysys Mason (2021), *Status, costs and benefits of 5G 26GHz deployments in Europe*, final report for Qualcomm and Ericsson, 14 May 2021. Available at ttps://www.analysysmason.com/contentassets/3716b071d2f647c9a9e57e56900b4f66/analysys-mason---status-costs-and-benefits-of-5g-26ghz-deployments-in-europe.pdf.

In other words, few if any benefits are expected beyond urban areas. This has significant implications for governments seeking to encourage economic growth beyond urban areas or to reduce the digital divide affecting unserved and underserved populations. A significant portion of the population in many Asia-Pacific countries (Exhibit 3.2) is yet to benefit from the same broadband access available in urban areas.

In the United States 5G deployment to date has focused on mmWave bands, including 28GHz. However there has been an increasing awareness that this focus will worsen the digital divide. As noted by Jessica Rosenworcel, Commissioner of the Federal Communication Commission:

> … we have made a series of choices that have put us behind when it comes to freeing key airwaves we need for 5G. That's because to date the United States has aggressively focused its early efforts to support 5G wireless service by bringing only high-band spectrum to market. We have yet to auction a single megahertz of mid-band spectrum.
>
> … our focus on millimeter wave spectrum is threatening to create 5G haves and have-nots in the United States. That's because while these airwaves have substantial capacity, their signals do not travel far. As a result, commercializing them is costly—especially in rural areas. The sheer volume of antenna facilities required to make this service viable will limit deployment to the most populated urban areas. This will deepen the digital divide that already plagues too many rural communities nationwide.[32]

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32 Jessica Rosenworcel (2020), *Statement of Jessica Rosenworcel, Commissioner, Federal Communications Commission before the Committee on Commerce, Science, and Transportation, United States Senate "Industries of the Future"*, 15 January 2020. Available at https://www.commerce.senate.gov/2020/1/industries-of-the-future.

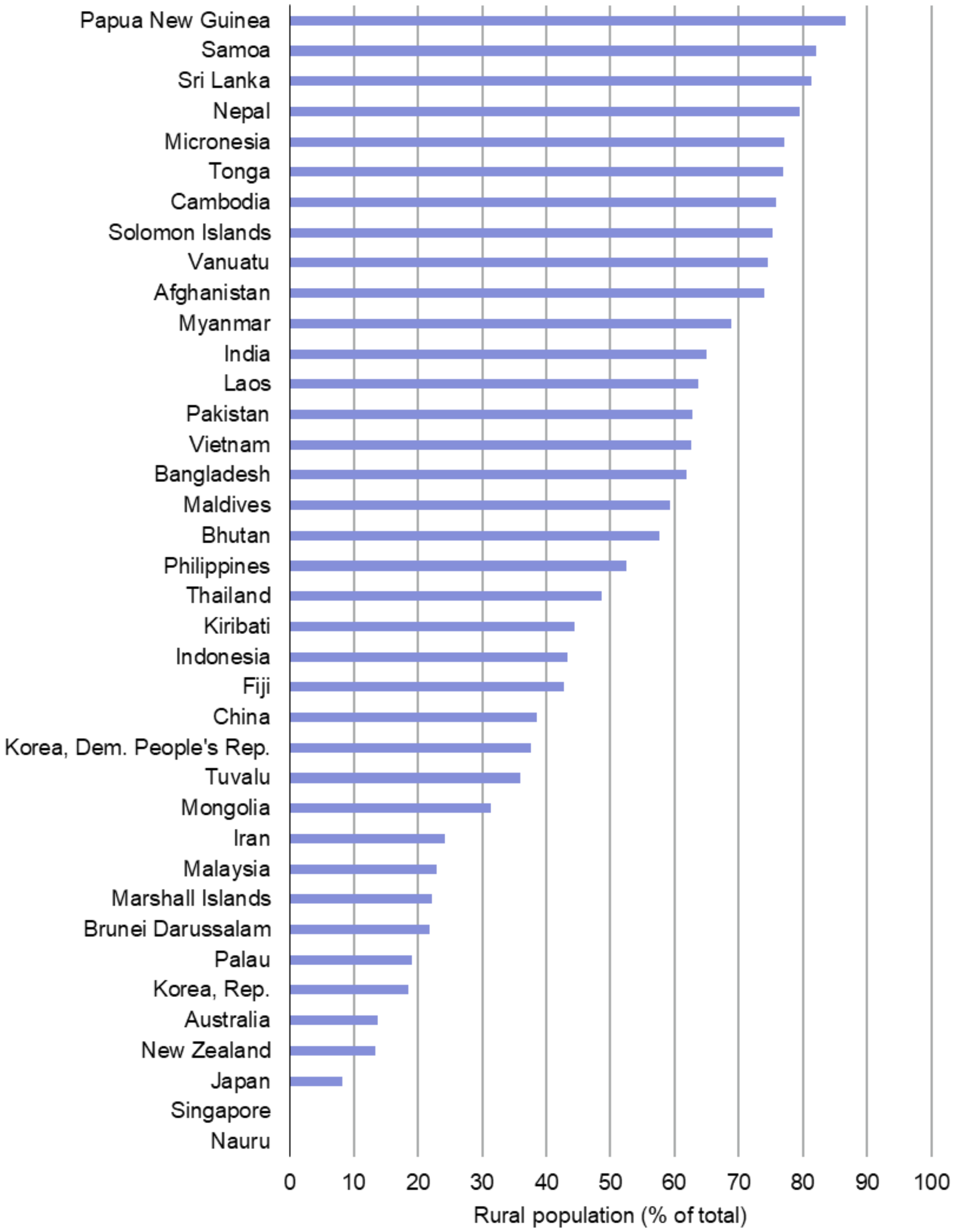

Exhibit 3.2: *Rural population as percentage of total population [Source: World Bank]*

3.2 Connectivity in the sky

Global revenues for aviation satellite communications were USD527 million in 2019. Although restrictions on travel and health concerns due to the COVID-19 pandemic have caused a major contraction in the airline industry worldwide, industry analysts are predicting compound annual growth of 3.3% to 2030.[33]

The International Civil Aviation Organization identified three data domains which categorise the type of information addressed by connectivity solutions.

Aircraft Control Domain (ACD)

ACD comprises mission-critical data that supports the safe operation of the aircraft, encompassing communications, navigation and surveillance data, flight information and alerting, and airline operations communication. The nature of this data requires real-time communication, under any conditions.

A 2017 study focussing on oceanic regions[34] found that satellite-enabled air traffic control applications delivered benefits of USD1.1 billion over the period 2001-16, comprising:

- direct benefit to airlines – USD420 million
- reduced carbon dioxide emissions – USD110 million
- indirect benefits for passengers – USD570 million.

A further USD1.9 billion in benefits were generated from satellite-enabled airline operations control over the same period. Note also that the annual benefits rose over time, as the number of 'connected aircraft' increased and aircraft separation reduced.

33 Frost & Sullivan (2021), *Global aviation satcom growth opportunities*, 28 July 2021. Available at https://store.frost.com/global-aviation-satcom-growth-opportunities.html.

34 Helios (2017), *The benefits of satcom to airlines*, report for Inmarsat. Available at https://www.inmarsat.com/content/dam/inmarsat/corporate/documents/aviation/insights/2017/Helios%20Study%20-%20Airline%20Benefits%20of%20Satcom%20-%20A%20Report%20for%20Inmarsat.pdf.coredownload.inline.pdf.

Airline information services domain (AISD)

AISD encompasses data for the operation of the aircraft, but not essential for the control of the aircraft, including applications for the cabin or flight crew. Although the data may be commercially or operationally important, it is not mission-critical.

For a single Boeing 787 flight, it is estimated that 500GB of data is collected.[35] By 2026 a latest generation aircraft is projected to generate 5-8TB of data per flight[36].

Legacy systems may be paper-based, or may be stored onboard in a digital format for later download once the aircraft is on the ground. Once on the ground connectivity may be problematic – due to lack of mobile coverage or airport mobile 'black spots' – or the data volumes that can be transmitted are constrained due to bandwidth limitations of the local networks.

Based on existing connected aircraft numbers, the operational benefits of connected aircraft, enabled through satellite communications with the Internet of Things, is estimated to yield annual savings of USD5.5-7.5 billion. By 2035, these savings are projected to increase to USD11.1-14.9 billion.[37]

Passenger information and entertainment services domain (PIESD)

The focus of the PIESD domain is to increase passenger value by providing an enhanced passenger experience through entertainment and personalised services, driving brand loyalty and repeat purchase decisions.

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35 Brendan Viggers (2015), *Using big data to schedule unplanned maintenance… streamlining the A&D support chain*. Available at https://www.aircraftit.com/articles/using-big-data-to-schedule-unplanned-maintenance-streamlining-the-ad-support-chain/.

36 Oliver Wyman (2017), *Aviation's data science revolution*, June 2017. Available at https://www.oliverwyman.com/our-expertise/insights/2017/jun/aviation-s-data-science-revolution.html.

37 LSE (2018), *Sky high economics – Chapter Two: evaluating the economic benefits of connected airline operations*, report for Inmarsat, June 2018. Available at https://www.lse.ac.uk/business/consulting/reports/sky-high-economics-chapter-two.

It encompasses ancillary revenue generators, such as e-commerce, digital advertising, Wi-Fi access and premium-priced in-flight entertainment. This component can deliver significant revenue streams – as an example, ancillary revenue for Wizz Air, a low-cost European carrier, comprised 56% of total revenue in FY21 (increased from 45% in FY20, due to a decline in ticket sales).[38]

Airlines will be seeking to rebuilding businesses devastated by the COVID-19 pandemic, while also addressing passenger concerns over safety from infection. Differentiation strategies and quality experiences will be critical for value creation.

In a November 2020 survey, 39% of respondents stated that the availability of in-flight Wi-Fi was more important than it was before COVID-19.[39]

The opportunities from broadband-enabled ancillary revenue are considerable, as estimated by an LSE study,[40] with the total market projected to grow from USD3.8 billion in 2018 to USD131 billion by 2035. Over that period the airline share of the revenue is estimated to increase from USD0.9 billion to USD30 billion (Exhibit 3.3). Asia-Pacific carriers are anticipated to take the largest share of airline revenue, from USD0.2 billion in 2018 to USD10 billion by 2035.

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38 Wizz Air Holdings (2021), *Annual report and accounts 2021*. Available at https://wizzair.com/static/docs/default-source/downloadable-documents/corporate-website-transfer-documents/annual-reports/wizz-air-holdings-plc-annual-report-and-accounts-2021_c86fdf69.pdf.

39 Inmarsat (2020), *Passenger confidence tracker*, November 2020

40 LSE (2017), *Sky high economics – Chapter One: quantifying the commercial opportunities of passenger connectivity for the global airline industry*, report for Inmarsat, September 2017. Available at https://www.lse.ac.uk/business/consulting/reports/sky-high-economics.

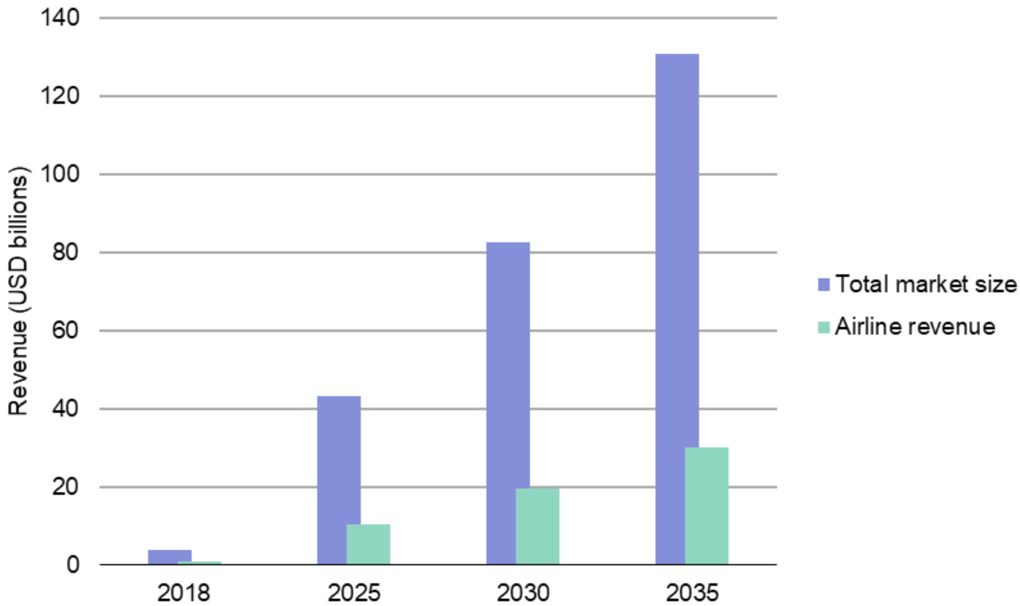


Exhibit 3.3: *Projections for broadband-enabled ancillary revenue and airline share, 2018 to 2035 [Source: LSE]*

The largest revenue category is broadband access, which accounts for just over half (53%) of the projected USD83 billion of broadband-enabled ancillary revenue in 2030 (Exhibit 3.4).

It is estimated that by the end of 2019, around 9,200 aircraft were equipped to provide in-flight connectivity, across 110 airlines, with this number expected to increase to between 15,000 and 18,000 aircraft by 2029.[41]

41 Euroconsult (2020), *COVID-19 shakes up in-flight connectivity industry*, 8 September 2020. Available at https://www.euroconsult-ec.com/press-release/covid-19-shakes-up-in-flight-connectivity-industry/.

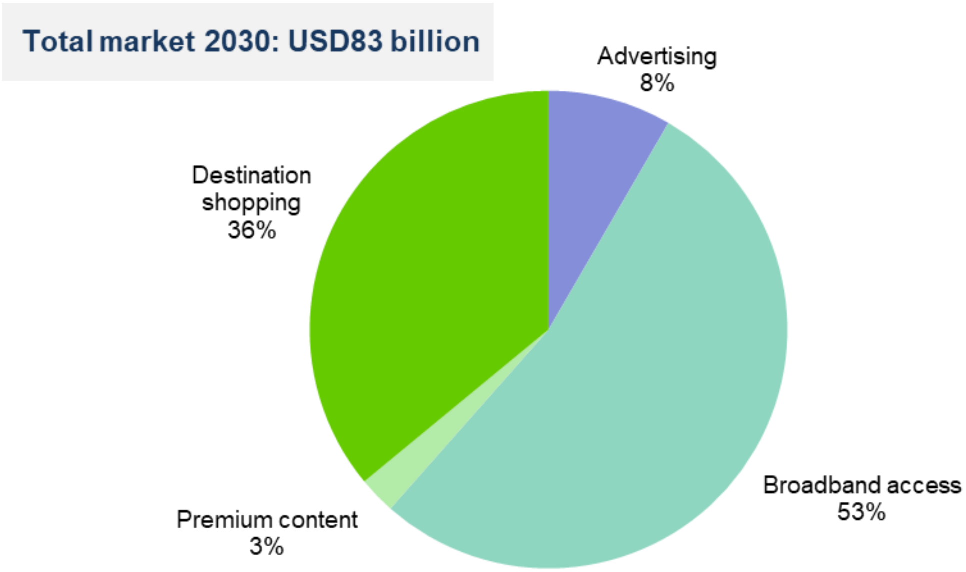


Exhibit 3.4: *Projected total market revenue by category, 2030 [Source: LSE]*

3.3 Connectivity on the seas

Satellite communications is becoming increasingly important for the maritime sector. Demand is continuing to shift away from legacy low-bandwidth mobile satellite services (MSS), delivered over L-band (1.5-2.5GHz) and C-band, as applications and expectations drive requirements for higher data-rates in Ku-band and in the band with widest bandwidth/ largest capacity available: the Ka-band.

After a slowdown in 2020 due to the effect of COVID-19, annual maritime satellite revenues are expected to reach USD2.5 billion by 2030 (Exhibit 3.5).[42]

42 Euroconsult (2021), *Impact of Global Pandemic on Maritime Connectivity Market Reflects Stark Contrast between Sectors*, press release, 27 April 2021. Available at https://www.euroconsult-ec.com/press-release/impact-of-global-pandemic-on-maritime-connectivity-market-reflects-stark-contrast-between-sectors/.

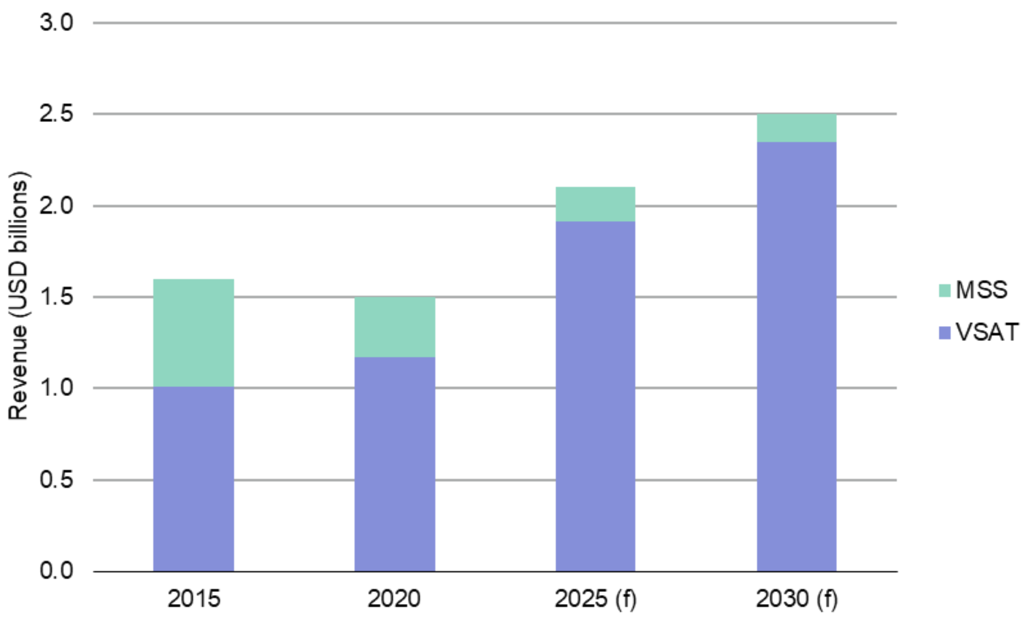


Exhibit 3.5: *Projected annual maritime satellite communications revenue, 2015 to 2030 (USD billion) [Source: Euroconsult]*

Bandwidth drivers for the maritime sector include:

Operational applications	According to the OECD, 'digitalisation increases the scale, scope and speed of trade'.[43] Operational applications address the need for greater efficiencies and improved safety procedures to reduce collisions and accidents due to human error. Such applications enable optimal route planning, improved fuel efficiency and remote monitoring of vessels.
Crew and passenger communications	Expectations of passengers on cruise ships and leisure vessels for always-on connectivity are driving demand for high speed broadband.
	Crew welfare and retention are key concerns for shipping companies, becoming more important due to longer periods at sea and

43 OECD (nd), *The impact of digitalisation on trade*. Available at https://www.oecd.org/trade/topics/digital-trade/.

quarantines as a result of COVID-19 restrictions. High-speed broadband also facilitates e-learning, addressing the need for continued training and up-skilling of crew.

Smart ships

As shipping companies seek to increase efficiency and reduce costs, smart ship applications are being developed. Artificial intelligence is being harnessed for automation in navigation and control technology, with benefits including improved safety through collision avoidance systems, optimal route planning and optimised vessel operations (addressing preventative maintenance, energy efficiency, emissions reduction and fuel consumption).

For example, real-time monitoring of performance can predict potential equipment failure, alerting crew in advance to replace or maintain equipment. This reduces the need for emergency replacements and minimises the time that the vessel is out of action due to equipment failure and unscheduled maintenance.

Significant investment is financing the development of autonomous and semi-autonomous vessels – for example, in Europe (MUNIN and YARA Birkeland), the United Kingdom (Mayflower), China, Korea and Japan – and several trials have been conducted.

Reliable high-speed bandwidth under all operating conditions will be essential for the data-centric systems to support smart ships and their applications.

In 2020 UNCTAD identified six priority areas for policy action, to respond to the COVID-19 pandemic and what it referred to as “the persistent challenges facing the maritime transport and trade of developing countries”:

- support trade so it can effectively sustain growth and development
- help reshape globalisation for sustainability and resilience
- promote greater technology uptake and digitalisation
- harness data for monitoring and policy responses

- enable agile and resilient maritime transport systems
- maintain the momentum on sustainability, climate-change adaptation and resilience building.

Merchant trade

Over 80% of global merchandise trade by volume is carried by sea[44], with the Strait of Malacca being one of the busiest shipping lanes in the world. Although the number of vessels has increased slightly in recent times (Exhibit 3.6), over the past 20 years vessel sizes have increased markedly as shipping companies seek to optimise costs through economies of scale. For ships built in the last four years, oil tankers are nine times larger, container ships four times larger, general cargo ships are three times larger and bulk carriers twice as large as ships built 20 years ago.[45]

A 2019 OECD study explored the effect of digitalisation on multi-factor productivity (MFP). Adopting high-speed broadband resulted in MFP for the average firm increasing by 1.4%, with large firms achieving an increase of 1.9%.[46] BCG noted that dynamic pricing enabled through advanced analytics for container vessels resulted in profitability increases of between 3-5%.[47]

We have used these results to scope the potential benefits that could be achieved by shipping companies through high-speed broadband enabled applications on vessels. For a sample of

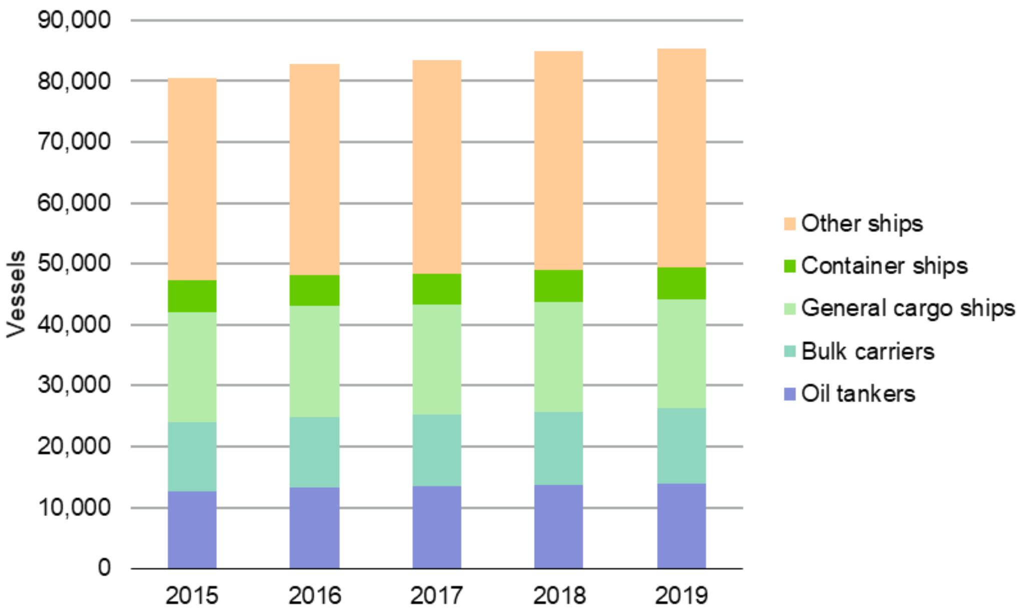
44 UNCTAD (2020), *Review of maritime transport 2020*, Available at https://unctad.org/topic/transport-and-trade-logistics/review-of-maritime-transport.

45 *Ibid*.

46 Peter Gal, Giuseppe Nicoletti, Theodore Renault, Stéphane Sorbe and Christina Timiliotis (2019), *Digitalisation and productivity: In search of the holy grail – Firm-level empirical evidence from EU countries*, OECD Working Papers No 1533, 9 February 2019. Available at https://dx.doi.org/10.1787/5080f4b6-en.

47 BCG (2018), *The Digital Imperative in Container Shipping*, 2 February 2018. Available at https://www.bcg.com/publications/2018/digital-imperative-container-shipping.

24 major publicly-listed global shipping companies[48], over the period 2021-25 the potential direct benefits would be between USD7.4 billion and USD11.6 billion.



Note: Data includes merchant vessels over 100 gross tonnage.

Exhibit 3.6: *World merchant fleet, 2015 to 2019 [Source: Equasis]*

Passenger vessels

High-speed satellite communications would provide cruise ships with similar operational benefits as for merchant vessels. Cruise ships also need to supply Wi-Fi access to their passengers, who typically expect high-speed broadband, with quality of service comparable to what they experience at home.

48 The sample included CMA CGM Group, COSCO, DHT Holdings, Euronav NV, Evergreen Line, Frontline Ltd, Hapag-Lloyd, HMM, International Seaways, Maersk, Mitsui, Navios Maritime Holdings, Nordic American Tankers, NYK Line, Orient Overseas Container Line, Overseas Shipholding Group, Scorpio Tankers Inc, SFL Corp Ltd, Star Bulk, Teekay Corp, Tsakos Energy Navigation, Wan Hai Lines, Yan Ming Marine Transport and ZIM.

Opportunities for revenue generation may be wider than simply providing passengers with Wi-Fi access. As is the case of aviation, potential revenue streams could also include e-commerce, premium content and advertising. Assuming cruise passengers return to pre-COVID-19 levels by 2022 and cruise ship operators ensure that their vessels have the capability for delivering broadband access, potential broadband-enabled revenues could reach USD2 billion by 2024 (Exhibit 3.7). This would also generate additional revenue for suppliers.

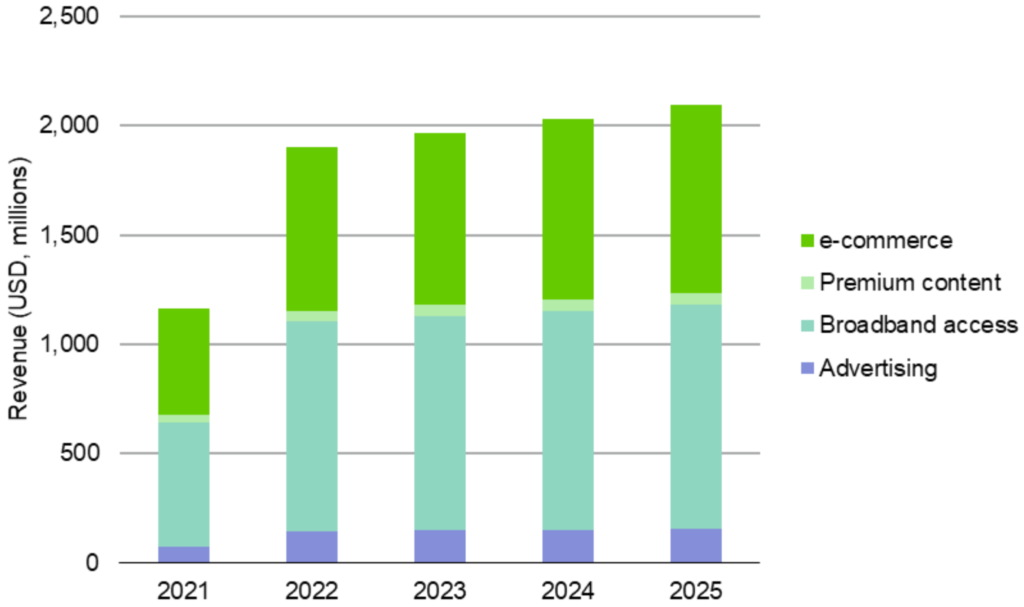


Exhibit 3.7: *Projected broadband-enabled cruise passenger revenue, 2021 to 2025 (USD, millions) [Source: Network Strategies]*

Some ferry operators provide Wi-Fi access to passengers. For example the Spirit of Tasmania ferry service operating between mainland Australia and Tasmania has a Wi-Fi service delivered by satellite. This market segment, however, lags that of cruise liners, although safety concerns – given a number of accidents over recent years – are likely to provide impetus for improved communications that would be resilient under all conditions.

HIGH-SPEED BROADBAND FOR MARITIME IN EUROPE

In 2018 the passenger sector (cruise ships and ferries) accounted for more than half of consumed bandwidth.[49] A number of ferry companies, including Stena Line – operating between England, Ireland, the Netherlands and Scandinavia – use the satellite service to provide its passengers with mobile connectivity via satellite as well as Wi-Fi access.

It has been noted that until recent years bandwidth requirements for fishing vessels had been relatively low, however requirements for catch reporting, new safety regulations, virtual fish markets and crew welfare have resulted in increased take-up of higher bandwidth services, even amongst smaller vessels as prices decrease and antennas have become more compact.[50]

Fishing vessels

As at 2018 there were 4.56 million fishing vessels, of which 3.1 million, or 68% were from Asia.[51] The three largest fishing fleets are from China, Indonesia and the Philippines (Exhibit 3.8). With regards to motorised fishing vessels, almost 75% or 2.1 million, are from Asia, of which over 80% are less than 12 metres in length.

49 Telenor Satellite (2019), *Data services set for success in 2020*. Available at https://www.telenorsat.com/data-services-set-for-success-in-2020/.

50 Telenor Satellite (2018), *VSAT designed to catch the fishing market*. Available at https://www.telenorsat.com/vsat-designed-to-catch-the-fishing-market/.

51 FAO (2020), *The state of world fisheries and aquaculture 2020*, Available at http://www.fao.org/3/ca9229en/ca9229en.pdf.

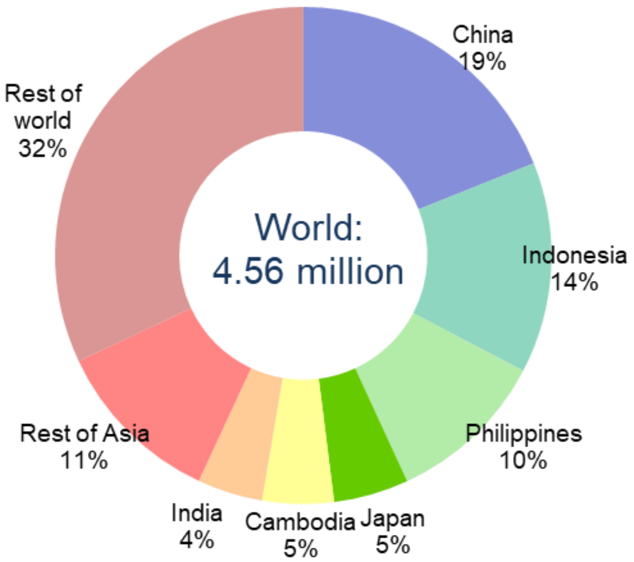


Exhibit 3.8: *Fishing vessels, 2018 [Source: FAO]*

For small fishing vessels that operate close to shore, terrestrial mobile networks can provide connectivity. This may not be an option in more isolated areas where coverage is limited or for vessels that operate further out to sea.

While larger fishing vessels have similar bandwidth drivers to that of merchant vessels, there are several applications specific to the fishing industry that could utilise high-speed broadband. Environmental factors and dwindling fish stocks are challenges, driving the adoption of sustainable practices to ensure the industry's survival.

Fisheries Innovation Scotland recently identified a number of areas in which satellite technology can aid the fishing industry[52]:

- supporting good decision making regarding fish stocks and sustainable levels of fishing
- improving the efficiency and sustainability of day-to-day fishing
- enabling a virtual fish market, enhancing the balance between supply and demand
- improved monitoring of illegal, unmonitored and unregulated fishing.

52 Fisheries Innovation Scotland (2021), *A review of satellite technology and opportunities for Scottish fisheries*, July 2021. Available at https://fiscot.org/wp-content/uploads/2021/07/FIS037-Final-Report.pdf.

4 Assessment of cost-effectiveness of satellite

One of the objectives of this study is to identify the point at which satellite becomes more cost-effective than terrestrial technologies (5G access and microwave backhaul) for a notional service. To undertake this analysis we developed a high-level reference model to assess the benefits of providing 5G service with satellite against that without satellite, using spectrum in the 28GHz band.

4.1 Model overview

The reference model calculates the cost incurred by a hypothetical operator in a South East Asian country when providing access and backhaul supply in underserved / unserved areas using satellite and 5G technologies.

Underserved / unserved areas are defined as population clusters with lower density (around 50 inhabitants per square kilometre) which are located more than 70km from the closest urban centre or traffic aggregation node.

The model calculates the Total Cost of Ownership (TCO) over the period from 2021 to 2026, for four scenarios (Exhibit 4.1):

- **Scenario 1: 5G** – in which the operator deploys a full 5G Radio Access Network (RAN) and connects the cell site via terrestrial microwave
- **Scenario 2: 5G RAN plus satellite** – same RAN network as in scenario 1 but using satellite connectivity instead of terrestrial microwave
- **Scenario 3**: **Wi-Fi plus satellite broadband connectivity** – deployment of Wi-Fi hotspots to provide broadband access via satellite connectivity
- **Scenario 4: Satellite** – in which the operator deploys a standalone satellite network to provide broadband connectivity.

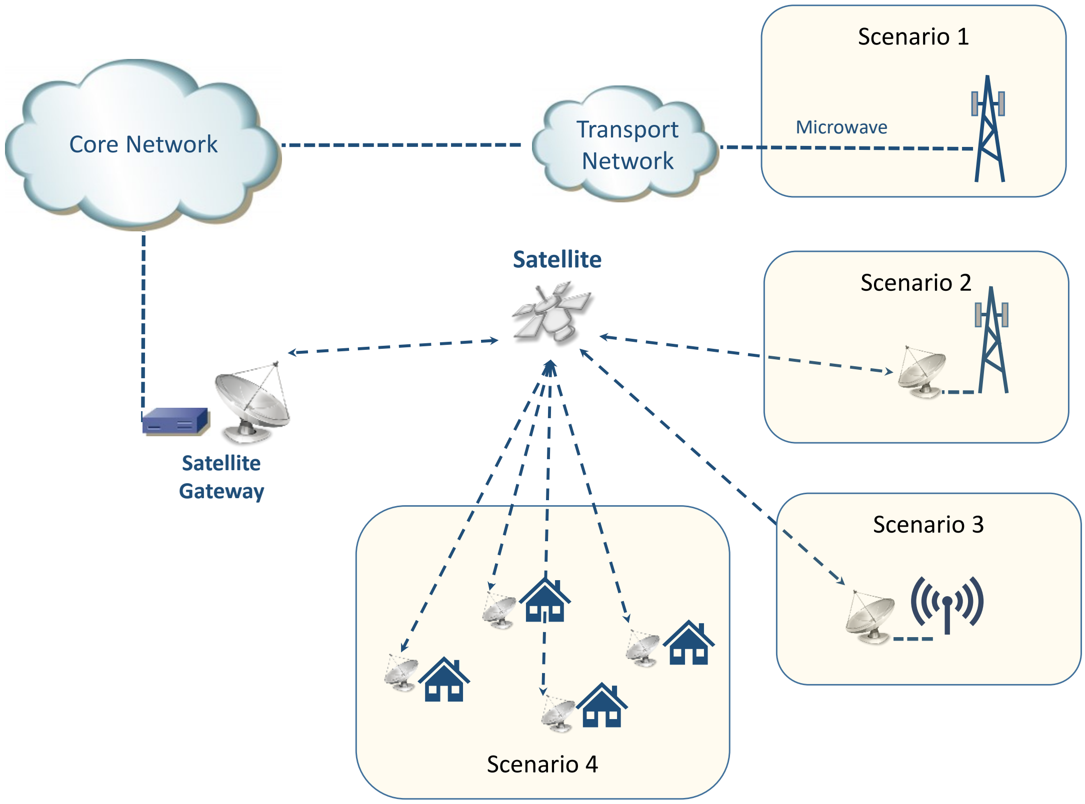


Exhibit 4.1: *Model scenarios [Source: Network Strategies]*

For scenarios with 5G technology the model assumes a 5G RAN operating in mmWave bands, namely 28GHz spectrum in scenario 1. This assumption is used to analyse the cost-benefit resulting from TCO when using the 28GHz band for either terrestrial or satellite broadband applications. Other scenarios where a 5G macrocell could use other 5G frequency ranges are out of scope, because the TCO of those macrocells would be subject to similar assumptions in terms of terrestrial microwave connectivity requirements in unserved/ underserved areas.

In each scenario the model calculates the cost of providing mobile and broadband services in an area equal to the coverage range of a single 5G radio site using mmWave bands.

4.2 Model results

From the analysis of the model results we conclude that satellite is the most cost-effective option for providing:

- Satellite-powered links instead of terrestrial microwave for mobile and broadband services
- Access and backhaul for broadband services.

The cost of satellite services is dependent on the amount of spectrum available. The model assumes that the satellite operator will have full access to the 28GHz band. Any reduction of the amount of 28GHz spectrum allocated for providing satellite services will result in a higher cost of satellite capacity due to reduced economies of scale, which in turn will diminish the economic benefits of using satellite in cases where other technologies are less cost effective.

The lowest cost alternative is scenario 3, followed by scenario 4. Both scenarios are more cost effective than the other two scenarios which include access over 5G technologies (Exhibit 4.2).

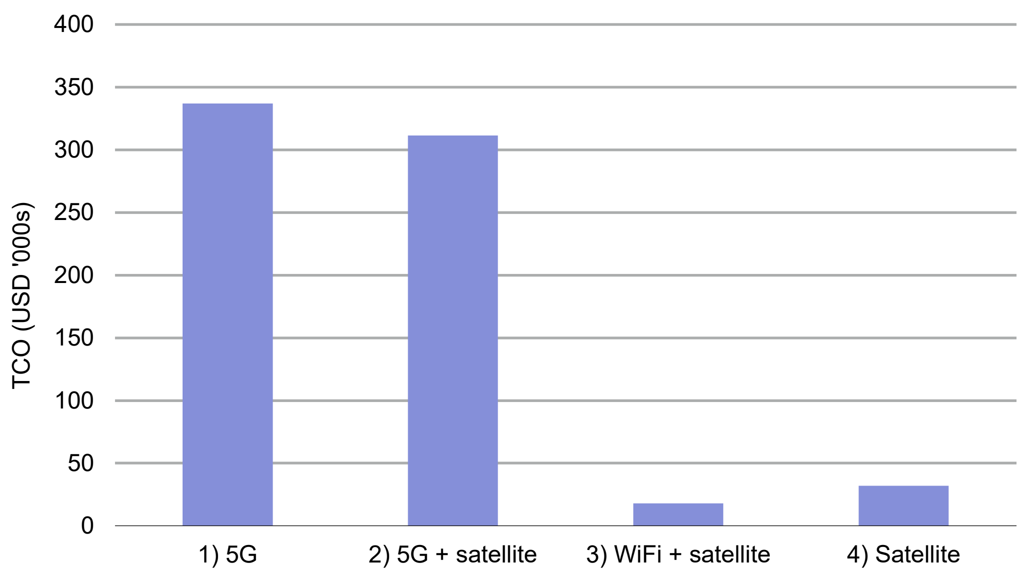


Exhibit 4.2: *Model results [Source: Network Strategies]*

A single Wi-Fi hotspot can serve several subscribers reducing the number of VSATs required in comparison to scenario 4 where one VSAT per subscriber is assumed. The lower capex required for scenario 3 makes this the most cost effective solution.

Note that the additional revenues generated by mobile services can offset the additional costs of the other scenarios which include 5G access. Therefore, as the most cost-effective alternative of the two suitable for providing mobile services, scenario 2 may be preferable to scenarios 3 and 4 when considering if any additional revenues are viable.

4.3 Results summary

Model results for each scenario are summarised in Exhibit 4.3.

Scenario	*TCO (USD '000s)*
1) 5G	336.8
2) 5G + satellite	311.4
3) WiFi + satellite	17.9
4) Satellite	32.0

Exhibit 4.3: *Model results [Source: Network Strategies]*

5 Concluding remarks

In most countries the 28GHz spectrum band is currently assigned to satellite services, providing connectivity to users without access to terrestrial services, particularly high-speed broadband services. These users could be in unserved or underserved areas, on ships or in the air, and without satellite services utilising 28GHz the options for high-speed broadband are limited. As yet only in Europe is the 28GHz band being fully protected for satellite services.

In the APAC region some countries, such as South Korea, Japan and Singapore, have recently assigned 28GHz for 5G, however it is important to note that a common characteristic of these countries is high availability and penetration of fibre. It is also noted that ESIM (aeronautical, maritime and land) is still of interest in these countries, where connectivity for aircraft “gate-to-gate” and maritime “pier-to-pier” is a driver in reconsidering the options to allow ESIM use in the 28GHz band. In many developing countries fibre backhaul is not ubiquitous and in such circumstances satellite is necessary to provide connectivity services. In countries such as India, even if there is interest in investing in 5G mmWave, terrestrial fibre is unlikely to be available for backhaul and therefore satellite services will be required. If the 26GHz band is assigned to 5G while also retaining 28GHz for satellite, then satellite backhaul remains a viable option for terrestrial mobile operators to reach subscribers where fibre or microwave backhaul is not feasible.

When re-planning spectrum bands many regulators, such as the Australian Communications and Media Authority, examine alternative uses to identify which use maximises the value of that spectrum.

Assessing the economic value of 28GHz for 5G must take into account the loss of value associated with removal of the arrangements for satellite services. This loss in value may have implications for national policy objectives as well as efforts to improve global trade and the aviation and maritime industries.

It therefore follows that the similar 26GHz band would have a higher value for 5G services, as unlike 28GHz assigning 26GHz to 5G will cause no disruption to existing and emerging

High-Throughput Satellite services including ESIM for which there are few, if any, alternatives.

Annex A: Model approach, inputs and assumptions

Our analysis of the relative benefits of providing access and backhaul supply in underserved / unserved areas using satellite and 5G technologies is based on a reference model of a hypothetical operator in a South East Asian country.

The model is based on inputs and assumptions which include:

- definition of underserved / unserved areas based on population density
- technical assumptions such as coverage area, spectrum efficiency and spectrum bandwidth for the hypothetical operator
- unit cost information for network resources such as base stations, microwave links and satellite earth stations
- demand assumptions covering the number of subscribers and usage profiles/parameters.

The following overview of the model (Exhibit A.1) illustrates the key inputs, assumptions and outputs.

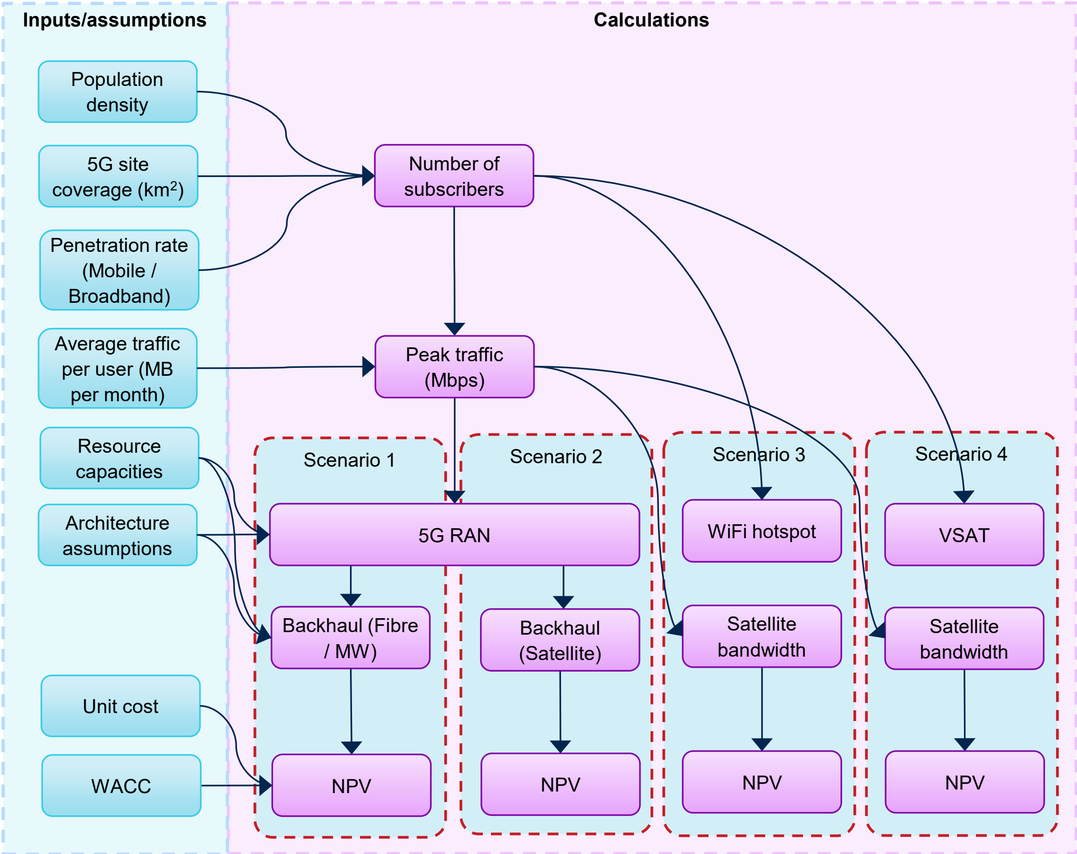


Exhibit A.1: *Cost model map [Source: Network Strategies]*

The model calculates the cost of providing mobile and broadband services in an area equal to the coverage range of a single 5G radio site using 28GHz spectrum. Population density and penetration rates (mobile and broadband subscribers per 100 inhabitants) are then used to calculate the number of subscribers in the coverage area.

Average traffic per subscribers (MB per month) and traffic assumptions (proportion of daily traffic in busy hour) are used to calculate the peak traffic (Mbit/s).

Using capacity and architecture assumptions the model then calculates the amount of resources needed to serve the estimated demand. This includes:

- number of 5G sites and base stations for scenarios 1 and 2
- satellite bandwidth for scenario 2

- Wi-Fi hotspots, VSATs and satellite bandwidth for scenario 3
- VSATs and satellite bandwidth for scenario 4.

Forecasts of mobile and broadband demand are used to calculate the resources needed for scenarios 1 and 2. In the case of scenarios 3 and 4, only broadband demand is considered as the solutions deployed do not support mobile services.

The main inputs and assumptions used in the model are summarised below.

Item	*Capex (USD)*	*Annual opex (USD)*
5G microcell (site and equipment)	99 811	22 761
Microwave (70km range using two hops link)	60 600	10 600
Satellite station	4 000	600
Wi-Fi hotspot and VSAT	1 400	194
VSAT	950	100
Satellite bandwidth ($ per Mbit/s)	-	720

Exhibit A.2: *Model assumptions – cost inputs [Source: Network Strategies]*

Item	*Value*
5G	
Spectral efficiency (b/s/Hz)	3.1 (2022) / 6.73 (2026)
28GHz (TDD) lot size (MHz)	400
Sectors per base station	3
Coverage of macrocell (km^2)	3.15
Wi-Fi	
Subscribers per hotspot[53]	8
Satellite	
Spectral efficiency (b/s/Hz)	2 (Download) / 1.5 (Upload)
28GHz lot size (MHz)	500

Exhibit A.3: *Model assumptions – resource capacities [Source: Network Strategies]*

53 While the Wi-Fi standard has a theoretical limit of 255 connected devices, in practice channel limitations result in performance being degraded with more than eight simultaneous user sessions per access port.

Item	*Value*
Subscriptions per 100 inhabitants	
Mobile	120.1
Broadband	10.7
Usage by subscription (MB per month)	
Mobile	11 720 (2022) / 39 936 (2026)
Broadband	23 189 (2022) / 31 360 (2026)
Population density (persons per km^2)	50

Exhibit A.4: *Model assumptions – demand inputs [Source: Network Strategies]*

The cost input values and resource capacities have been obtained from public sources and our in-house databases. When required, inputs and assumptions were adjusted to reflect the local conditions of the country modelled.

Demand information used in the model is specific for the country modelled and was sourced from the national telecommunications regulator and a local operator, and complemented with publicly available information.[54]

54 Ericsson Mobility Reports, available at https://www.ericsson.com/en/mobility-report?gclid=Cj0KCQjw5auGBhDEARIsAFyNm9GT-foEcP_0i9nGrVfatmE6nz8pYdhN7YwlMD4K7eDypylMTJNh6ycaAtnsEALw_wcB&gclsrc=aw.ds.