# Expanding digital connectivity through satellite broadband in the 28 GHz band in Africa

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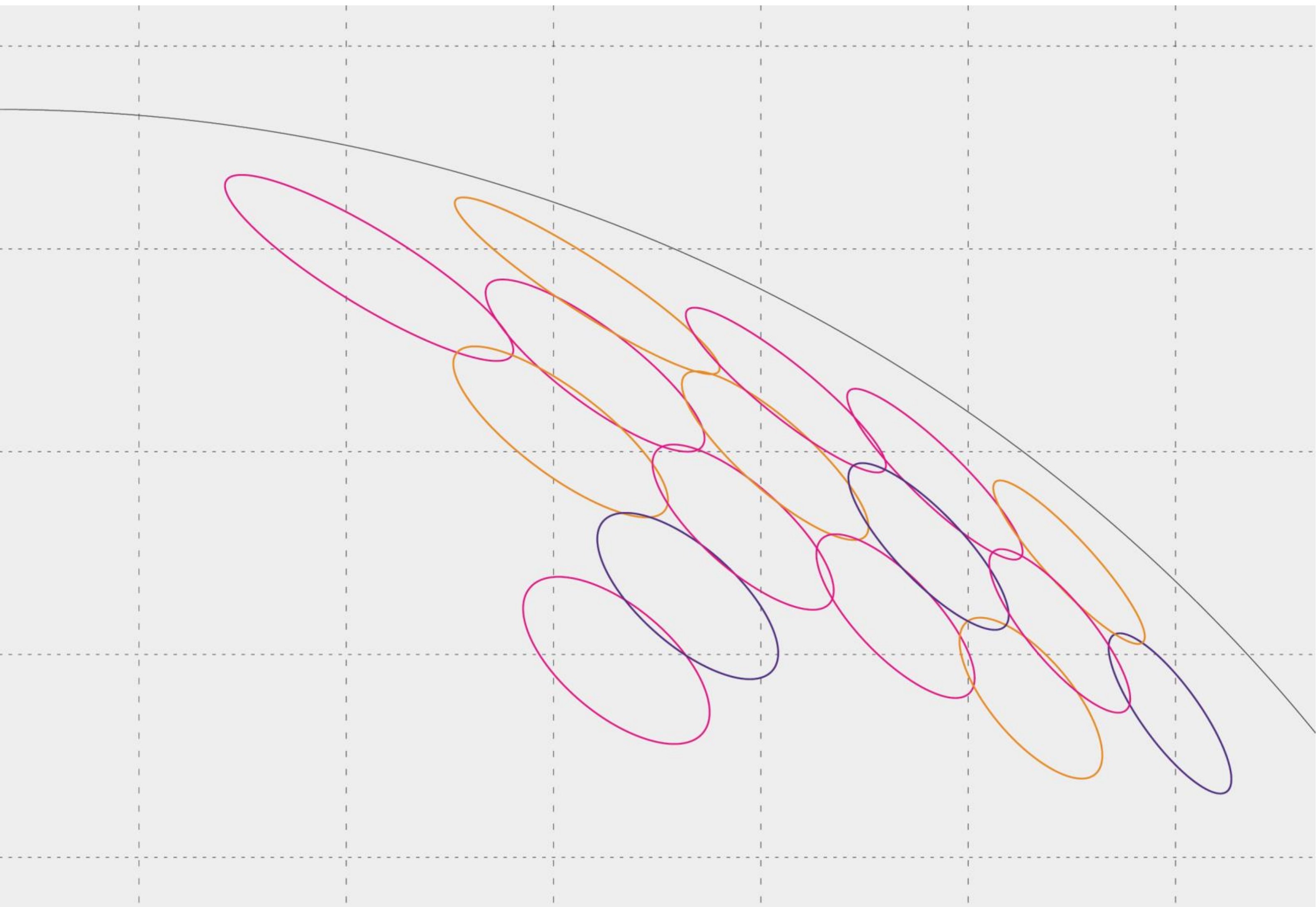

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## About Plum

Plum is an independent consulting firm, focused on telecommunications, media, technology, and adjacent sectors. We apply rigorous analysis to address challenges and opportunities across regulatory, radio spectrum, economic, commercial, and technology domains.

## About this study

This study considers the use of the 28 GHz band (27.5-29.5 GHz) to support the deployment of advanced satellite broadband services and the benefits that these could offer for countries in the African region.

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# Summary


Radio spectrum is an essential input for the provision of all forms of wireless communications and services and its value and contribution to economy and society has risen tremendously in the last two decades.

At WRC-19, a total of 17.25 GHz of spectrum was identified for IMT services to support 5G development in the high-frequency range above 24 GHz (mm-wave spectrum). The 28 GHz band (27.5-29.5 GHz) is part of the Ka-band (17.7-21.2 and 27.5-31 GHz) which is allocated for fixed satellite services (FSS). It is not among the identified IMT bands, and only a small number of countries have assigned (or partially assigned) this band for IMT. In most countries, the assignment of mm-wave spectrum has been in the adjacent 26 GHz band, which is fully harmonised on global basis for IMT. To date, 5G use cases are still emerging and demand for mm-wave spectrum remains uncertain.

The space economy is forecast to reach over USD1 trillion in the 2040s and much of this growth over the next 20 years will be driven by Internet access and broadband connectivity.[1] Next-generation high throughput satellite (HTS)[2] systems are capable of delivering gigabit connectivity, and the 28 GHz band is a key enabler to achieving this, especially as the Ku-band (11-14 GHz range) is increasingly congested. It is important for satellite to continue to have full access to the Ka-band to meet the requirements of various use cases, including communications on the move, direct broadband connectivity, and satellite-powered services to end users. Satellite technology is a key component for the provision of broadband solutions globally, and it is anticipated to have a significant role in the future expansion of the 5G ecosystem.

If IMT services are deployed in the 28 GHz band, potential interference between satellite earth stations and IMT receivers (base stations and terminals) is likely to occur. HTS services are expected to be deployed ubiquitously and on the move through earth stations in motion (ESIM), and in such a situation co-channel uses of HTS services and IMT in 28 GHz is not feasible.

In emerging markets, including those in Africa, satellite deployments in the Ka-band can contribute to economic benefits including:

- Broadband connectivity for unserved areas and communities,
- Improvements in broadband service quality for underserved locations,
- Wider choice of broadband and pricing options, and
- New applications and connectivity services for expanding market segments, such as land, aeronautical and maritime transport routes, through earth stations in motion (ESIM).

The scale of economic impact across these benefits varies significantly depending on market conditions and availability of alternative broadband options. Across Africa as a whole, there is an estimated 681 million population who are not covered by at least a 4G mobile service. We estimate that the economic benefits of providing high speed broadband connectivity via satellite to these unserved regions in Africa will be an increase in GDP of between 1.02% and 2.09% by 2030. These values only consider the GDP impact of the provision of broadband connections to those who are currently unconnected. There are also broader socio-economic benefits of digital inclusion and general wellbeing through better access to health facilities, education and other essential services, which are not included in the economic estimate.


[1] OECD (2019). The Space Economy in Figures: How Space Contributes to the Global Economy.
[2] These are commonly termed as very high-throughput satellite (VHTS) and ultra-high throughput satellite (UHTS) systems.

In addition to connecting the unserved population, satellite broadband can also benefit the underserved segment of the population in terms of wider choice, more competitive offerings and better service quality for consumers and enterprises. It is complex to assess the full scale of the benefits for underserved population due to limitations in the data on the quality of fixed broadband infrastructure, the options available and adoption levels, as well as and consumer preferences on pricing, broadband needs, and the extent of substitution between fixed and mobile services.

For six major African economies (Democratic Republic of the Congo, Egypt, Kenya, Nigeria, Rwanda and South Africa) we have adopted a high-level approach that considers both the unserved and the underserved population. For the latter we take account of the level of FTTH broadband coverage, the proportion of rural population and differences in broadband quality in urban and rural locations. Unlike our previous study in Asia Pacific, there is insignificant FTTH coverage outside of urban areas in Africa, meaning that the entirety of the rural areas does not have access to high-quality connections using this technology. Figure 1 shows the estimates of the economic impact in terms of the additional GDP per annum by 2030 for the six countries.

**Figure 1: Economic impact of satellite broadband, additional GDP per annum by 2030**

| Country | Total addressable market population (households), million[3] | Annual GDP increment |
|---|---|---|
| DRC | 66.5 (7.65) | 1.49% – 1.84% |
| Egypt | 58.0 (12.5) | 0.40% – 0.92% |
| Kenya | 39.5 (8.4) | 0.76% – 1.73% |
| Nigeria | 122.6 (25.1) | 1.19% – 2.62% |
| Rwanda | 9.0 (2.7) | 0.44% – 1.42% |
| South Africa | 20.3 (4.7) | 0.26% – 0.63% |

The estimates range from an increase of 0.26% for South Africa, where there is relatively high LTE coverage and adoption alongside an uran-dominated population, to 2.62% for Nigeria, where FTTH coverage is almost non-existent and adoption of all types of broadband is low. These figures are derived based on potential increases in broadband adoption, and represent a plausible upper bound of the potential economic contribution of satellite broadband. It should also be noted that the figures may not solely be indicative of satellite broadband take-up, but the overall effect of increased broadband adoption driven by the wide-spread availability of satellite connectivity and a more competitive broadband market.

In addition, emerging satellite applications enabled by ESIMs in the Ka-band are also expected to contribute significantly to the growth of the aviation and maritime connectivity markets in the coming years. Satellite-connectivity will provide not only high-quality, uninterrupted broadband connectivity for air and sea passengers, but also drive economic benefits through digital transformation. For industry players including airlines, shipping companies and ports, satellite-enabled applications such as real-time monitoring, fleet tracking, traffic control, route optimisation, communications and reporting, offer substantial gains including operational efficiency, cost savings and environmental benefits.

For policymakers and regulators in these countries, it is important to carefully assess the requirements of satellite and IMT in deciding on the future allocation of the 28 GHz band. This will need to consider the level of broadband infrastructure, the needs of those in unserved and underserved regions, emerging satellite fixed and mobile applications in other industry sectors such as aeronautical and maritime, and the associated economic value and trade-offs involved.

[3] Includes unserved and unserved population.

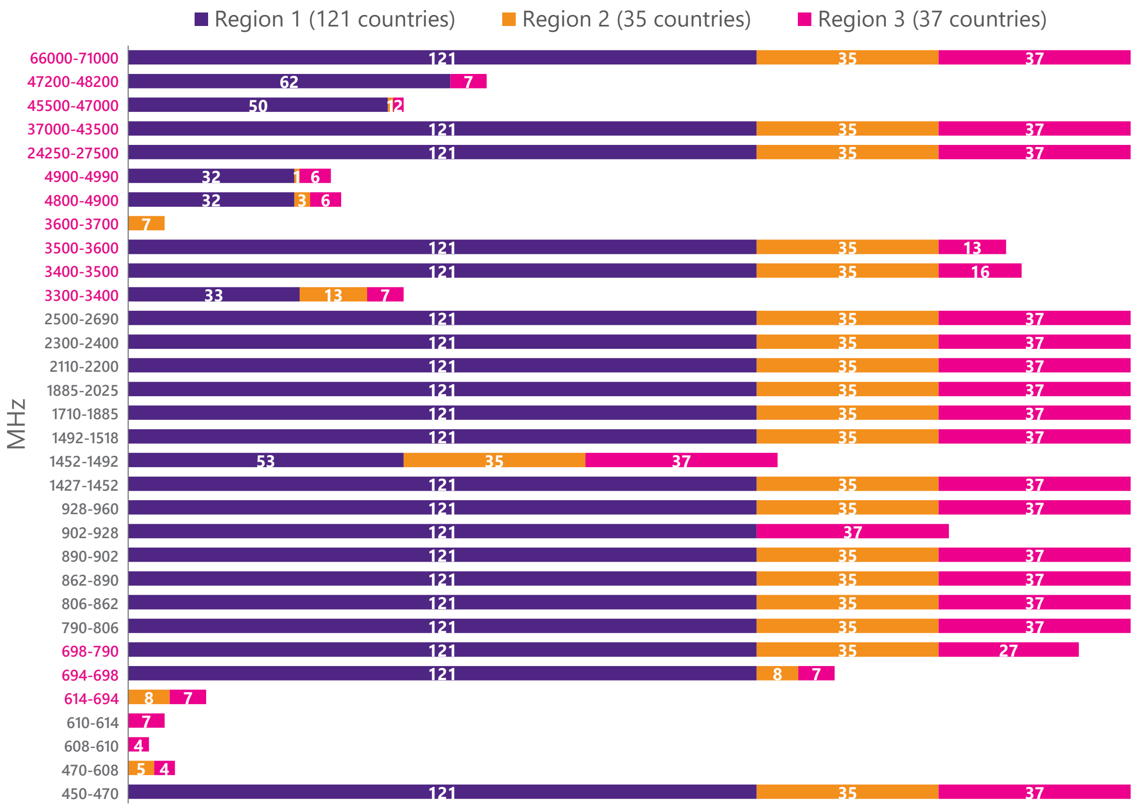
# 1 Satellite technologies and spectrum access

Radio spectrum is an essential input for the provision of all forms of wireless communications and services and its value and contribution to economy and society has risen tremendously in the last two decades. The importance and the value of radio spectrum resource makes the task of managing it ever more crucial, particularly as technologies continue to evolve and new uses for spectrum emerge.

## 1.1 WRC-19 and the expansion of spectrum bands for IMT

At the previous World Radiocommunication Conference in 2019 (WRC-19), a total of 17.25 GHz of spectrum was identified for IMT services to support 5G development. The majority of the new spectrum identified for IMT was in the high-band range (or mm-wave frequencies) including 24.25–27.5 GHz, 37–43.5 GHz, 45.5–47 GHz, 47.2–48.2 GHz and 66–71 GHz. Figure 1.1 shows the frequency bands identified for IMT across the three ITU regions following WRC-19; Africa is included here within Region 1.

**Figure 1.1: Spectrum bands identified for IMT across ITU Regions following WRC-19[4,5]**




To date, most 5G networks deployed have been based on mid-band spectrum, in particular 3400-3800 MHz (C-band).[6] There is strong interest across the mobile industry globally for these frequencies given their suitability for relatively wide-area coverage and capacity requirements for enhanced mobile broadband. There has also

[4] Note: Bands in magenta based on WRC-19 decisions.
[5] Source: ITU Radio Regulations 2020.
[6] As of May 2021 there are 178 operators which have deployed, are deploying or have access to licensed spectrum in the C-band. In comparison, 27 operators have deployed or are deploying 26/28 GHz spectrum. Source: GSA (24 June 2021). GSA Snapshot. H1 2021 Review.

been some deployment in the 700 MHz bands in Region 1, particularly in rural areas where the lower frequency spectrum can travel longer distances.

### 1.1.1 Status of 26 GHz and 28 GHz bands

Among the mm-wave frequencies, most regulatory and industry activities to date have focused on the 26 GHz (24.25 – 27.5 GHz) and the adjacent 28 GHz (27.5 – 29.5 GHz) which is part of the Ka-band, typically allocated for satellite in most countries. 28 GHz is not a globally harmonised band for IMT, and only small number of countries have awarded (or partially awarded) this band for 5G use.

Figure 1.2 shows the current status of the 26 GHz and 28 GHz bands across the three ITU regions. Most regulators in Region 1 (Europe, Middle East, Africa) are prioritising the 26 GHz band for IMT, though in some markets incumbent use in parts of the band (such as fixed links, licence-exempt, satellite and military) has implications on the availability of spectrum across the band. The picture is more mixed in Region 2 (Americas) and Region 3 (Asia Pacific). In cases where regulators have assigned the 28 GHz for IMT, there are usually some coexistence measures (for example, geographic separation, restrictions) in place to manage potential interference between IMT and other uses including satellite services. The 10 administrations that have assigned parts of the 28 GHz band for IMT represent a population of just over 600 million (under 8% of global population).

**Figure 1.2: Status of IMT in the 26/28 GHz bands (as of February 2022)[7,8]**

| Status | ITU Region | 26 GHz (24.25 – 27.5 GHz) | 28 GHz (27.5 – 29.5 GHz) |
|---|---|---|---|
| Assigned / available for licensing | Region 1 | • Denmark<br>• Finland*<br>• Germany*<br>• Greece<br>• Italy<br>• Norway<br>• Slovenia<br>• Russia<br>• UK*<br>• UAE | • Norway* (only fixed assignments in parts of band) |
| | Region 2 | • Chile<br>• USA | • USA (over 9,000 satellite gateway earth stations in 27.5-28.35 GHz)<br>• Canada (satellite gateways allowed in 27.5-28.35 GHz) |
| | Region 3 | • Australia*<br>• Hong Kong<br>• Japan<br>• South Korea<br>• Singapore<br>• Thailand | • Australia* (no mobile IMT, satellite is primary in all areas except metro areas; gateways co-primary in metro areas)<br>• Hong Kong* (satellite gateways allowed)<br>• Japan*<br>• South Korea (27.5-28.9 GHz)<br>• Singapore* (satellite ESIM allowed)<br>• Taiwan |

[7] Note: * includes individual local licensing for private networks.
[8] Source GSA, Plum analysis, national regulators.

| Status | ITU Region | 26 GHz (24.25 – 27.5 GHz) | 28 GHz (27.5 – 29.5 GHz) |
|---|---|---|---|
| Planned / under consultation | Region 1 | • Austria<br>• Belgium<br>• Croatia<br>• Czechia<br>• Estonia<br>• France<br>• Ireland<br>• Kosovo<br>• Luxembourg<br>• Macedonia<br>• Malta<br>• Montenegro<br>• Netherlands<br>• Norway<br>• Spain<br>• Sweden<br>• Nigeria<br>• Saudi Arabia<br>• South Africa | |
| | Region 2 | • Brazil<br>• Canada<br>• Peru | |
| | Region 3 | • China<br>• New Zealand (considering)<br>• South Korea<br>• Viet Nam | |

The demand for mm-wave spectrum for IMT uses is not as strong as that for mid-band and low-band spectrum at present.[9] There are various possible reasons behind this, including the lack of clear business models, a device ecosystem that is still nascent, and the availability and suitability of alternative bands or alternative technologies.

In the case of the United States, the initial focus on the deployment of 5G had been in the mm-wave bands. However, in a Senate Committee hearing in January 2020, Jessica Rosenworcel, now Chair of the Federal Communication Commission admitted that the attention on mm-wave frequencies for 5G, at the expense of mid-band spectrum, had been a mistake as it risked deepening the digital divide between urban areas and rural communities:[10]

> **“... our focus on millimetre 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, commercialising 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.”**

The international focus on lower frequency spectrum is illustrated by the availability of handsets that support different spectrum bands. The first Apple phone to support 5G technologies was the iPhone 12, and this included mm-wave connections, but only on devices sold in North America. In other regions, the 5G connections supported only low-band and mid-land spectrum. Similarly, Samsung’s Galaxy S20 supported mm-wave bands on the model that was compatible with Verizon, but other bands did not have mm-wave compatibility and indeed had additional RAM and SD expansion slots in the space made available. This demand for mm-wave for North American devices seems to have been short-lived, with Apple’s most recent 5G model, the 2022 iPhone SE, offering 5G connections but with no mm-wave capability[11].

[9] For example, see https://plumconsulting.co.uk/stimulating-demand-for-26-GHz-in-europe/

[10] 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

[11] See https://www.theverge.com/22968066/apple-iphone-se-5g-mmwave-verizon-uw for details.

## 1.2 Satellite technology and connectivity solutions

Satellite is an established technology that is increasingly used for next-generation access (NGA) high speed fixed and mobile data communications. Its biggest advantage over terrestrial technologies is the extensive level of coverage and the ability to achieve this in a cost-effective way, with services available wherever there is a line of sight to the satellite from a station located anywhere within the satellite's footprint. Satellite networks are particularly useful for reaching urban, suburban, and rural geographies.

Satellite networks are usually grouped in three different categories: geostationary Earth orbit (GEO), middle Earth orbit (MEO) and low Earth orbit (LEO) systems. GEO satellites which orbit the Earth at an altitude of 35,786 km have a very wide coverage footprint area. This allows GEO systems to achieve global coverage with as few as three satellites and deploy additional satellites with additional capacity focused where greatest demand exists. On the other hand, LEO constellations require a large network of satellites for coverage due their lower altitudes and shorter orbital periods. Improvements in satellite technology are expanding the capacity and capability of next-generation satellites, commonly known as high throughput satellite (HTS) systems. HTS systems, offer significant advantages in data transmission rates due to narrower beams, increased power and the ability to reuse the same frequencies with multiple steerable spot beams, increasing capacity in the allocated amount of frequency band.

The improved cost efficiency, coupled with the relatively smaller user terminals which further reduces system costs, makes HTS systems a viable option for data-heavy applications such as enterprise and consumer broadband, with prices close enough to be competitive with terrestrial networks. The latest generation of HTS systems, such as ViaSat-3,[12] is designed and built to deliver broadband with end-user speeds of up to 1 Gbit/s and throughputs of over 1 Tbit/s per satellite. The ViaSat-4 design will further increase this throughput by 5-7 times.

### 1.2.1 Spectrum for satellite

The availability of radio spectrum is one of the key factors to the success of the satellite communication industry. In determining the demand on spectrum resources, it is important to consider various technical factors including technology availability, type of applications to be supported, demand and capacity requirements as well as commercial factors. Satellite systems usually have a long investment cycle and, therefore, long-term strategic planning is necessary for satellite spectrum allocations.

Satellite networks, particularly those for commercial satellite uses, are deployed in a limited number of frequency bands and thus it is necessary to consider the implications of reducing the amount of spectrum available to satellite services. Access to sufficient spectrum is critical to enable the capacity on HTS networks in a cost-efficient way, lowering the cost per bit and ensuring that more bandwidth can be delivered with the same capital cost. The major commercial satellite use cases and associated bands are summarised below.

- Major global GEO satellite communications operators are found in Ka-band frequencies. These include Eutelsat, SES, Viasat, Intelsat, Inmarsat, Avanti, Hispasat, Telesat, Arabsat, Optus and EchoStar. Services supported in this band include existing and planned fast-broadband access for a range of fixed and mobile (ESIM) applications in business and residential markets.

- The Ka band is also being used by emerging initiatives based on the deployment of constellations of LEO satellites to provide global broadband services. These services are expected to face heavy competition amongst the growing number of LEO systems, as well as existing GEO operators.

[12] https://www.viasat.com/space-innovation/satellite-fleet/viasat-3/

- There is also growing interest in providing reliable and high data rate (>100Mbps) satellite broadband services to aircrafts, ships and land vehicles (such as trains, trucks and coaches), across urban and beyond urban areas. Earth stations in motion (ESIM) are earth stations operating with GEO satellites under FSS in Ka-band frequencies (17.7-20.2 GHz and 27.5-30 GHz) to provide high-capacity communication links to moving platforms. At WRC-19, Footnote 5.517A was adopted providing the regulatory framework for operation of ESIMs.

### 1.2.2 Satellite and 5G

While 5G has primarily been associated with mobile networks, it is also incorporating the unique features provided by the satellite networks. Satellite stakeholders are actively participating in 5G standardisation bodies such as 3GPP and ETSI. Within 3GPP, work is ongoing to incorporate non-terrestrial networks into the 5G radio access standards. For example, 3GPP technical report 22.822 (published as part of Release 16 specifications) provides three categories of potential applications (comprising service continuity, ubiquity and scalability) for satellite access in 5G together with 12 main use case scenarios.[13] Some of the main 5G use case scenarios for satellite are as follows.

- Communications on the move – provision of enhanced mobile broadband (eMBB) connectivity using multicast-enabled direct links to satellite terminals on planes, vessels, trains and road vehicles by means of pre-positioning of content in an on-board cache for local storage and use, and backhauling of aggregated machine-to-machine (M2M) or Internet-of-Things (IoT) traffic from moving platforms.

- Direct connectivity for end-user devices and premises – provision of direct connectivity to those in hard-to-reach areas, for example, via user equipment capable of accessing both terrestrial and satellite technologies to ensure extended service reach, reliability and resilience.

- Alternative to fibre – for connectivity of individual cell sites; temporary and short term uses (including disaster relief operations and mission-critical communications); and aggregation nodes (where the traffic of multiple 5G cell sites is aggregated, such as trunking) as well as the delivery of high capacity eMBB content closer to the network edge, for example, in the form of pre-positioning of content in caches or the multicast streaming of live video.[14]

The key advanced satellite technologies that underpin these applications are: [15,16,17,18]

- the use of Ka-band on LEO, MEO and GEO next-generation HTS[19] using a large number of narrow spot beams with Gigabit capabilities to meet increasing fixed / mobile demand for broadband services;

- software-based design enabling in-orbit reprogrammable features to provide flexibility to adapt to requirements of dynamic markets;

- dynamic beam shaping and tracking capabilities to achieve power and throughput optimisation to serve, in particular, maritime, aeronautical and land-based transportation;

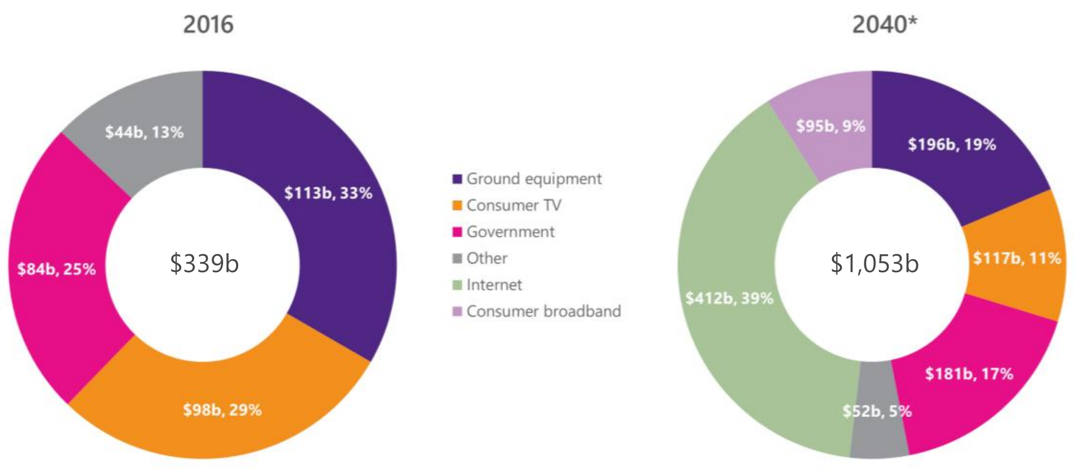
[13] https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3372
[14] ESOA (July 2020). Satellite Communications Services: an integral part of the 5G ecosystem. https://gscoalition.org/cms-data/position-papers/2278%20ESOA%205G%20Ecosystems%20UPDATE%20NOV%202020.pdf
[15] Eutelsat. Future Eutelsat satellite launches. https://www.eutelsat.com/en/satellites/future-launches.html
[16] SES. Innovating the Future. https://www.ses.com/networks/signature-solutions/signature-government/innovating-future
[17] Intelsat. Epic Fleet Brochure. https://www.intelsat.com/wp-content/uploads/2020/04/intelsat-epic-fleet-brochure.pdf
[18] Via Satellite (January 2020). 2020s: A New Decade in Satellite Infrastructure Flexibility. http://interactive.satellitetoday.com/via/january-2020/2020s-a-new-decade-in-satellite-infrastructure-flexibility/
[19] These are commonly termed as very high-throughput satellite (VHTS) and ultra high-throughput satellite (UHTS) systems.

- dynamic traffic routing and flexible uplink and downlink bandwidth allocation;
- progressive ground segment deployment; and
- support for VSAT private networks via a large number of mesh spot beams.

## 1.3 The importance of Ka-band for satellite broadband services

The space economy has attracted significant interest from both the public and private sectors in recent years, and is forecast to reach over USD 1 trillion in the 2040s.[20] The space economy encompasses different value chains from hardware manufacturing to digital applications and solutions across various industry sectors. Much of this growth over the next 20 years will be driven by the Internet and consumer broadband segments as illustrated in Figure 1.3.

**Figure 1.3: Size of the global space economy by the 2040s[21]**




The Ka-band, comprising downlink (receive) frequencies at 17.7-21.2 GHz and uplink (transmit) frequencies at 27.5-31 GHz, is widely seen as a core band for commercial satellite connectivity solutions, including for 5G non-terrestrial networks (NTN).[22] It offers significant advantages over traditional satellite bands such as the C-band, which has been the subject of reallocation for terrestrial 5G mobile in recent years, and the Ku-band, which is a highly congested satellite band and under consideration as a potential IMT band under agenda item 9.1.c of WRC-23.

The Ku-band has traditionally been used by satellite for delivering broadcasting and FSS services yet it is bandwidth limited as compared to Ka band (see Figure 1.4), although it is suitable for wide beams and has relatively low sensitivity to tropospheric impairments. However, there has been growing congestion in the Ku-band for a number of years particularly in the geostationary orbital positions.[23] This has meant the Ka-band is necessary because of the wide bandwidth requirements of HTS networks, allowing the expansion of satellite capacity and the introduction of new services. Satellite operators globally have been deploying Ka-band systems

[20] OECD (2019). The Space Economy in Figures: How Space Contributes to the Global Economy.
[21] Note: *2040 estimates. Source: Morgan Stanley
[22] 3GPP. Technical Report TR 38.821. Solutions for NR to support Non-Terrestrial Networks (NTN). https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3525
[23] It is generally recognised that a minimum orbital separation of two degrees is required between a given satellite and its neighbours, using the same frequencies and serving the same geographic area, to avoid interference.

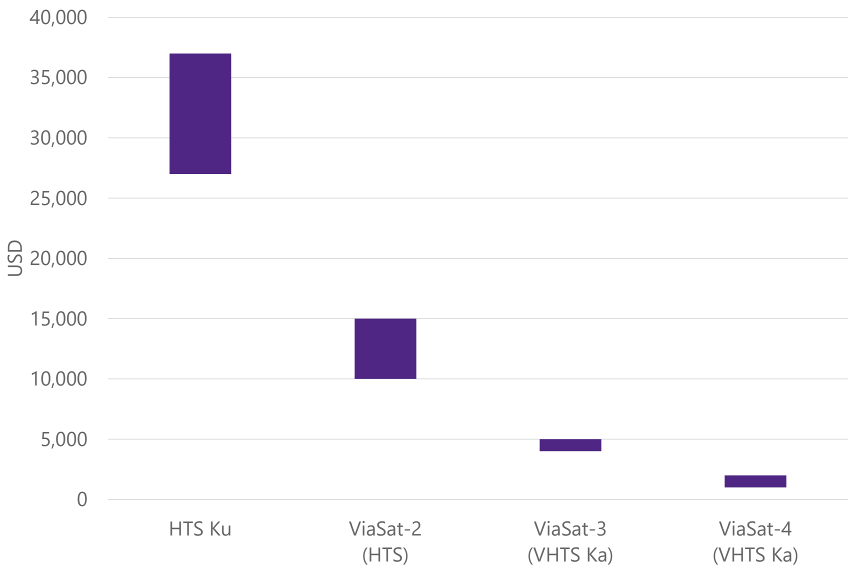
over the last decade to support a wide range of applications including broadband, enterprise, video distribution, satellite news gathering.

The wider bandwidth of Ka-band means that HTS operators are able to deliver higher throughput per transponder. Furthermore, new HTS systems operate multiple narrow spot beams that facilitate high frequency reuse, and these can be dynamically activated and configured to adapt to traffic demand and user density. These advantages translate into lower cost per bit transferred as illustrated in Figure 1.5. Equipment costs for Ka-band is also more affordable and widely available compared to Q-V bands, which are still very much in the nascent stage of development.

**Figure 1.4: Typical FSS bands and frequencies [24]**

| | Frequency range (DL/UL) | Bandwidth (DL/UL) | Transponder bandwidth |
|---|---|---|---|
| C-band | 3.6-4.2 / 5.85-6.45 GHz | 0.6 / 0.6 GHz | Typically 36 MHz |
| Ku-band | 10.7-11.7 and 12.5-12.75 / 12.75-13.25 and 13.75-14.8 GHz | 1.25 / 1.55 GHz | Typically 54 MHz |
| Ka-band | 17.7-21.2 / 27.5-31 GHz | 3.5 /3.5 GHz | Various sizes, in the order of hundreds of MHz |

**Figure 1.5: Economics of next-generation HTS systems (cost per Gbps per month)[25]**




There are innovative techniques in Ka satellite communications systems that mitigate downlink and uplink losses, making it more cost-effective than Ku-band implementations:

- Uplink power control (UPC) – gateways and user terminals can use amplifiers that can increase the power supplied to the antenna to compensate for measured atmospheric loss;

[24] Note: These are the typical frequencies for FSS in ITU Region 1 for Europe and Africa. The exact frequency range can differ across ITU regions and countries. Source: Plum Consulting
[25] Source: ViaSat.

- Automatic level control (ALC) – satellites can be instructed to ensure that every signal comes down to the gateway or users at the necessary amount of power regardless of atmospheric loss;

- Adaptive coding and modulation (ACM) – user terminals can choose to transmit at a less efficient but more robust modulation and coding scheme, maintaining connectivity at the expense of reduced throughput; and

- Diversification of gateway sites – detailed local statistical analyses can ensure that gateway locations are chosen to provide sufficient diversity such that when severe weather conditions are experienced at one antenna, services can be switched to another antenna to avoid disruption.

These techniques enable Ka-band HTS systems to perform better than Ku-band in terms of service availability in most circumstances.[26] This would make the Ka-band feasible for most connectivity solutions in more tropical regions, since the above four techniques address high rainfall rates, enabling direct broadband satellite-to-the-premise, to mobile users (ESIM), enterprise data, gateways, community Wi-Fi and satellite-powered cellular base stations.

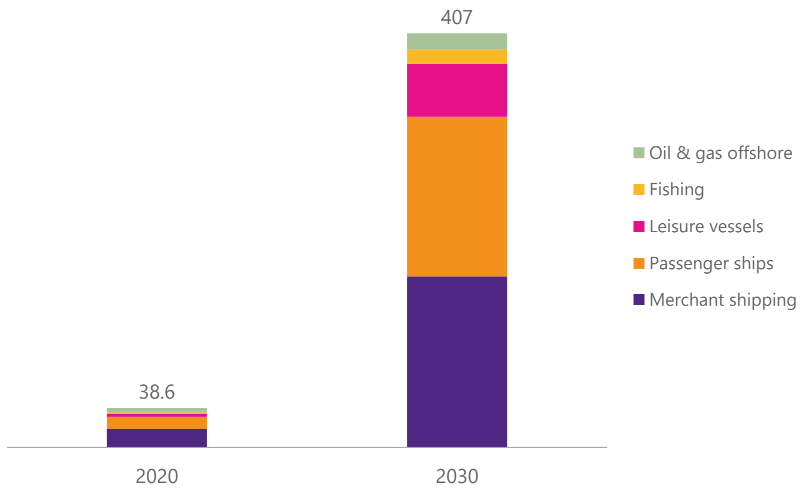
While only accounting for 3% of the total satellite service revenues at present, consumer satellite broadband is a fast-growing segment. Over the 2016-2020 period, global subscriber numbers have increased by 51% to 2.7 million with revenue growing by 40% to USD2.8 billion.[27] By 2026, subscribers are projected to increase to 5.2 million while revenue will expand to USD4.1 billion.[28] In Africa, future demand for HTS bandwidth will be driven by a need for broadband access and enterprise data services, particularly in more remote areas.[29]

Another key growth area is in satcom mobility which comprises three market segments – aeronautical or in-flight, maritime and land mobile communication services. Although the aeronautical and maritime markets have been adversely affected by the Covid-19 pandemic, both are expected to recover and grow in the coming years as digital applications proliferate.[30] These satellite-enabled solutions range from broadband connectivity for passengers, to data communications for operational needs which allow airline and shipping operators to increase fleet efficiency, optimise energy consumption and reduce maintenance costs.

Global demand for maritime satellite communications is forecast to grow rapidly over the next decade, especially for high-bandwidth VSAT solutions. Leased bandwidth is projected to increase by 10-fold come 2030 as illustrated in Figure 1.6, and this will be driven primarily by increase in Ka-band terminals. Global revenue of VSAT service providers is projected to grow from USD1.2 billion in 2020 to USD2.3 billion by 2030.[31]

[26] Avanti (April 2021). Ka vs Ku band HTS. https://www.avantiplc.com/wp-content/uploads/2021/04/Avanti-White-Paper-Ka-vs-Ku-HTS.pdf
[27] Satellite Industry Association (June 2021). State of the Satellite Industry Report 2021.
[28] ABI Research (15 April 2021). LEO broadband services will propel satellite broadband market revenues to USD4.1 billion in 2026. https://www.abiresearch.com/press/leo-broadband-services-will-propel-satellite-broadband-market-revenues-us41-billion-2026/
[29] Space in Africa (2022): "The State and Future of LEO Satellite Internet Connectivity in Africa", from http://interactive.satellitetoday.com/via/january-february-2022/the-state-and-future-of-leo-satellite-Internet-connectivity-in-africa/ .
[30] Via Satellite (29 January 2021). Can VSAT, Smart Shipping Demand Revive the Hard-Hit Maritime Connectivity Market? https://www.satellitetoday.com/opinion/2021/01/29/can-vsat-smart-shipping-demand-revive-the-hard-hit-maritime-connectivity-market/
[31] Source: Euroconsult (April 2021). Prospects for Maritime Satellite Communications, 9th edition.

**Figure 1.6: Global demand for maritime satellite services (leased bandwidth, Gbps)[32]**




The land mobile market is also forecast to feature strongly as narrowband services are phased out in favour of broadband with connected vehicles and trains driving future growth prospects.[33] Access to the Ka-band will be central to the development of satellite networks to meet these needs. Ka-band spectrum will also be key to service provision on aircraft.

## 1.4 Ka-band satellite use cases

Ka-band satellite enables and supports a range of use cases and services as discussed below.

### 1.4.1 Consumer broadband

For millions of people in thousands of unserved and underserved communities including, metropolitan areas, the use of a combination of residential VSAT terminals and Wi-Fi can deliver fast-broadband connectivity in a cost-effective manner. This is an efficient way of delivering affordable, high-quality broadband connections to these areas. Some examples of this type of implementation[34,35] are found in several markets across the world, where HTS systems deliver Internet to households that lack access to other types of broadband service and desire a dedicated connection, or who prefer an alternative to terrestrial services.

### 1.4.2 Broadband for business, education, financial inclusion and healthcare

HTS networks in the Ka-band have the ability to position broadband capacity anywhere on the surface of the Earth, allowing the provision of high-quality, affordable broadband services to residential and business users, schools, medical facilities, banks and agricultural facilities, regardless of whether they are located in urban, suburban or rural areas. HTS can support a variety of applications from education and telemedicine to financial services. This enables financial inclusion and grows the business sector by improving economic productivity.

[32] Source: Euroconsult (April 2021).
[33] Satellite Markets & Research (9 October 2020). Whither the Satcom Mobility Market? http://satellitemarkets.com/news-analysis/whither-satcom-mobility-market
[34] See https://fortune.com/change-the-world/2019/viasat/.
[35] See https://www.fastcompany.com/90490840/heres-how-one-company-is-delivering-the-Internet-to-remote-villages

Schools and students need Internet access for education, research, and communicating with family and classmates. HTS networks can cover a large-scale area like a school campus, with high-speed Internet allowing the students to stay connected everywhere within the campus. Satellite broadband technology enhances Internet connectivity to schools, enabling a "hybrid" virtual and in-person educational system and empowering students with access to the Internet.

### 1.4.3 Broadband on the move for aviation

Global and regional airlines are benefiting from broadband connectivity, with a rapidly growing uptake, being delivered via Ka-band satellite networks. ESIM enable mobile broadband service to aircraft, ships, and land-based users. Passengers and crew demand gate-to-gate, high-speed broadband for communications and entertainment, cabin support, and fleet digitisation and maintenance.

This reflects just a small part of the current demand. The size of the inflight connectivity market is described in a report by the London School of Economics (LSE), which forecasts ubiquitous global inflight connectivity by 2035, as reaching 7.2 billion passengers creating a $130 billion economic ecosystem for the benefit of airlines, content providers, retail goods suppliers, hotel and car suppliers, and advertisers.[36] Trains, inter-city buses, ambulances, emergency and public safety and other land-based vehicles also rely on satellite broadband services for passenger connectivity, operations and maintenance support, and fleet tracking.

### 1.4.4 Network-as-a-Service (NaaS) for mobile network operators

Network-as-a-Service (NaaS) involves partnering with mobile network operators (MNOs) to use HTS networks to extend MNO coverage to unserved and underserved areas that an MNO does not cover with its existing network. Under this approach, the HTS operator takes on the capital expenditure for wireless infrastructure deployment at locations jointly agreed with the MNO. It then operates the terrestrial network, typically featuring LTE network technology, providing connectivity back to the MNO core network (using satellite, fibre, or microwave, as appropriate).

### 1.4.5 Government services

Ranging across satellites, backhaul, ESIM (air, sea, land), and end-user terminals, Ka-band UHT satellites can provide end-to-end communications delivering a cost-effective solution for high-speed, high-capacity communications systems to government users anytime, anywhere.

### 1.4.6 Broadband for agriculture

Numerous case studies have demonstrated the value of the Internet to agricultural communities. In areas where agriculture is a main economic activity, Ka-band satellite can help farmers source better market data, to drive their planning and business decisions. This in turn leads to increased income, which drives social and economic development in those areas. Terrestrial networks have largely bypassed these areas, due to uneconomic business cases for their purposes. As satellite-powered Internet features a lower cost of infrastructure compared to that of conventional terrestrial-only networks, UHT satellites can engage these low population density areas and provide affordable and meaningful connectivity.

[36] LSE (2017). Sky High Economics. Chapter One: Quantifying the commercial opportunities of passenger connectivity for the global airline industry. Available at https://www.inmarsat.com/en/insights/aviation/2017/the-skys-the-limit.html

# 2 Technical considerations in 28 GHz allocation

## 2.1 Current allocations and use in the band

The current ITU Radio Regulations (ITU RR) allocations in 27.5-29.5 GHz band are as shown in Figure 2.1. The primary allocations are for the fixed, mobile and fixed satellite services. There is also a secondary allocation in the upper half of the band to Earth exploration-satellite service (EESS).

**Figure 2.1: ITU RR allocations for the 27.5 – 29.5 GHz band[37]**

| Frequency range (GHz) | Service allocations |
|---|---|
| 27.5-28.5 | FIXED 5.537A<br>FIXED-SATELLITE (Earth-to-space) 5.484A 5.516B 5.517A 5.539<br>MOBILE 5.538 5.540 |
| 28.5-29.1 | FIXED<br>FIXED-SATELLITE (Earth-to-space) 5.484A 5.516B 5.517A 5.523A 5.539<br>MOBILE<br>Earth exploration-satellite (Earth-to-space) 5.541 5.540 |
| 29.1-29.5 | FIXED<br>FIXED-SATELLITE (Earth-to-space) 5.516B 5.517A 5.523C 5.523E 5.535A 5.539 5.541A<br>MOBILE<br>Earth exploration-satellite (Earth-to-space) 5.541 5.540 |

Parts of the 27.5-29.5 GHz band are identified for high density FSS applications (5.516B), varying by region. The operation of ESIMs in 27.5-29.5 GHz (Earth-to-space) has been validated as an application of the FSS with the adoption of Footnote 5.517A, with restrictions as per Resolution 169. Broadcasting satellite feeder links can be deployed in 27.5-30 GHz band under FSS (5.539). FSS allocations also include downlink beacon transmissions used for uplink power control (5.538 and 5.540). The use of the band 29.1-29.5 GHz (Earth-to-space) by FSS is limited to GSO systems and feeder links to NGSO systems operating in MSS (5.535A). These feeder links are required to employ uplink adaptive power control to minimise the level of mutual interference (5.541A).

The use of the fixed service in 27.9-28.2 GHz also covers the operation of high-altitude platform stations (HAPS) in Cameroon and Sudan[38]. This operation is limited to HAPS-to-ground and shall not cause harmful interference to or claim protection from other fixed service systems and co-primary services (5.537A).

## 2.2 Characteristics of these uses

In the context of FSS use, the band is mainly used by major international and regional GSO satellite operators to enable satellite broadband to end-users and satellite gateways. Services supported by these systems include TV/radio/data broadcasting; private networks; satellite newsgathering; Internet backhaul connectivity; and broadband access for a range of fixed and mobile (ESIM) applications in business and residential markets.

As discussed in Section 1.2 there are significant investments in existing and planned satellite uses in the Ka-band for HTS involving GEO, MEO and LEO constellations for global broadband service, and for ESIMs to provide reliable, high capacity, ubiquitous satellite broadband to aircraft and ships for gate-to-gate and pier-to-pier

[37] Primary service is indicated in capital letters; secondary service in lower case. The numbers refer to footnotes in the Radio Regulations.
[38] GSMA (2021): "High Altitude Platform Systems" p30, from https://www.gsma.com/futurenetworks/wp-content/uploads/2021/06/GSMA-HAPS-Towers-in-the-skies-Whitepaper-2021.pdf

connectivity and to trains, trucks and coaches. There are 15 LEO companies servicing South Africa, with 12 in Nigeria and eight in Kenya[39].

For IMT systems, the main technical characteristics of the mm-wave deployments are expected to be:[40]

- limited coverage ranges – for example, base station densities in the range 10-30 per km$^2$ for hotspots;
- low base station antenna heights – deployed below roof top heights, typically 6m;
- active antennas – with arrays of active elements typically configured 8×8 (BS) and 4×4 (user equipment) which are used for beamforming to enable the pointing of antenna beam towards the intended receiver and minimise emissions in other directions; and
- wideband channels – for example, 200 MHz wide channels.

These characteristics imply that use cases requiring very high capacity and low latency over short ranges can be supported in the band. Typical deployments are expected to be in outdoor hotspots and indoor micro or pico environments in public and private enterprise settings (such as busy urban areas, stadiums, shopping malls, transport hubs, and factories).

The primary use of FS systems deployed in mm-wave bands is for mobile backhaul. Wider available channel bandwidths are used to meet additional capacity requirements. Other potential uses include fixed wireless access (FWA) and long-haul trunk infrastructures.[41]

## 2.3 Is IMT compatible with FSS?

Figure 2.2 illustrates potential interference paths between IMT and FSS in the 28 GHz band. Potential interference paths include, for example, interference between earth stations (operating in FSS feeder and service links) and IMT receivers (base stations and user terminals assuming TDD operation) and IMT transmitters interfering with FSS satellite receivers.

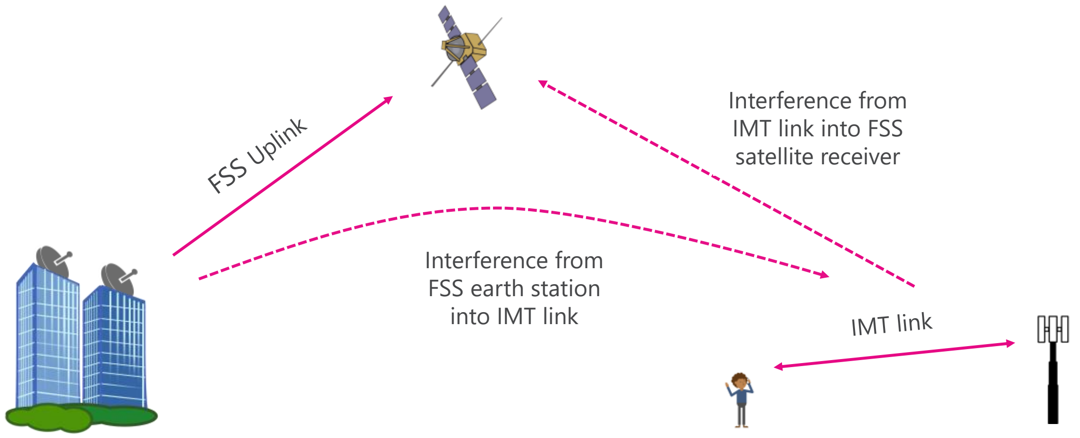
[39] Space in Africa (2022), "The State and Future of LEO Satellite Internet Connectivity in Africa", from http://interactive.satellitetoday.com/via/january-february-2022/the-state-and-future-of-leo-satellite-Internet-connectivity-in-africa/

[40] ITU-R. Liaison statement to Task Group 5/1 – Spectrum needs and characteristics for the terrestrial component of IMT in the frequency range between 24.25 GHz and 86 GHz, 28 February 2017. Available at https://www.itu.int/md/R15-TG5.1-C-0036/en

[41] ITU-R. Fixed service use and future trends. Report ITU-R F.2323-1. November 2017. Available at https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-F.2323-1-2017-PDF-E.pdf

**Figure 2.2: Potential interference paths**




In cases of ubiquitous services provided by FSS ESIM and IMT the services are unable to coexist if operating co-channel. It should be noted that the use of the 27.5-29.5 GHz band has not been identified as a key band for IMT and there are therefore a limited number of sharing studies addressing the potential for co-channel coexistence between FSS and IMT in this band. The majority of studies address the 24.25-27.5 GHz band only.

### 2.3.1 ITU-R TG 5/1 studies

Studies were undertaken in ITU-R TG 5/1 between FSS and IMT for the 26 GHz band (24.25-27.5 GHz)[42]. The focus of the studies in TG 5/1 was on aggregate interference from IMT stations into FSS space stations, and did not consider the implications of the ubiquity that both uses require. It is also noted that "*some administrations were of the view that, based on the results of studies using IMT characteristics other than those provided by the involved groups and in the clarifications and guidance developed by the ITU-R on how to use the parameters provided in sharing and compatibility studies, mitigation techniques are required to address potential cases of interference and achieve compatibility between IMT stations and FSS space stations.*" Several studies noted the importance of examining any proposed changes to IMT parameters.

There were four studies that addressed the case of IMT receivers and FSS earth stations. It was concluded that "*the results of studies showed separation distances of less than 100 m up to about 10 km between the FSS earth station and IMT stations*" would be necessary. In addition it was noted that "*in case of deployment of small FSS earth stations at unspecified locations and IMT stations in the same geographical area the separation distance between FSS and IMT stations cannot be ensured. Therefore, sharing may or may not be feasible and could be dealt with on a case-by-case basis.*"

Two of the studies (see Appendix A) concluded the following:

> "**In case a frequency band is used for ubiquitous deployment of small FSS earth stations (ESIM), sharing between IMT and the FSS is not practicable.**"

> "**For the case of ubiquitous deployment of small FSS earth stations, sharing between IMT [5G] and the FSS is not practicable within the same geographical areas, particularly as it is not feasible to individually coordinate large numbers of ubiquitous earth stations, nor is it even possible to determine a coordination contour around ubiquitous earth stations.**"

[42] ITU. Report on the sixth meeting of Task Group 5/1 (Geneva, Switzerland, 20-29 August 2018). Annex 03 Part 3. Available at https://www.itu.int/md/R15-TG5.1-C-0478/en

In essence, co-channel use of FSS, FSS ESIM and IMT poses regulatory challenges of managing interference risks, due to incompatibility, particularly in ubiquitous applications. This indicates that deploying these dissimilar services in separate bands would better mitigate interference risks, while reducing inefficient use of the spectrum due to geographical exclusion zones. More details on these four studies are provided in Appendix A.

### 2.3.2 Conclusion

The studies summarised above indicate that preventing interference between envisaged co-channel IMT networks and FSS uses in the same band would be challenging. For example, avoiding interference between IMT base station receivers and feeder link earth station transmitters cannot be achieved without exclusion zones and, when both IMT and FSS ESIM operate in ubiquity, coordination is impractical.

There is no immediately obvious solution when considering the use of IMT networks and FSS service links in the same band, as options will depend on deployment issues such as:

- The density of service earth stations across different geographic areas (urban, sub-urban and rural). It is expected that FSS deployment will be ubiquitous, so geographic separation would not be a realistic option.
- The anticipated demand for ESIMs by the aeronautical, maritime and transport sectors and likely deployment considerations (for example, at airports, ports, railway stations and lines) where geographic separation may not be a realistic option.

Emerging FSS requirements and new demands requiring additional FSS deployment areas makes the use of both IMT and FSS in the same band not feasible in practice. Further, any option incorporating a band segmentation within the 28 GHz band would need careful consideration as this may lead to sub-optimal outcomes. Reducing the bandwidth available to FSS has implications on the capacity and data speeds that can be delivered to users and costs.

The amount of spectrum available for satellite broadband networks directly affects the number of consumers who can be served with a given satellite and the cost of the service to end-users. For example, a global GEO HTS satellite system, such as ViaSat-3, with full access to 3.5 GHz of downlink and uplink spectrum (17.7-21.2 GHz and 27.5-31 GHz), would be able to provide high speed broadband to millions of customers simultaneously. Reducing the amount of Ka-band spectrum available by 500 MHz (therefore using only 27.5-28.0 GHz), would significantly decrease the number of end users that can be supported.[43] Band segmentation would not be beneficial to end users, particularly considering the amount of mm-wave spectrum already available to IMT.

In light of the above, a more practical approach is to consider the allocation of IMT (mobile or FWA) to just the 26 GHz band, which is globally identified for IMT by WRC-19. This approach would provide more flexibility for satellite deployments in the 28 GHz band without interference risks and the related impracticalities, enabling all HTS systems, including ESIM, to be fully available for nationwide coverage.

[43] ViaSat (7 June 2021). Submission to the RSM consultation on the use of the 24-30 GHz range in New Zealand.

# 3 Potential benefits of 28 GHz for satellite

This section explores the potential economic benefits of satellite access to the 28 GHz band. We first examine the type of benefits that satellite broadband can deliver before discussing the possible scale of these benefits in the context of six markets in Africa – the Democratic Republic of the Congo (DRC), Egypt, Kenya, Nigeria, Rwanda and South Africa.

## 3.1 Types of benefits arising from Ka-band satellite use

In general, the economics of terrestrial fixed broadband networks dictates that deployment costs are driven by last mile access which scales by distance to the nearest aggregation node or exchange. Terrestrial wireless networks offer a lower cost alternative to fixed networks although service quality is dependent on the availability of suitable spectrum bands and adequate bandwidth and how cell capacity is shared between users covered. Thus, while public mobile broadband networks typically offer wide area coverage, it is not feasible for mobile to offer the same level of service guarantee that fixed broadband networks, in particular FTTH, are capable of.

As discussed in Section 1.2 above, improvements in satellite technologies and access to the Ka-band will enable HTS systems to offer a cost-effective solution for high-quality broadband access in rural locations and communities which are unserved or underserved by existing terrestrial networks. Figure 3.1 provides a high-level comparison of the characteristics of different last-mile connectivity options.

**Figure 3.1: Comparison of last-mile technology options**[44]

| Technology | Fixed network | | | Terrestrial wireless | | Satellite (HTS/VHTS/ UHTS) |
|---|---|---|---|---|---|---|
| | FTTH | Cable | Copper xDSL | Mobile | FWA | |
| Passive layer | Fibre optic cable | Coaxial cable | Copper or mix of copper and fibre | Cellular towers | Towers | Satellite user equipment |
| Active layer | GPON / active Ethernet | DOCSIS 3.0 / 3.1 | ADSL2 / VDSL / G.Fast | 3G / 4G /5G | 4G / 5G / Wi-Fi / WiMAX | Proprietary satellite technology |
| Realistic performance | 100-1000+Mbps | 30-250Mbps | 30-50 Mbps | 10-50Mbps | 5-50Mbps | Up to and higher than 100Mbps+ |
| Deployment speed | Slow | Slow | Medium | Fast | Fast | Fast |
| Estimated deployment cost per household (USD) | 500-1000 (urban), 1000-5000 (rural) | 400-800 (urban) 1000-5000 (rural) | 300-500 for upgrade from ADSL | Depends on target coverage area, spectrum used | Depends on technology, target coverage area | ~300-500 (VSAT terminal) |
| Operating costs | Low | Medium | High | Medium/High | Medium | Low/Medium |

Hence, the impacts of satellite access to the 28 GHz band would include:

- Broadband coverage for unserved locations and communities,
- Improvements in broadband service quality for underserved locations, and

[44] Source: Adapted from World Bank Group (2018). Innovative Business Models for Expanding Fiber-Optic Networks and Closing the Access Gaps.

- A wider choice of broadband options and pricing options.

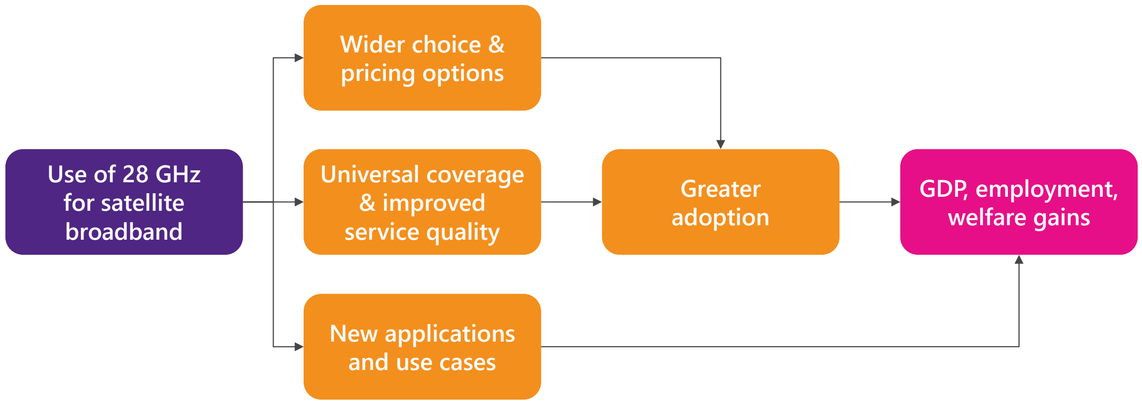
These would in turn promote wider adoption and use of broadband, delivering social and economic benefits not just to rural communities but to unserved and underserved locations across whole countries, and closing the digital divide. The universal availability of high-quality broadband will improve the economic wellbeing of people, improve their lives through access to health facilities, education and other essential services.[45] Improvements in connectivity will also have a beneficial impact on existing users of telecommunications services through a network externality effect.

In addition, the availability of the Ka-band for ESIMs can help to extend broadband connectivity and capacity in other hitherto hard-to-serve locations, such as transport routes, and contribute to growing market segments such as passenger connectivity on aircraft and ships, and connected airline and maritime operations.[46]

## 3.2 Estimating the economic value of satellite in 28 GHz

The Internet underpins a wide range of digital technologies and applications. From government services, education and health to manufacturing and agriculture, increased digitisation is driving productivity and efficiency gains across vast sectors of the economy. As discussed in Section 3.1 and illustrated in Figure 3.2 below, there are several ways through which the use of 28 GHz for satellite broadband can contribute to positive outcomes for the economy and society.

**Figure 3.2: Economic contribution of satellite allocation in the 28 GHz band**




The most important benefit of HTS satellite is its ability to swiftly expand broadband network coverage across the entire national territory. This is particularly true of GEO networks which are able to offer global coverage with the least number of satellites, enabling countries to bridge the existing gaps in digital infrastructure in a fast, cost-effective manner. However there is an increasing role for non-geostationary networks in providing greater capacity to all regions of the world.

By accessing the 28 GHz band, satellite networks will be able to help bridge the gap in the level and quality of broadband infrastructure between well-served locations and unserved or underserved locations, and drive up

[45] For example, a report by UNICEF and ITU estimated around three-quarters of school-age (3-17 years old) children in rural households do not have Internet access at home, compared to around 60 per cent in urban households. See UNICEF-ITU (2020). How many children and young people have Internet access at home? Available at https://www.unicef.org/press-releases/two-thirds-worlds-school-age-children-have-no-Internet-access-home-new-unicef-itu

[46] For example, a report by LSE estimated that ubiquitous inflight connectivity will see the total market for broadband-enabled airline ancillary services grow from USD3.9 billion in 2018 to USD131 billion by 2035. See LSE (2017). Sky High Economics. Chapter One: Quantifying the commercial opportunities of passenger connectivity for the global airline industry. Available at https://www.inmarsat.com/en/insights/aviation/2017/the-skys-the-limit.html

adoption of broadband and usage of an ever-increasing range of digital services by both consumers and enterprises. This in turn translates into economic benefits and welfare gains.

Though there is limited literature specifically on the economic impact of satellite broadband, the socio-economic benefits of broadband networks and services are well-recognised and have been extensively studied within academia and by the telecommunications industry. Below we provide a summary of relevant studies which have examined the economic impacts of broadband which will guide our assessment of the potential benefits from satellite broadband in the 28 GHz band.

### 3.2.1 Adoption and coverage

Long-run GDP growth is derived primarily from productivity gains.[47] A substantial number of studies have found a significant increase in GDP as a result of higher fixed or mobile broadband adoption while others have identified some positive impacts on employment.

Figure 3.3 presents a summary of the findings from selected studies. The estimates have been adjusted to reflect the impact of a 10-percentage point change in broadband take-up on GDP growth rate. As the time periods and samples vary across the studies, direct comparisons may not be feasible and some of the higher estimates may be overstated given that some of them cover time periods prior to the introduction of broadband. While these studies cover a range of geographies, it is clear that the results are largely consistent across all countries.

**Figure 3.3: Estimates of the economic impact of broadband adoption**

| Authors (date) | Impact of broadband adoption[48] | Context and comment |
|---|---|---|
| Katz and Callardo (2019a)[49] | • A 10% increase in fixed broadband penetration yields a 0.3% increase in GDP per Capita<br>• A 10% increase in mobile broadband penetration (unique subscribers) yields a 2.5% increase in GDP per Capita | Panel data for 34 African countries from 2010-2017 |
| Koutroumpis (2018)[50] | • A 10% increase in fixed broadband penetration increases annual GDP on average by 0.3%. | Panel data 35 OECD countries from 2002-2016. |
| World Bank and GSMA (2020) | • A 10% increase in mobile broadband availability among poor regions leads to a 0.8% increase in total consumption in the long term<br>• 10% increase in mobile broadband availability leads to 0.7% fall in proportion of houses below the extreme poverty line. | Empirical data from Nigeria: estimated increase of 8% of consumption per household after two years of broadband availability |
| Katz and Callardo (2019b)[51] | • A 10% increase in fixed broadband adoption (per 100 households) yields a 1.63% increase in GDP per capita.<br>• A 10% increase in mobile broadband penetration (unique subscriber) yields a 0.51% increase in GDP per capita.<br>• A 10 per cent increase in mobile broadband penetration (unique subscriber) yields 2.43% increase in GDP per capita in low-middle income countries. | Panel data for 24 countries in the Asia Pacific region from 2011-2017. |

[47] Employment rate and multifactor productivity are other economic outcomes that are commonly considered to reflect productivity.
[48] For clarity, when we note a 2-percentage point increase in GDP growth, this means that GDP growth would increase from (for example) 5% to 7%.
[49] Katz R and Callardo F (2019a). Economic contribution of broadband, digitization and ICT regulation: Econometric modelling for Africa. ITU; Geneva
[50] Koutroumpis P (2018), "The economic impact of broadband: evidence from OECD countries", Ofcom, UK.
[51] Katz R and Callardo F (2019b). Economic contribution of broadband, digitization and ICT regulation: Econometric modelling for Asia-Pacific. ITU, Geneva.

| Authors (date) | Impact of broadband adoption[48] | Context and comment |
|---|---|---|
| Analysys Mason (2015)[52] | • A 10% increase in total broadband (fixed and mobile) penetration leads to an increase in GDP of 0.26% - 0.92%.<br>• Addition of 1,000 new broadband connections leads to creation of up to 33 new jobs. | Estimates for Asia Pacific region for 2013-2020.<br>Based on multiplier derived from previous studies, with adjustments for country and regional characteristics based on level of ICT development. |
| Czernich et al (2011)[53] | • A 10% change in broadband penetration (per 100 inhabitants) leads to a 0.9-1.5 percentage point increase in annual GDP per capita growth rate. | Panel data of OECD countries from 1996-2007. |
| Thompson and Garbacz (2011)[54] | • A 10% increase in fixed broadband adoption (per 100 households) increases GDP per household by 0.77%. | Data for developed countries from 2005-2009. |
| Katz and Avila (2010)[55] | • A 10% increase in broadband penetration (per 100 inhabitants) yields 0.178% increase in GDP.<br>• A 10% increase in broadband penetration in Chile results in an increase of 1.8 points in the employment rate. | Cross-section data for 24 countries in Latin America and Caribbean from 2004-2008; Chile from 2002-2009. |
| Koutroumpis (2009)[56] | • A 10% increase in broadband penetration (per 100 inhabitants) leads to a 0.38 percentage point increase in GDP annual growth rate. | Data from 15 European Union countries from 2003-2006. |
| Qiang and Rossotto (2009)[57] | • A 10% increase in broadband penetration (per 100 inhabitants) leads to a 1.2-1.4 percentage point increase in GDP per capita growth rate (the higher end of range is for low and middle-income countries) | Data on telecommunication and economic indicators for 120 countries from 1980-2006. |
| Lehr et al (2006)[58] | • Availability of broadband increases total employment at local level by 1.0-1.5 percentage point. | Panel data for USA from 1998-2002. |

Some studies (Katz and Callardo 2019; Katz and Koutroumpis 2012[59]) have also found a greater impact of mobile broadband than fixed broadband in lower income countries where fixed broadband coverage tends to be less well developed. In many low and middle-income countries in Africa, it is generally the case that mobile connectivity is the primary means of Internet access for significant parts of the population (see section 3.3) and that the coverage of high-quality fixed networks is less extensive than those in more advanced, high-income countries. World Bank and GSMA (2020) notes:

> **"Almost a quarter of the continent's population is not covered by a mobile broadband network and almost three quarters do not use mobile Internet."**

This observation is true not just for mobile broadband but also for all other types of broadband access, showing the scope of the opportunity for ubiquitous and high-quality connections. This paper also considers how

[52] Analysys Mason (2015). "The impact of mobile broadband in the Asia-Pacific region, and future spectrum needs". Report for the GSMA and Huawei.
[53] Czernich N, Falck O, Kretschmer T, and Woessmann L (2011). "Broadband infrastructure and economic growth", *The Economic Journal*, 121(552), 505–532.
[54] Thompson H and Garbacz C (2011), "Economic impacts of mobile versus fixed broadband", Telecommunications Policy, 35(1), 999-1009.
[55] Katz R and Avila J (2010), The Impact of Broadband Policy on the Economy, Conference Paper for Proceedings for the *4th ACORN-REDECOM Conference Brasilia May 14-15, 2010.*
[56] Koutroumpis P (2009), "The economic impact of broadband on growth: A simultaneous approach", *Telecommunications Policy*, 2009, 33(9), 471-485.
[57] Qiang C, and Rossotto C. (2009), "Chapter 3 Economic Impacts of Broadband," in Information and Communications for Development 2009: Extending Reach and Increasing Impact Washington, D.C., World Bank, 2009.
[58] Lehr WH, Osorio CA, Gillett SE and Sirbu MA (2006). Measuring broadband's economic impact. MIT Engineering Systems Division, Working Paper Series ESD-WP-2006-02.
[59] Katz R and Koutroumpis P (2012). The economic impact of broadband in the Philippines.

availability of broadband can lead to a significant impact of lifting households above the extreme poverty line (defined as an income of less than $1.90 per day):

> **"the proportion of households below the extreme poverty line ($1.90 per day) drops by about 4 percentage points after one year of gaining mobile broadband coverage and by about 7 percentage points after two or more years of coverage. This corresponds to moving approximately 2.5 million people out of extreme poverty. The study also shows that rural households in particular stand to gain more than urban households from such benefits in relative terms."**

While fixed and mobile networks may be seen as substitutes in certain situations, they also have complementary characteristics. Fixed networks can effectively take on the "heavy-lifting" role in helping meet the increasing demand of mobile networks, especially where mobile spectrum is scarce. Globally, 54% of mobile data traffic was offloaded to Wi-Fi fixed networks in 2017 and this proportion is estimated to reach 59% in 2022.[60] This is reflected in the difference in fixed and mobile broadband data traffic per connection – in 2019 the global average monthly fixed broadband usage was 122 GB compared to 4.5 GB for mobile broadband, and growth rates of both fixed and mobile data usage have grown at similar rates over the 2014-2019 period.[61]

Given the important role of satellite in contributing to the expansion of fixed broadband access and to improving mobile connectivity beyond urban centres, the economic impacts of allocating the 28 GHz for satellite can be associated with the incremental broadband adoption that is realised through its use for service delivery.

Another important aspect relates to use cases which are not possible for terrestrial networks to address, primarily in the aeronautical and maritime sectors. The provision of high-quality, uninterrupted broadband connectivity on board aircrafts and ships will not just deliver benefits to air and sea passengers,[62] but also drive economic benefits through digital transformation. For industry players including airlines, shipping companies and ports, digital applications such as real-time monitoring, fleet tracking, traffic control, route optimisation, communications and reporting, offer substantial gains including operational efficiency, cost savings and environmental benefits.[63] A 2018 study by the London School of Economics estimated that connected aircraft solutions could generate savings for the global airline industry of USD5.5-7.5 billion annually, rising to US$11.1-14.9 billion by 2035.[64] Given the anticipated increase in demand from these use cases, the 28 GHz band will have a key role in meeting future satellite capacity needs.

### 3.2.2 Prices and affordability

There are relatively few studies that directly examine the impact of prices of broadband services on economic outcomes but those that have done so have found that prices are a significant factor in adoption as summarised in Figure 3.4. As can be seen, there is a much higher impact in African countries than the global average.

[60] Cisco (2019). Global mobile networks will support more than 12 billion mobile devices and IoT connections by 2022; Mobile traffic approaching the Zettabyte milestone. News release, 19 February 2019. https://newsroom.cisco.com/press-release-content?articleId=1967403

[61] Based on statistics reported in the ITU Digital Development Dashboard. Available at https://www.itu.int/en/ITU-D/Statistics/Dashboards/Pages/Digital-Development.aspx

[62] For example, the global market for inflight entertainment and connectivity is forecast to grow at a compound annual growth rate of 9.5% between 2020 and 2028. Source: Grand View Research (March 2020). Available at https://www.grandviewresearch.com/industry-analysis/in-flight-entertainment-connectivity-ifec-market

[63] Cobham. Benefits of maritime satellite Internet. https://sync.cobham.com/satcom/knowledge-library/business-case-for-maritime-satellite-Internet/benefits-of-maritime-satellite-Internet/

[64] LSE (2018). Sky High Economics. Chapter Two: Evaluating the economic benefits of connected airline operations. Available at https://www.lse.ac.uk/business/consulting/reports/sky-high-economics-chapter-two

**Figure 3.4: Estimates of broadband prices on adoption**

| Authors (date) | Impact of price | Context and comment |
|---|---|---|
| Katz and Callardo (2019a)[65] | • A 10% reduction in fixed broadband prices boosts fixed adoption by more than 3.1% | Panel data for 34 African countries from 2010-2017 |
| Katz and Callardo (2019b)[66] | • A 10% reduction in fixed broadband prices boosts fixed adoption by 0.6%. | Panel data for 24 countries in the Asia Pacific region for 2011-2017. |
| Lange (2017)[67] | • A 10% decrease in fixed broadband price increases average household broadband adoption by 0.6% to 0.9%.<br>• A 10% increase in tariff diversity results increases average household broadband adoption by 0.6%. | Panel data on residential fixed broadband tariffs from 23 European countries from 2003-2011.<br>Tariff diversity is calculated based on five measures of central tendency. |
| Galperin and Ruzzier (2013)[68] | • On average in countries with 10% lower prices, a 22% higher broadband penetration rate was observed.<br>• Identified broadband demand price elasticities: total sample: -0.58; Latin America and Caribbean: -2.20; OECD: -0.36 | Cross-section data for 52 countries (23 from Latin America and the Caribbean, and 29 OECD countries) from a survey of tariffs conducted by authors in 2010. |

Tariff diversity – in terms of differences in prices, bandwidth and data caps – has also been linked to increased take-up of broadband services (Haucap et al 2016[69]; Lange 2017). One possible explanation for this is that tariff diversity allows consumers to select packages, based on price and usage preferences, that will maximise their consumer welfare and thus encourage take-up.

While high speed terrestrial broadband options, such as FTTH, may be available in selected urban locations, the latest generation of HTS networks is capable of delivering much higher capacity at lower costs.[70] This enhances satellite's price competitiveness particularly in areas beyond urban centres which are either unserved or underserved by existing terrestrial technology options. Considering that terrestrial networks are not available in a uniform way across urban, suburban and rural areas, the allocation of 28 GHz for satellite can contribute to higher broadband adoption and economic benefits.

### 3.2.3 Service quality

Most research studies on the economic impact of broadband service quality have focused on speed and its impacts on GDP. In general the conclusion is that faster broadband access has a positive impact on GDP growth, and this can be explained by two effects of better connectivity, namely:

- Contribution to productivity gains as a result of the adoption of more efficient business processes, such as improved access to markets and supply chain optimisation; and
- Acceleration of the introduction of new products, services and facilitation of innovative business models.

[65] Katz R and Callardo F (2019a).
[66] Katz R and Callardo F (2019b).
[67] Lange M (2017), "Tariff diversity and competition policy: Drivers for broadband adoption in the European Union", *DICE Discussion Paper*, No. 262, Düsseldorf Insatiate for Competition Economics (DICE), Düsseldorf.
[68] Galperin H and Ruzzier C (2013), "Price elasticity of demand for broadband: Evidence from Latin America and the Caribbean", *Telecommunications Policy*, 37(6-7), 429–438.
[69] Haucap J, Heimeschoff U and Lange M (2016), "The impact of tariff diversity on broadband penetration - An empirical analysis", *Telecommunications Policy*, 40:8, 743-754.
[70] Via Satellite (June 2020). Bandwidth pricing: How low can it go? http://interactive.satellitetoday.com/via/june-2020/bandwidth-pricing-how-low-can-it-go/

Figure 3.5 provides a summary of the benefits of economic impacts of broadband speed.

**Figure 3.5: Estimates of impact of broadband speed**

| Authors (date) | Impact of broadband speed | Context and comment |
|---|---|---|
| Carew et al (2018)[71] | • A doubling of broadband speed results in a 1.37% increase in real GDP. | Panel data for USA from 2010-2017. |
| Briglauer and Gugler (2018)[72] | • A 10 per cent increase in basic broadband adoption was found to increase GDP by about 0.15%<br>• A 10 per cent increase in ultrafast (FTTx) broadband adoption led to an incremental increase of 0.02-0.05% of GDP. | Panel data on EU27 Member States from 2003-2015. |
| Koutroumpis (2018)[73] | • An increase of broadband speed from 2Mbps to 8Mbps over 10 years leads to an increase in annual GDP by 0.1%.<br>• A same increase in speed achieved over 5 years leads to an increase in annual GDP by 0.22%. | Panel data 35 OECD countries from 2002-2016. |
| Kongaut and Bohlin (2014)[74] | • A 10% increase in broadband speed produces an increase in GDP per capita of 0.8% for a general sample of countries, 1.0% for low-income countries and 0.6% for high income countries. | Panel data for 33 OECD countries from 2008-2012. |
| Rohman and Bohlin (2012)[75] | • A doubling of broadband speed contributes 0.3% to GDP growth from base year. | Panel data for 33 OECD countries for 2008-2010. Speed based on blended mobile and fixed broadband download speed. |

There may also be impacts associated with broadband speed which are not captured by a GDP measure. For consumers, higher speed broadband generally means better user experience, time savings and access to wider range of online applications and services. Some of these aspects may not be reflected in “productive” activity (for example, more time on leisure activities which are not “valued” by the market) and thus not captured by GDP. These benefits are usually estimated in the form of consumer surplus, or welfare. For example, a 2009 study on consumer benefits of broadband connectivity in the USA estimated the benefits of a 10-fold in broadband speed from 5Mbps to 50Mbps are around USD6 billion per year for existing broadband households, equivalent to a surplus of around USD80 per household.[76]

### 3.2.4 Digital inclusion and broader social impacts

The expansion of high-quality broadband in unserved and underserved areas is essential to improving the economic and social wellbeing of the population. For example, broadband access will enable children and youths to access quality digital learning materials and opportunities online. Similarly, Internet-enabled devices may be used to assist healthcare workers to monitor and diagnose patients, deliver specialised medical care

[71] Carew D, Martin N, Blumenthal M, Armour P and Lastunen J (2018). The potential economic value of unlicensed spectrum in the 5.9 GHz frequency band: insights for allocation policy. RAND Corporation.
[72] Briglauer W and Gugler K (2018) : Go for gigabit? First evidence on economic benefits of (ultra-)fast broadband technologies in Europe, ZEW Discussion Papers, No. 18-020.
[73] Koutroumpis P (2018), “The economic impact of broadband: evidence from OECD countries”, Ofcom, UK.
[74] Kongaut C and Bohlin E (2017). Impact of broadband speed on economic outputs: An empirical study of OECD countries, Economics and Business Review, Vol. 3 (17), No. 2, 2017: 12–32.
[75] Bohlin E and Rohman I (2012). Does Broadband Speed Really Matter for Driving Economic Growth? Investigating OECD Countries? Available at SSRN: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2034284
[76] Dutz M, Orszag J and Willig R (2009). The substantial consumer benefits of broadband connectivity for US households. Commissioned by the Internet Innovation Alliance, July 2009.

services. Studies have shown that broadband access can help reduce poverty,[77] boost digital inclusion and narrow the gender gap by making education and information, employment opportunities and financial services more accessible to those in rural communities [78]

The Covid-19 pandemic has accelerated the use of the Internet for day-to-day economic and social activities, such as work, school and entertainment, and for essential needs, such as shopping, banking, financial and public services. Many of these step changes in behaviour are likely to persist even after the pandemic subsides. The ability to deliver consistent, high-quality broadband throughout a country is thus crucial to bridging the digital divide, reducing inequality in accessing digital services and enhancing social and economic resilience. In this regard, satellite is expected to have a crucial role, particularly in countries where unfavourable geography means the economics of terrestrial broadband deployment are challenging.

## 3.3 Broadband in emerging African markets

The advantages of HTS systems and associated benefits will vary by country depending on a range of factors including the level of broadband infrastructure, geography and market-related considerations. In this study we focus on six major countries in Africa – the Democratic Republic of the Congo (DRC), Egypt, Kenya, Nigeria, Rwanda and South Africa

Figure 3.6 provides a summary of the socio-demographic characteristics of these markets. In total they comprise 524.1 million in population, of which nearly 281.7 million are residing in rural locations.

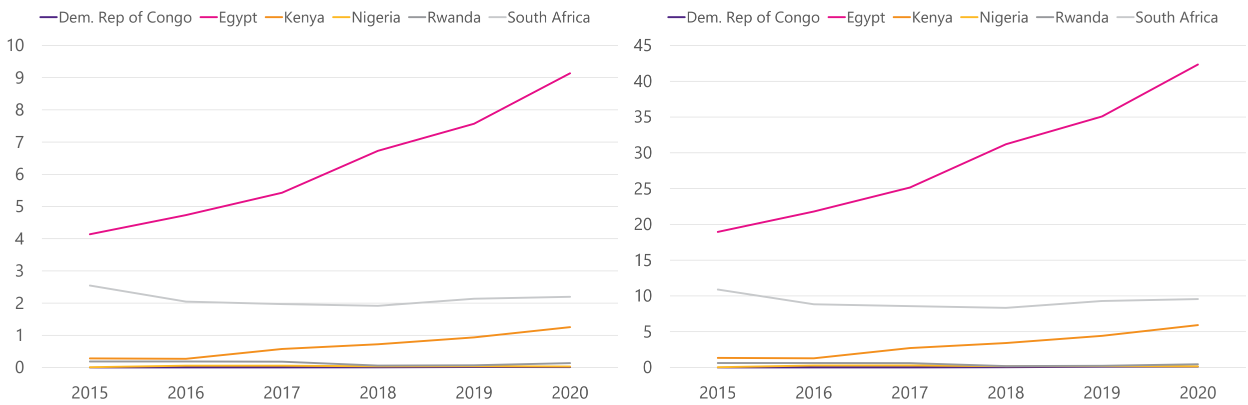
**Figure 3.6: Key socio-demographic indicators[79]**

| Indicator | DRC | Egypt | Kenya | Nigeria | Rwanda | South Africa |
|---|---|---|---|---|---|---|
| Area (km$^2$) | 2,344,860 | 1,001,450 | 580,370 | 923,770 | 26,340 | 1,219,090 |
| Population (million) | 89.6 | 102.3 | 53.8 | 206.1 | 13.0 | 59.3 |
| Households (million) | 10.3 | 22.1 | 11.4 | 42.2 | 3.9 | 13.6 |
| Rural population, % of total population (million) | 56% (50.1) | 57% (58.0) | 74 % (40.0) | 51% (104.3) | 69% (9.0) | 34% (20.3) |
| Urban & rural population density (pop per km$^2$) | 2,850 & 17 | 1,466.9 & 49.6 | 2,3239.3 & 27.8 | 4,007.7 & 101.8 | N/A | 596.1 & 362.0 |
| GDP (current USD billion) | 48.712 | 365.26 | 101.0 | 432.3 | 10.3 | 335.4 |
| GDP per capita (USD) | 544 | 3569 | 1,878 | 2,097 | 798 | 5,656 |

Cross-country data on fixed broadband network coverage in African markets is relatively limited. However, figures on fixed broadband adoption suggests that the extent of fixed broadband infrastructure varies significantly across the five countries as shown in Figure 3.7.

[77] GSMAi and World Bank (Dec 2020). The poverty reduction effects of mobile broadband in Africa: Evidence from Nigeria.
[78] GSMAi, Transforming Women's livelihoods through Mobile Broadband.
[79] Sources: ITU, World Bank, Plum analysis.

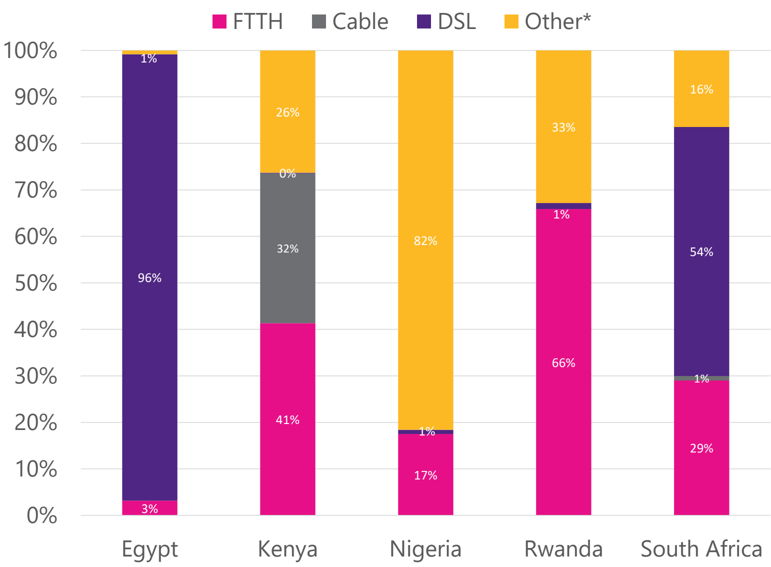
**Figure 3.7: Fixed broadband adoption (in percentage terms) by population (left) and household (right)[80]**




Household adoption levels across Africa are well below those in advanced markets internationally – for example, average fixed broadband take-up in the EU was at 78% in 2019[81]. Although fixed broadband adoption in Egypt is increasing, this is an anomaly on the continent where mobile broadband is by far the most common connectivity solution.

There is also wide variation in terms of technology mix which reflects the quality of broadband connectivity to households across these five countries. In Rwanda over 60% of fixed connections are FTTH, following a significant investment in urban areas by Liquid Telecom, but this must be considered against the exceptionally low penetration rate (with fixed broadband installed in only 0.5% of households). Conversely, in Egypt and South Africa, which have comparatively high fixed broadband penetration for the continent (but low rates when compared to the global take-up), the majority of connections are via xDSL.

**Figure 3.8: Fixed broadband connections by technology (2019)[82][83]**



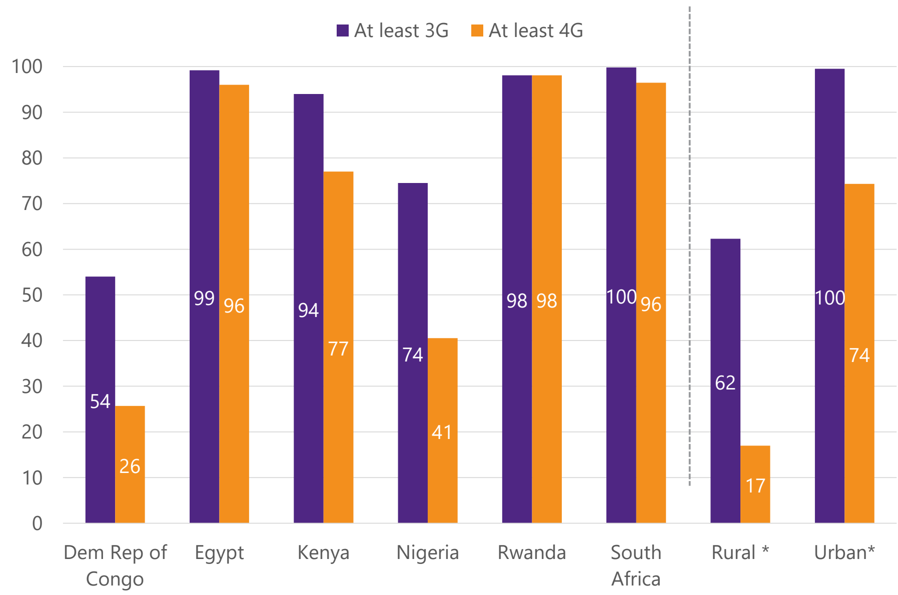

Globally FTTH broadband coverage and adoption has been growing over recent years. Across these six markets, this trend has been led by Kenya and Rwanda, although as noted these are confined to a very low number of connected households. There is virtually no FTTH deployment outside of urban areas across Africa. Future

[80] Source: ITU, Plum analysis
[81] European Commission. Digital Economy and Society Index (DESI) 2020.
[82] Note: * includes terrestrial fixed wireless, satellite, ethernet LAN; and broadband-over-powerline (BPL) communications. Source: ITU.
[83] Data for DRC is not available.

FTTH expansion, particularly into rural regions, will slow as the incremental cost of deployment rises. To achieve universal broadband coverage alternative technologies, including satellite broadband solutions, will be needed given the geographic scale of these countries.

In terms of mobile broadband networks, coverage at a national level is relatively advanced in most of our example countries, as illustrated in Figure 3.9, with over 90% of the population covered by 4G in three of the countries and 3G coverage exceeding the 90% level in four countries.  However, there is around 18% of the population of these countries – over 98 million people – who are not covered by at least 3G networks.  Across Africa as a whole this value is even higher, with around 22% of the population living outside of 3G coverage areas.  The majority of them will be those living in hard-to-reach rural locations.

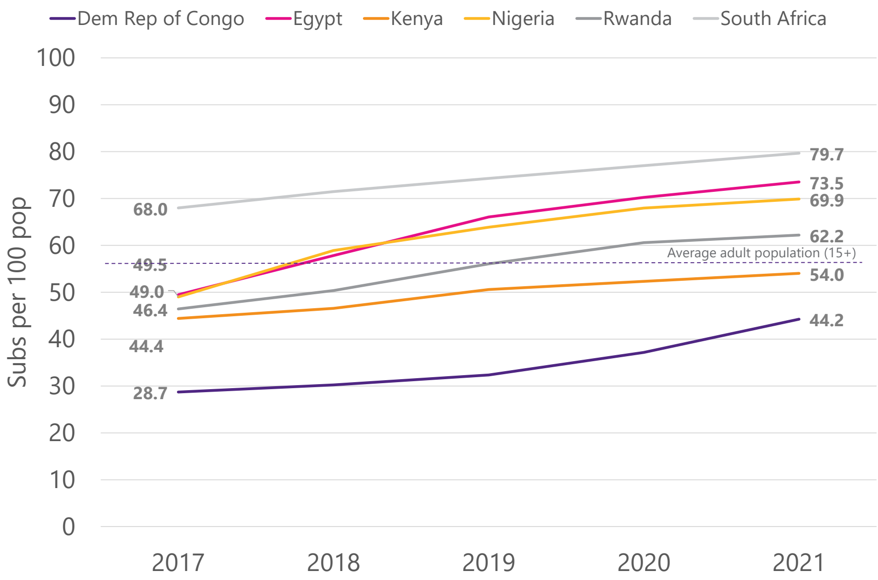
**Figure 3.9: Mobile broadband network coverage by technology (%population, 2020)[84]**




Mobile broadband adoption as measured by unique subscribers across the six markets is shown in Figure 3.10. With the adult population (ages 15 and above) in most countries typically around 55%, this shows there is a still significant proportion of people, especially in DRC and Kenya, without access to mobile broadband despite the growth in the last five years. This could be due to a variety of reasons including lack of coverage, affordability issues and low digital skills.

[84] Note: * Urban and rural coverage based on average figures for Africa. Source: ITU and GSMAi

**Figure 3.10: Mobile broadband adoption by population (unique subscribers)**[85]




There is limited information on the quality of broadband services in the six countries. As shown in Figure 3.11, the quality of fixed and mobile broadband is particularly poor in DRC, and average download speeds in Kenya, Nigeria and Rwanda are also comparatively low. It is useful to compare the uptake of fixed broadband – as shown in Figure 3.7 – to the speeds registered; even though they have a greater reliance on xDSL, markets in Egypt and South Africa show that greater broadband seeds and quality are linked to higher uptake. This is evidence of the benefits that high quality connections can bring.

At the same time there are differences in the way consumers in these markets access broadband. With the low penetration of fixed broadband, mobile broadband is typically the primary mode of broadband access for the majority of the population across the region, but particularly in Kenya and Nigeria where mobile connections are around twice as fast as fixed. This means the quality of mobile broadband is even more important in these markets.

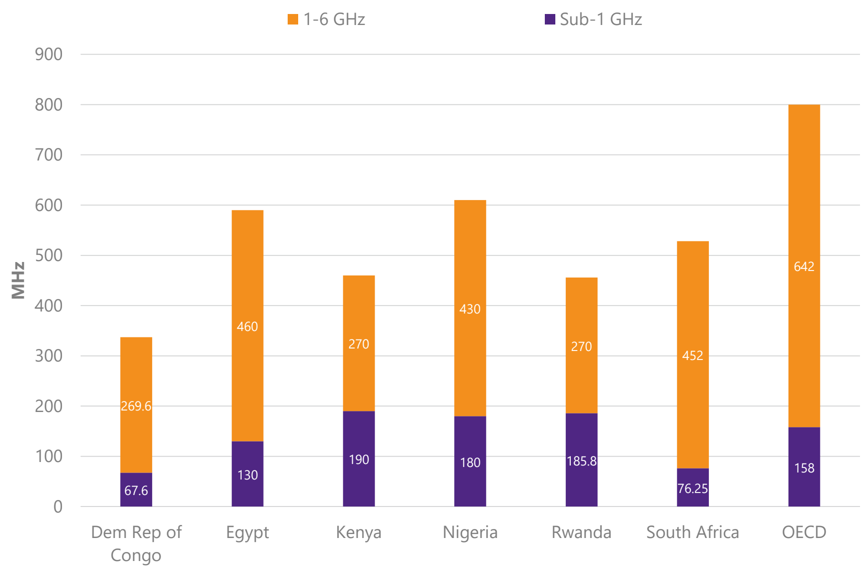
**Figure 3.11: Broadband quality of service**[86]

| Country | % FBB subs with ≥ 10Mbps[87] | FBB download speed Mbps[88] | % mobile subs with 4G[89] | MBB download speed Mbps[81] |
|---|---|---|---|---|
| DRC | - | 7.74 | 3.97% | 13.53 |
| Egypt | 100.00% | 39.49 | 32.00% | 19.61 |
| Kenya | 39.91% | 8.86 | 13.71% | 17.15 |
| Nigeria | 17.06% | 10.39 | 11.99% | 17.76 |
| Rwanda | 71.11% | 9.59 | 14.74% | - |
| South Africa | 65.33% | 30.69 | 38.78% | 32.26 |

[85] Source: GSMA Intelligence.
[86] Source: ITU, GSMA, Ookla Speedtest.
[87] Percentage of fixed connections that receive 10Mbps or above, as of 2020.
[88] National median speeds, as of February 2022.
[89] Percentage of mobile connections that are 4G, as of 2021

The supply of spectrum for mobile is a key determining factor in the quality of service and the capacity of mobile networks. Sub-1 GHz frequencies which have better propagation characteristics are more suitable for coverage. Frequencies in the 1-6 GHz range are less suited for coverage but offer more capacity due to the larger bandwidths available. As indicated in Figure 3.12, the amount of mobile spectrum available in the six markets is significantly less than those in high income markets (OECD countries). Of the six countries, DRC has the least spectrum available to operators; South Africa had relatively low amounts of sub-1 GHz spectrum available but the auction which concluded in March 2022 is likely to have rectified this, pending confirmation.

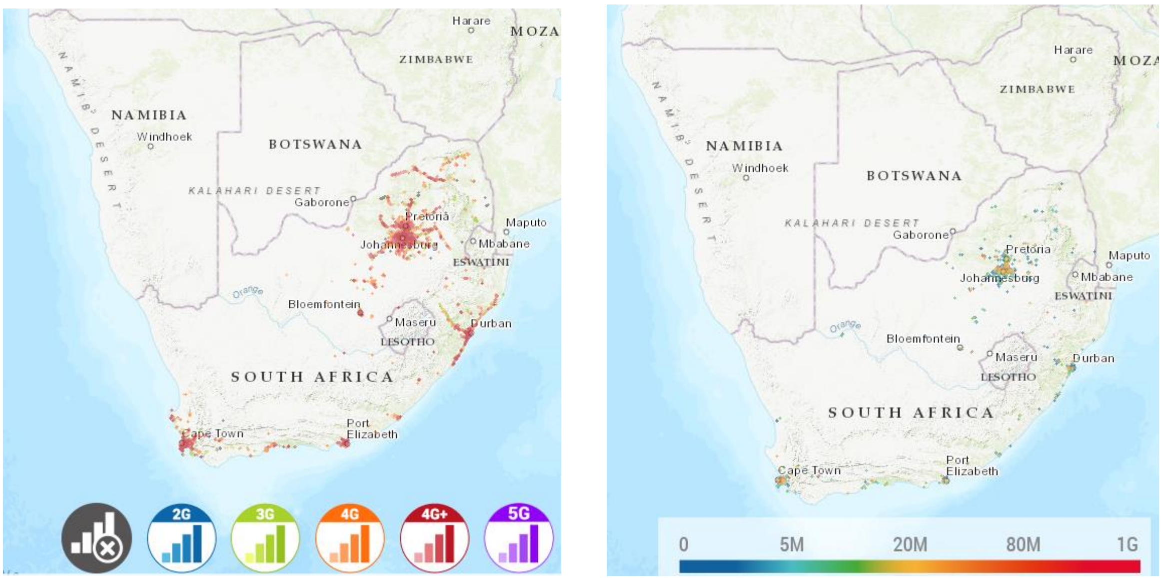
**Figure 3.12: Mobile spectrum supply below 6 GHz[90]**




Although mobile broadband coverage by population across the six markets is generally high, as illustrated in Figure 3.9, the quality of mobile service is likely to vary considerably by geography within each market. Outside of urban regions where population densities are much lower and fibre infrastructure is typically less well developed, the economics of network deployment are more challenging, and the lack of sub-1 GHz spectrum means mobile users in sub-urban and rural locations are likely to have a poorer broadband service than urban users. For example, as illustrated in Figure 3.13, 4G coverage in South Africa is highly concentrated in urban locations and the quality of mobile broadband in terms of download speeds outside of urban areas is generally much lower, around 5Mbps or lower.

[90] Source: Plum analysis based on data from national regulators, GSMAi and spectrummonitoring.com; figures for South Africa do not include the outcome of the auction which concluded in March 2022.

**Figure 3.13: Mobile coverage and download speed in South Africa (Telkom)[91]**




## 3.3.1 Estimation of economic impacts

We first consider the potential economic impact of satellite broadband in terms of connecting the unserved population in Africa. As there is limited data on the level of fixed broadband coverage (and what there is indicates a very low penetration rate), we estimate the unserved population based on the level of mobile broadband coverage. It is assumed that unserved population is represented by the population who are not covered by 4G services as shown in Figure 3.14[92]. These are likely to be conservative estimates as the proportion of population who are not served by fixed broadband networks will be much higher, and so there will be a large proportion of the population who have very limited choice in terms of connectivity.

**Figure 3.14: Estimated unserved population in Africa (without at least 4G access as of 2020)[93]**

| | Population | Households |
|---|---|---|
| Total (million) | 1,277 | 243.6 |
| Percentage unserved (%) | 53% | 51% |
| Number unserved (million) | 681.2 | 123.8 |

Next, we estimate the potential economic impact of satellite broadband. Satellite solutions for universal broadband access comprise direct consumer broadband connectivity, community Wi-Fi hotspots and satellite-powered mobile access. A take-up rate of 50% in the long run is assumed based on the GSMA's estimates of mobile broadband coverage and usage gap in Africa.[94] This means, of the 51% of households that were previously unserved, 50% of these (25.5% of the total number of households) are likely to become Internet users

[91] Source: nPerf (accessed 24 September 2021).

[92] While there is some segment of this population with access to 3G services, it would not be appropriate to consider 3G as adequate broadband provision given its lower quality in terms of speed and capacity, and 3G networks are likely to be switched off in many markets over the next decade.

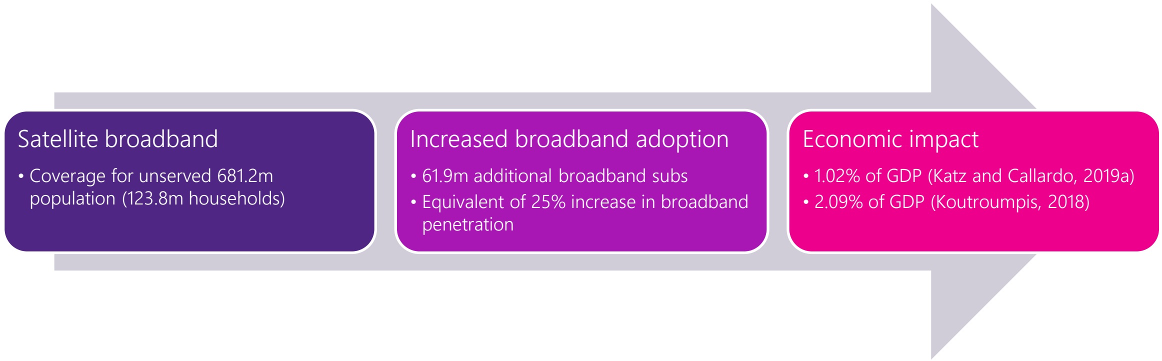
[93] Source: ITU, Plum analysis

[94] According to the GSMA, there are around 878 million people in Sub-Saharan Africa who are covered by mobile broadband networks but only 303 million are mobile Internet subscribers; there is a usage gap of 575 million (those who are covered but do not subscribe to the mobile Internet). However, this usage gap is decreasing rapidly, so a long-run estimate of 50% take-up is conservative. Source: GSMA. The Mobile Economy Sub-Saharan Africa 2021.

following the deployment of satellite solutions. We then derive the associated economic impact in terms of GDP contribution drawing on the findings of two recent economic research studies summarised in Section 3.2.1.[95,96]

The estimated GDP increment as a result of satellite broadband coverage in unserved regions by 2030 is in the order of 1.02% to 2.09% as shown in Figure 3.15. It should be noted that these figures only relate to the impact from direct service take-up. There are also further benefits from broadband connectivity in these locations, for example through community Wi-Fi solutions which enable wider access and deliver broader socio-economic benefits as discussed in Section 3.2.4.

**Figure 3.15: Potential economic impact of satellite broadband – unserved Africa (2030)**




## Underserved households

The other important segment is the underserved population – those in areas where terrestrial broadband is available, but with limited speed and inadequate quality of service. These are mainly rural and suburban regions, and satellite broadband can offer a viable alternative to terrestrial broadband options. For the underserved population, the availability of satellite broadband can also deliver benefits and welfare improvements, by offering better service quality for consumers and enterprises in these areas, wider choice of broadband providers and tailored pricing options. This can help drive competition, thus improving economic outcomes irrespective of adoption levels of satellite broadband.

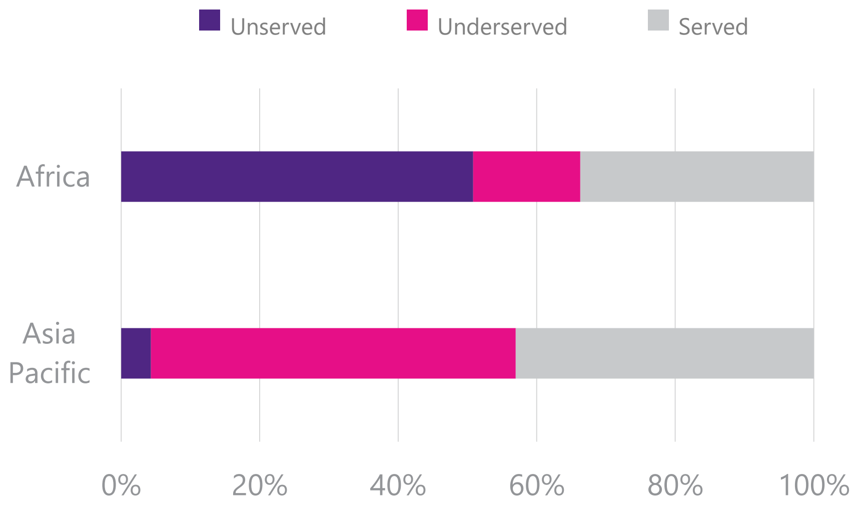
In a previous paper, we examined the relationship between unserved and underserved regions in Asia Pacific, finding that there were significant proportions of the population which were nominally served by mobile broadband but which had a lack of choice or a potentially poor quality connection. This was estimated by taking into account the percentage of the population in rural areas, and adjusting it for the number of households passed by FTTH – if FTTH coverage was particularly high, as was seen in Thailand and Viet Nam, the addressable market was smaller than the total rural population.

In Africa, however, there is a significantly lower coverage of mobile broadband, let alone FTTH, leading to a much higher proportion of the population which is unserved and a lower proportion that is underserved. This contrast can be seen in Figure 3.17. In many African countries, both 4G and FTTH coverage is restricted to dense urban areas only, meaning that the entire rural population is unserved.

[95] Koutroumpis (2018) finds that a 10% increase in fixed broadband penetration (per 100 people) in increases annual GDP on average by 0.3% over 14 years.
[96] Katz and Callardo (2019a) find that a 10% increase in fixed broadband adoption (per 100 households) yields a 0.3% increase in GDP per capita over six years.

**Figure 3.16: Proportions of served, unserved and underserved households[97]**




We estimate the potential economic impacts arising from the provision of satellite broadband in underserved regions for the six countries examined above. In considering the underserved segment in each market that is addressable by satellite we take account of the level of FTTH broadband coverage, the proportion of rural population and differences in broadband quality in urban and rural locations.[98] We note this is an upper bound on the size of the addressable market as alternative terrestrial broadband technologies (such as cable DOCSIS 3.0 or higher and 5G mobile) are not taken into account due to limited data on the extent of coverage of different broadband technologies.[99]

To consider the potential economic impact in underserved regions, we assume a potential 15% adoption rate of broadband within the underserved segment in the long run (by 2030).[100] There are many variables that influence consumer decisions on broadband. It should thus be noted that the incremental broadband take-up can include not only satellite broadband but also the overall effect of increased adoption across all broadband technologies driven by the wide-spread availability of satellite connectivity which leads to a more competitive broadband market, lower prices and better quality of service.

Figure 3.17 shows the estimated potential economic impact of satellite connectivity in the six African markets, including both unserved and underserved regions. There is wide variation across the six countries, and this reflects the differences in existing broadband infrastructure and market size. In Nigeria, where there is very limited FTTH coverage and negligible fixed broadband adoption, the increase in GDP per annum could be up to 2.6% by 2030. In DRC, with extremely low 4G coverage and almost zero fixed broadband, the increase in GDP per annum could be up to 1.8%. Conversely, in South Africa and Rwanda, where there are more extensive 4G networks in place, the increase could be more modest.

[97] Note the proportion of underserved households in Asia Pacific is extrapolated from five major economies due to data limitations.
[98] We consider that rural locations without FTTH coverage to be underserved.
[99] The coverage of the FTTH and alternative gigabit broadband technologies are expected to increase over time which could reduce the addressable market for satellite broadband.
[100] This is in line with estimates in previous studies on satellite broadband. For example, see ECC Report 152. The use of the frequency bands 27.5-30.0 GHz and 17.3-20.2 GHz by satellite networks, September 2010. See Annex 2.

**Figure 3.17: Economic impact of satellite broadband, increase in GDP per annum by 2030**

| Country | Total addressable population (million)[101] | Potential increment in broadband connections (per 100 households) | Koutroumpis (2018) | Katz and Callardo (2019a) |
|---|---|---|---|---|
| | | | % GDP | % GDP |
| DRC | 66.5 | 37.2% | 1.8% | 1.5% |
| Egypt | 58.0 | 9.9% | 0.9% | 0.4% |
| Kenya | 39.5 | 19.1% | 1.7% | 0.8% |
| Nigeria | 122.6 | 29.7% | 2.6% | 1.2% |
| Rwanda | 9.0 | 11.1% | 1.4% | 0.4% |
| South Africa | 20.3 | 6.4% | 0.6% | 0.3% |

There is limited data on rural connectivity in many African markets, but applying regional averages to population demographics, and considering that (as explained above) the majority of rural areas are not just underserved but are in fact unserved, we find that when considering the underserved population as well as unserved means that our total estimated economic benefits:

- Increase from 1.02% to 1.11% additional GDP when estimated using Katz and Callardo (2019a)
- Increase from 2.09% to 2.28% additional GDP when estimated using Koutroumpis (2018)

## 3.4 Conclusion

The main advantage of satellites has always been their ubiquitous access to connectivity. Advancements in satellite technology in recent years has made satellite broadband a viable, cost-effective solution for the provision of broadband for a wide range of consumer and enterprise applications. These improvements are heavily dependent on access to the Ka-band including the frequencies in the 28 GHz range.

The benefits of satellite connectivity include:

- Ubiquitous broadband coverage for unserved areas and communities,
- Improvements in broadband service quality for underserved locations,
- Wider choice of broadband options and pricing options,
- New applications and connectivity services through ESIM for hard-to-serve locations and market segments, such as land, aeronautical and maritime transport routes, and
- Ubiquitous fast-broadband availability in urban contexts across airports and seaports in major cities and their connecting routes in Africa (ESIM powered broadband gate-to-gate onboard aircrafts and pier-to-pier on board vessels), as well as ground transportation routes.

[101] Includes unserved and unserved population.

The scale of economic impact across these benefits varies significantly depending on market conditions and availability of alternative broadband options. It is difficult to assess the full scale of each of these benefits due to data limitations.

Across the African region as a whole, there are currently more than 681 million people (123 million households) who are not covered by at least a 4G mobile service. We estimate that the economic benefits of satellite broadband coverage for this unserved population could lead to an increase in GDP of 1.02% to 2.09% per annum for Africa by 2030.

In addition to connecting the unserved population, there is a wider underserved segment of the population who could also benefit from access to satellite connectivity. For the six African markets considered, the potential economic impact by 2030 in terms of GDP growth ranges from around 0.3% in South Africa, where there are already extensive fixed broadband networks and high quality mobile coverage, to over 2.6% in Nigeria where there is negligible FTTH coverage and fixed broadband adoption is low. Over the entirety of Africa, the economic benefits of covering both the unserved and underserved together could lead to an increase in GDP of 1.11% to 2.28%.

In deciding on the future allocation of the 28 GHz band, it will be important for policymakers and regulators to carefully consider the needs of satellite and IMT uses in their respective markets and associated trade-offs in terms of economic value and opportunity costs involved.

# Appendix A Coexistence studies

This Appendix provides a summary of findings from coexistence studies presented in ITU-R TG 5/1 between FSS and IMT for the 26 GHz band[102]. It is noted that the studies relate to the 24.25-27.5 GHz band, which is not used by today's high throughput satellite (HTS) broadband user terminals. Studies for other relevant scenarios, for example, concerning ESIM operations, or scenarios concerning IMT aggregate interference into FSS space receivers are limited or not yet available.

Although the studies identify the potential to define separation distances between IMT base stations and FSS earth stations they do not all take into account the ubiquitous deployment of small earth stations ESIM.

Study L specifically notes:

> **“ In case a frequency band is used for ubiquitous deployment of small FSS earth stations, sharing between IMT and the FSS is not practicable. ”**

Similarly Study O notes:

> **“ For the case of ubiquitous deployment of small FSS earth stations, sharing between IMT and the FSS is not practicable within the same geographical areas, particularly as it is not feasible to individually coordinate large numbers of ubiquitous earth stations, nor is it even possible to determine a coordination contour around ubiquitous earth stations. ”**

## A.1 Study B

The interference from the FSS earth station towards the IMT nodes was investigated. Two different FSS earth station antenna sizes and two different earth station elevation angles were investigated. The small earth station antenna was assumed to be placed above local clutter height, while the large earth station antenna was assumed to be placed below local clutter height and any needed separation distance between IMT nodes and the FSS earth station was based on an I/N criterion of -6 dB. Using the worst-case assumption, the simulation results show a needed average separation distance between them is in the range 100 to 250 m. However, the spread in the interference level towards the IMT nodes was very wide (~90 dB), so depending on the actual environment and conditions where IMT and FSS earth stations are deployed, the needed separation can be anywhere between <100 m to >5 km.

## A.2 Study C

The interference from the FSS earth station towards IMT stations was also investigated and the necessary co-channel separation distance between them was 28 km in the worst case where the FSS transmit earth station and outdoor IMT BS face each other in azimuth, noting that the necessary separation distance may vary depending on the actual environment and conditions where the IMT network and FSS earth station are deployed.

It is concluded that the sharing between IMT systems and FSS systems in the band 24.25-27.5 GHz is feasible where FSS earth stations are placed at known, specific locations, and deployment of IMT is limited to the areas outside the minimum required separation distances for each azimuth to protect IMT stations from these specific

[102] [478] Annex 03 Part 3, https://www.itu.int/md/R15-TG5.1-C-0478/en

FSS earth stations. In this case, the IMT protection criteria should be used to determine the necessary separation distances to ensure protection to the IMT stations.

Furthermore, sharing between IMT and FSS systems may be feasible in case that FSS earth stations are operated at such angles that are larger than the required minimum elevation angles corresponding to the required separation distances in the same geographical area.

In the case of Carrier #13 whose antenna diameter of the earth station is 0.45 m, the necessary separation distance was 28 km for the worst case where the FSS transmit earth station and IMT BS face each other in azimuth and the elevation angle of the FSS earth station was 5 degrees. Considering the actual operational limitation where the elevation angle of the FSS earth station is limited to a higher elevation angle, can reduce the necessary separation distance. For instance, it was reduced to 12 km for Carrier #13 with a 10-degree elevation angle.

In the case of Carrier #14, whose antenna diameter of the earth station is 13.2 m, the necessary separation distance was 18 km for the worst case where the FSS transmit earth station and IMT BS face each other in azimuth and the elevation angle of the FSS earth station was 5 degrees. Depending on the actual environment where the off-axis angle in azimuth of the FSS earth station directed to the IMT station is considered, the necessary separation distance can be reduced. For instance, it was reduced to 7 km for Carrier #14 with a 10 degree of off-axis angle in azimuth in the same 5-degree elevation angle of the FSS earth station.

**Figure A.1: Example separation distances**

| Carrier | BS direction | FSS azimuth off-axis (degree) | BS separation distance (km) | | | UE separation distance (km) | | |
|---|---|---|---|---|---|---|---|---|
| | | | Clutter 1% | Clutter 10% | Clutter 50% | Clutter 1% | Clutter 10% | Clutter 50% |
| #13 (5-degree elevation) | Front | 0 | 28 | 14 | 6 | 12 | 6 | 3 |
| | | 5 | 19 | 9 | 4 | 8 | 4 | 2 |
| | | 10 | 11 | 5 | 3 | 5 | 3 | 2 |
| | | 48 | 2 | 1 | 0.7 | 0.9 | 0.7 | 0.45 |
| | Back | 48 | 0.3 | 0.25 | 0.25 | 0.9 | 0.7 | 0.45 |
| #13 (10-degree elevation) | Front | 0 | 12 | 6 | 3 | 5 | 3 | 2 |
| | | 5 | 11 | 5 | 3 | 5 | 3 | 2 |
| | | 10 | 8 | 4 | 1 | 4 | 2 | 0.9 |
| | | 48 | 2 | 1 | 0.7 | 0.9 | 0.7 | 0.45 |
| | Back | 48 | 0.3 | 0.25 | 0.25 | 0.9 | 0.7 | 0.45 |
| #14 (5-degree elevation) | Front | 0 | 18 | 9 | 4 | 8 | 4 | 2 |
| | | 5 | 12 | 6 | 3 | 5 | 3 | 2 |
| | | 10 | 7 | 4 | 2 | 3 | 2 | 0.8 |
| | | 48 | 2 | 0.8 | 0.5 | 0.8 | 0.5 | 0.35 |
| | Back | 48 | 0.25 | 0.25 | 0.25 | 0.8 | 0.5 | 0.35 |
| #14 (10-degree elevation) | Front | 0 | 8 | 4 | 2 | 4 | 2 | 0.9 |
| | | 5 | 7 | 4 | 2 | 3 | 2 | 0.8 |
| | | 10 | 5 | 3 | 2 | 3 | 2 | 0.7 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 48 | 2 | 0.8 | 0.5 | 0.8 | 0.5 | 0.35 |
| | Back | 48 | 0.25 | 0.25 | 0.25 | 0.8 | 0.5 | 0.35 |

## A.3 Study L

In case a frequency band is used for large FSS earth stations at known locations (gateways), appropriate zones around FSS earth stations where IMT base stations could potentially receive interference can be determined. Thus, it would be possible to ensure compatibility and co-existence of IMT and FSS earth stations.

In case a frequency band is used for ubiquitous deployment of small FSS earth stations, sharing between IMT and the FSS is not practicable.

**Figure A.2: Examples of separation distances between FSS earth stations and IMT base stations**

| | Unit | OPEN SPACE | OUTDOOR | OUTDOOR | OUTDOOR | OUTDOOR | OUTDOOR | OUTDOOR | OUTDOOR | OUTDOOR |
|---|---|---|---|---|---|---|---|---|---|---|
| Frequency range | GHz | 27-27.5 | 27-27.5 | 27-27.5 | 27-27.5 | 27-27.5 | 24.65-25.25, 27-27.5 | 24.65-25.25, 27-27.5 | 24.65-25.25, 27-27.5 | 24.65-25.25, 27-27.5 |
| Earth station carrier | | Carrier #13 | Carrier #13 | Carrier #13 | Carrier #13 | Carrier #13 | Carrier #19 | Carrier #19bis | Carrier #19 | Carrier #19bis |
| Antenna diameter | M | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 5 | 13 | 5 | 13 |
| Peak transmit antenna gain | dBi | 40.4 | 40.4 | 40.4 | 40.4 | 40.4 | 59.7 | 68.2 | 59.7 | 68.2 |
| Peak transmit power spectral density (clear sky) | dB(W/Hz) | -56.0 | -56.0 | -56.0 | -56.0 | -56.0 | -73.0 | -56.5 | -73.0 | -56.5 |
| Antenna gain pattern (ITU-R Recommendation) | – | Rec. ITU-R S.465-6 | Rec. ITU-R S.465-6 | Rec. ITU-R S.465-6 | Rec. ITU-R S.465-6 | Rec. ITU-R S.465-6 | Rec. ITU-R S.1855 | Rec. ITU-R S.1855 | Rec. ITU-R S.1855 | Rec. ITU-R S.1855 |
| Minimum elevation angle of transmit earth station | Deg | 5 | 5 | 10 | 5 | 10 | 10 | 15 | 10 | 15 |
| Off-axis gain towards the BS | dBi | 14.5 | 14.5 | 7.0 | 14.5 | 7.0 | 7 | 2.6 | 7.0 | 2.6 |
| EIRP density towards the BS | dB(W/Hz) | -41.5 | -41.5 | -49 | -41.5 | -49.0 | -66 | -53.9 | -66.0 | -53.9 |
| EIRP density towards the BS | dBm/MHz | 48.5 | 48.5 | 41 | 48.5 | 41.0 | 24 | 36.1 | 24.0 | 36.1 |
| clutter loss | dB | 0 | 37 | 35 | 42 | 40 | 37 | 35 | 42 | 40 |
| IMT antenna discrimination | dB | 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| I/N | dB | -6 | -6 | -6 | -6 | -6 | -6 | -6 | -6 | -6 |
| IMT protection level | dBm/m$^2$/MHz | -76.2 | -76.2 | -76.2 | -76.2 | -76.2 | -76.2 | -76.2 | -76.2 | -76.2 |
| Separation distance | M | 8 643 | 6 866 | 3 634 | 3 861 | 2 044 | 408 | 2 067 | 229 | 1 162 |

## A.4 Study O

For an earth station elevation angle to satellite of 20°, which is used in operation in the frequency band under study, the required distance between the FSS and IMT varies between 2 km and 7.5 km, depending on the propagation conditions such as clutter loss, IMT BS orientation, FSS earth station orientation. Therefore, it is not possible to determine a fixed distance where IMT networks will not be affected; this will have to be handled on a case-by-case basis.

For the case of large FSS earth stations at known locations such as gateways, coordination zones around FSS earth stations can be determined to avoid interference towards IMT base stations. In this case, compatibility between both systems can be achieved by coordination, allowing for the effective co-existence of IMT and FSS earth stations.

For the case of ubiquitous deployment of small FSS earth stations, sharing between IMT and the FSS is not practicable within the same geographical areas, particularly as it is not feasible to individually coordinate large numbers of ubiquitous earth stations, nor is it even possible to determine a coordination contour around ubiquitous earth stations.

# Appendix B Country case studies

This appendix sets out further details for the six key African markets identified in the report.

## B.1 Democratic Republic of the Congo (DRC)

The Democratic Republic of the Congo is the second largest (by land area) country in Africa, after Algeria. Of the 89.56 million inhabitants, 56% are living in rural locations. The adoption of fixed broadband is almost null as the country only accounts for 11,900 subscriptions which represents 0.1% of households. 3G is the main mobile broadband technology used in the country as 4G coverage has only reached 40% of the population.

Mobile broadband adoption has increased over the last five years, but this is still relatively low at 44.2 unique subscribers per 100 inhabitants compared to the other African countries. Monthly mobile data usage is the lowest amongst the other African countries – 0.58 GB per subscription – and fixed data usage is not reported.

### Figure B.1: Status of broadband market in DRC[103]

| Indicators | Value | Source |
|---|---|---|
| **Economic and demographic** | | |
| Population (million) | 89.56 | ITU |
| Households (million) | 10.3 | ITU |
| Proportion of rural population (%) | 56% | World Bank |
| Labour force participation (% of total 15+ population, 2019) | 64.1% | World Bank |
| GNI per capita (current USD) | 550 | World Bank |
| **Broadband indicators** | | |
| 4G mobile broadband coverage (% population) | 40%[104] | ITU |
| Mobile broadband subscriptions (% population) | 23% | ITU |
| Mobile broadband adoption, unique subs (% population, 2021) | 44.2% | GSMA |
| Mobile broadband data usage per subscription (GB per month, 2019) | 0.58 | ITU |
| Mobile spectrum supply, all sub-6 GHz and sub-1 GHz (MHz) | 337.2 (67.6) | Plum analysis |
| Fixed broadband adoption (% households) | 0.1 % | ITU |
| Fixed broadband ≥ 10Mbps (% households) | - | ITU |
| FTTH coverage (% homes passed, end-2019) | - | - |
| Fixed broadband data usage per subscription (GB per month, 2019) | - | ITU |
| **Prices** | | |
| Mobile broadband (voice and data, high usage, current USD) | 30.1 | ITU |
| Mobile broadband (% of monthly GNI) | 69.46% | ITU |

[103] Data for 2020, unless otherwise stated.
[104] Data from GSMAi and ITU on 4G conflicts.

| Indicators | Value | Source |
|---|---|---|
| Fixed broadband (entry level, at least 5GB, current USD) | - | ITU |
| Fixed broadband (% of monthly GNI) | - | ITU |

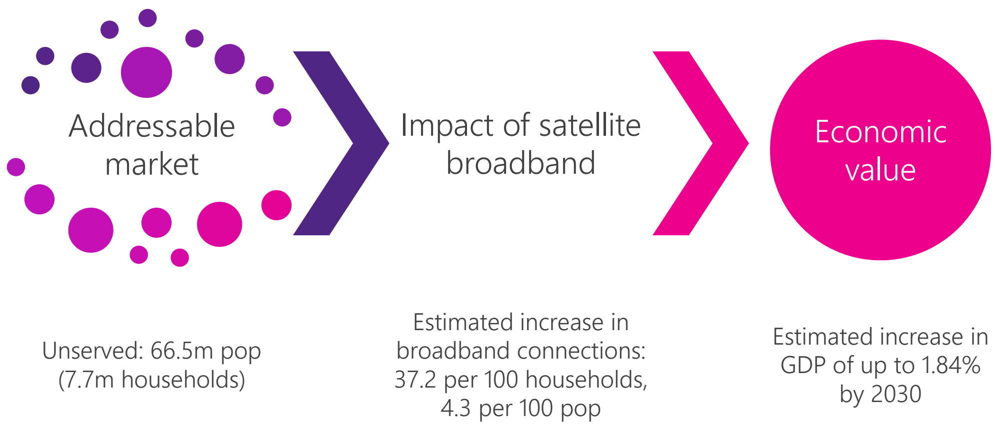
### B.1.1 Current situation in the 26 GHz and 28 GHz bands

The Autorité de Régulation de la Poste et des Télécommunications du Congo (ARPTC) has made no statements on the future allocation of either the 26 GHz or 28 GHz bands.

### B.1.2 Potential benefits of 28 GHz for satellite broadband

There are several different types of benefits from the use of the 28 GHz for satellite service provision as discussed in Section 1.4 of this report. To realise these benefits satellite operators must be able to provide services to unserved and underserved populations, leading to an increase in subscriptions. Below we provide high level estimates of the potential economic impact of satellite broadband provision in unserved and underserved regions for DRC.

**Figure B.2: Potential economic impact of satellite broadband in DRC**




It is estimated that increase in broadband adoption as a result of satellite coverage in unserved regions will contribute an increase in GDP of between 1.49% and 1.84% per annum by 2030.

In addition there are potential economic benefits from new applications and connectivity services through ESIMs in the aeronautical and maritime sectors. Due to limited information, these benefits have not been assessed in this study. However, they should also be taken into consideration by policymakers and regulators when deciding on the allocation of the 28 GHz band.

## B.2 Egypt

Egypt is the second largest economy in Africa in terms of GDP, and 57% of its population is living in rural areas. It has the highest fixed broadband adoption rate compared to the other countries – 42.3% of households- and DSL make up most of the connections. Mobile coverage of 4G networks has expanded rapidly in the last 5 years, reaching almost 96% in 2020.

There has been strong growth in the adoption of fixed and mobile broadband services. While still relatively low, household fixed broadband adoption has more than doubled from 4.1 to 9.1 per 100 households over 2015-2021. Mobile broadband adoption has grown by 49% over 2017-2021 to reach 73.5 % of the population. Monthly mobile data usage was 1.89 GB per subscription as of 2019, compared to fixed broadband usage of 91 GB per subscription; this may be due to capacity issues suffered by operators due to a lack of mid-band spectrum allocation.

**Figure B.3: Status of broadband market in Egypt[105]**

| Indicators | Value | Source |
|---|---|---|
| **Economic and demographic** | | |
| Population (million) | 102.3 | ITU |
| Households (million) | 22.1 | ITU |
| Proportion of rural population (%) | 57% | World Bank |
| Labour force participation (% of total 15+ population, 2019) | 47.9% | World Bank |
| GNI per capita (current USD) | 3000 | World Bank |
| **Broadband indicators** | | |
| 4G mobile broadband coverage (% population) | 96% | ITU |
| Mobile broadband subscriptions (% population) | 65% | ITU |
| Mobile broadband adoption, unique subs (% population) | 73.5% | GSMA |
| Mobile broadband data usage per subscription (GB per month, 2019) | 1.89 | ITU |
| Mobile spectrum supply, all sub-6 GHz and sub-1 GHz (MHz) | 590 (130) | Spectrum monitoring.com, Plum analysis |
| Fixed broadband adoption (% households) | 42.3% | ITU |
| Fixed broadband ≥ 10Mbps (% households) | 100% | ITU |
| FTTH coverage (% homes passed, end-2019) | - | - |
| Fixed broadband data usage per subscription (GB per month) | 91.5 | ITU |
| **Prices** | | |
| Mobile broadband (voice and data, high usage, current USD) | 4.85 | ITU |
| Mobile broadband (% of monthly GNI) | 1.8% | ITU |
| Fixed broadband (entry level, at least 5GB, current USD) | - | ITU |
| Fixed broadband (% of monthly GNI) | 3.2% | ITU |

## B.2.3 Current situation in the 26 GHz and 28 GHz bands

The 24.65-25.25 GHz is used for fixed links, FSS and SRD. The 25.25-27 GHz is allocated to the earth exploration-satellite (space-earth), fixed, inter-satellite, space research and is mainly used for fixed links and SRD.

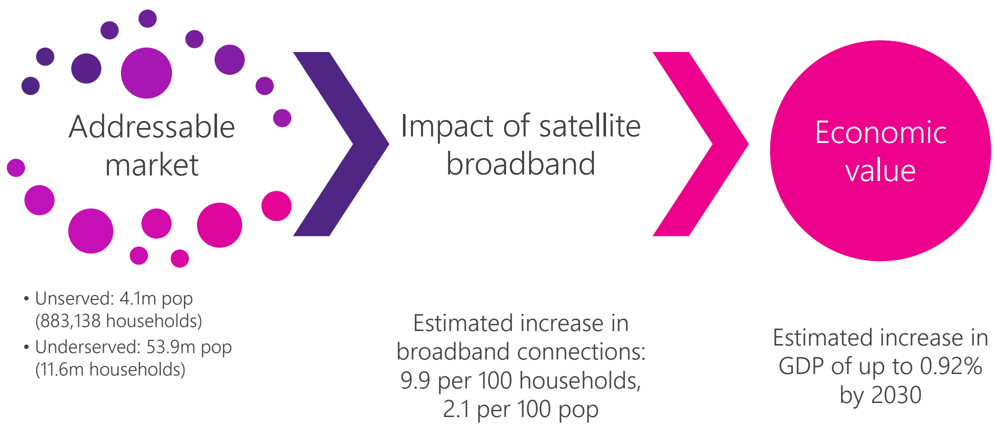
[105] Data for 2020, unless otherwise stated.

The 27.5-28.5 GHz band is allocated to the fixed-satellite service (space to Earth) on a primary basis for the beacon transmissions intended for up-link power control. It can also be used by the fixed-satellite service (Earth-to-space) for the provision of feeder links for the broadcasting-satellite service.[106]

### B.2.4 Potential benefits of 28 GHz for satellite broadband

There are several different types of benefits from the use of the 28 GHz for satellite service provision as discussed in Section 1.4 of this report. Below we provide high level estimates of the potential economic impact of satellite broadband provision in unserved and underserved regions for Egypt

**Figure B.4: Potential economic impact of satellite broadband in Egypt**




It is estimated that increase in broadband adoption as a result of satellite coverage in unserved and underserved regions will contribute an increase in GDP of between .0.40% and 0.92% per annum by 2030.

In addition there are potential economic benefits from new applications and connectivity services through ESIMs in the aeronautical and maritime sectors. Due to limited information, these benefits have not been assessed in this study. However, they should also be taken into consideration by policymakers and regulators when deciding on the allocation of the 28 GHz band.

## B.3 Kenya

Kenya has the highest rural population rate among the six countries considered in this study. Of the 53.8 million inhabitants, 74% live in rural locations. Fixed broadband adoption is relatively low, although significantly higher than other countries such as DRC, Nigeria and Rwanda – around 5.9% of households- and FTTH make up 41% of the connections. The coverage of 4G networks reached 77% in 2020.

As of 2020, fixed broadband adoption is five times higher than in 2015 although it still only represents 1.3% of households. 73.5% of the population are mobile broadband subscribers. In terms of monthly data consumption, the average usage per subscriber was 1.83GB for mobile broadband as of 2020.

[106] https://www.tra.gov.eg/wp-content/uploads/2021/06/EGY-NTRA-June21-NFAT-1.pdf

**Figure B.5: Status of broadband market in Kenya**[107]

| Indicators | Value | Source |
|---|---|---|
| **Economic and demographic** | | |
| Population (million) | 53.8 | ITU |
| Households (million) | 11.4 | ITU |
| Proportion of rural population (%) | 74% | World Bank |
| Labour force participation (% of total 15+ population, 2019) | 74.6% | World Bank |
| GNI per capita (current USD) | 1,840 | World Bank |
| **Broadband indicators** | | |
| 4G mobile broadband coverage (% population) | 77% | ITU |
| Mobile broadband subscriptions (% population) | 47% | ITU |
| Mobile broadband adoption, unique subs (% population) | 54% | GSMA |
| Mobile broadband data usage per subscription (GB per month, 2020) | 1.83 | ITU |
| Mobile spectrum supply, all sub-6 GHz and sub-1 GHz (MHz) | 460 (190) | Spectrum monitoring.com, Plum analysis |
| Fixed broadband adoption (% households) | 5.9% | ITU |
| Fixed broadband ≥ 10Mbps (% households) | 39.91% | ITU |
| FTTH coverage (% homes passed, end-2019) | - | - |
| Fixed broadband data usage per subscription (GB per month, 2019) | - | ITU |
| **Prices** | | |
| Mobile broadband (voice and data, high usage, current USD) | 10.05 | ITU |
| Mobile broadband (% of monthly GNI) | 7.12% | ITU |
| Fixed broadband (entry level, at least 5GB, current USD) | - | ITU |
| Fixed broadband (% of monthly GNI) | 16.2% | ITU |

## B.3.5 Current situation in the 26 GHz and 28 GHz bands

In Kenya, the 24.25-24.75 GHz band is used for fixed wireless access and inter-satellite links. The 25.5-27.5 GHz is used for FWA, fixed links, space research and earth exploration. The 27.0-27.5 GHz is also used for point-to-point links and mobile services. The 27.5-29.5 has been allocated to FS, FSS for gateway uplink as well as for mobile and FWA.[108]

In its 2020 National ICT policy Guidelines[109], the Kenyan government announced that a Broadband Spectrum Policy will be developed to promote the acceleration of uptake of broadband services.

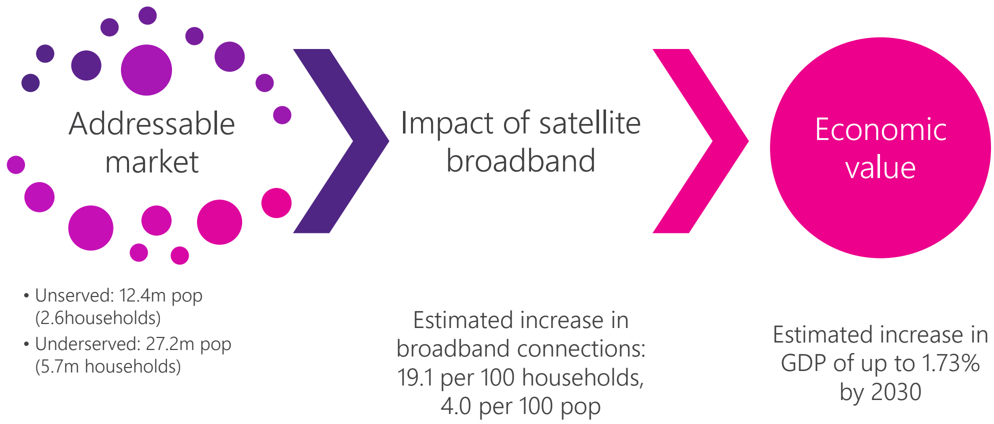
[107] Data for 2020, unless otherwise stated.
[108] https://www.ca.go.ke/wp-content/uploads/2018/02/The_National_Table_of_Frequency_Allocation_2017.pdf
[109] https://www.ca.go.ke/wp-content/uploads/2020/10/National-ICT-Policy-Guidelines-2020.pdf

The Kenyan telecom regulator suspended licensing of the 26 GHz band because of the foreseen potential identification of portion of the band for 5G services. According to its roadmap, the authority expects to allocate pilot frequencies in the 26 GHz band and authorize 5G frequencies for verticals by April 2022[110].

### B.3.6 Potential benefits of 28 GHz for satellite broadband

There are several different types of benefits from the use of the 28 GHz for satellite service provision as discussed in Section 1.4 of this report. Below we provide high level estimates of the potential economic impact of satellite broadband provision in unserved and underserved regions for Kenya.

**Figure B.6: Potential economic impact of satellite broadband in Kenya**




It is estimated that increase in broadband adoption as a result of satellite coverage in unserved and underserved regions will contribute an increase in GDP of between 0.76% and 1.73% per annum by 2030.

In addition there are potential economic benefits from new applications and connectivity services through ESIMs in the aeronautical and maritime sectors. Due to limited information, these benefits have not been assessed in this study. However, they should also be taken into consideration by policymakers and regulators when deciding on the allocation of the 28 GHz band.

## B.4 Nigeria

Nigeria is the largest economy and the most populous country in Africa and 51% of its population are living in rural locations. Fixed broadband is lacking as adoption stands at a mere 0.2% of households. Coverage of 4G networks is at 41% as of 2020.

Fixed broadband in Nigeria has not matched the expectations of the first Broadband plan implemented in 2013. Most fixed broadband connections in the country are based on terrestrial FWA, but this represents a very small proportion of total connections. Mobile broadband on the other hand has seen a significant growth with the deployment of 3G and 4G in the country and accounts for approximately 99.8% of the broadband base[111]. As of 2021, 69.9% of the population subscribed to mobile broadband, compared to 49% in 2017. The average mobile data usage per subscriber is at 1.39 GB per month while fixed broadband usage was at 50.7GB per month as of 2020.

[110] https://www.ca.go.ke/wp-content/uploads/2021/10/Public-Consultation-Paper-on-5G-Roadmap.pdf
[111] https://www.ncc.gov.ng/documents/880-nigerian-national-broadband-plan-2020-2025/file

Figure B.7: Status of broadband market in Nigeria[112]

| Indicators | Value | Source |
|---|---|---|
| **Economic and demographic** | | |
| Population (million) | 206.1 | ITU |
| Households (million) | 42.2 | ITU |
| Proportion of rural population (%) | 51% | World Bank |
| Labour force participation (% of total 15+ population, 2019) | 56..7% | World Bank |
| GNI per capita (current USD) | 2,000 | World Bank |
| **Broadband indicators** | | |
| 4G mobile broadband coverage (% population) | 41% | ITU |
| Mobile broadband subscriptions (% population) | 42% | ITU |
| Mobile broadband adoption, unique subs (% population 2021) | 69.9% | GSMA |
| Mobile broadband data usage per subscription (GB per month) | 1.39 | ITU |
| Mobile spectrum supply, all sub-6 GHz and sub-1 GHz (MHz) | 610 (180) | GSMAI, Plum analysis |
| Fixed broadband adoption (% households) | 0.2% | ITU |
| Fixed broadband ≥ 10Mbps (% population) | 17.06% | ITU |
| FTTH coverage (% homes passed, end-2019) | - | - |
| Fixed broadband data usage per subscription (GB per month, 2019) | 50.7 | ITU |
| **Prices** | | |
| Mobile broadband (voice and data, high usage, current USD) | 5.56 | ITU |
| Mobile broadband (% of monthly GNI) | 3.53% | ITU |
| Fixed broadband (entry level, at least 5GB, current USD) | - | ITU |
| Fixed broadband (% of monthly GNI) | 22.1% | ITU |

### B.4.7 Current situation in the 26 GHz and 28 GHz bands

The frequencies 24.45-25.25 GHz are used by fixed and inter-satellite services. The 25.25-25.50 GHz, 27-27.50 GHz, 27.50-28.50 are used by FS, FSS and mobile services.

The National regulator has announced that the country was reserving the 26 GHz band for 5G mobile broadband licensing.[113] Currently only one operator has a license in the band for point-to-point service delivery under the old plan which is FDD. The new plan is TDD so the spectrum shall be refarmed and replanned for 5G[114].

A National Broadband Plan for 2020-2025 has been announced in Nigeria[115]. The plan is designed to deliver data download speeds of a minimum of 25 Mbps in urban areas and 10 Mbps in rural areas with effective

[112] Data for 2020, unless otherwise stated.
[113] https://allafrica.com/stories/201909240266.html
[114] https://www.ncc.gov.ng/docman-main/legal-regulatory/legal-other/918-draft-deployment-plan-for-5g-network-in-nigeria/file
[115] https://www.ncc.gov.ng/documents/880-nigerian-national-broadband-plan-2020-2025/file

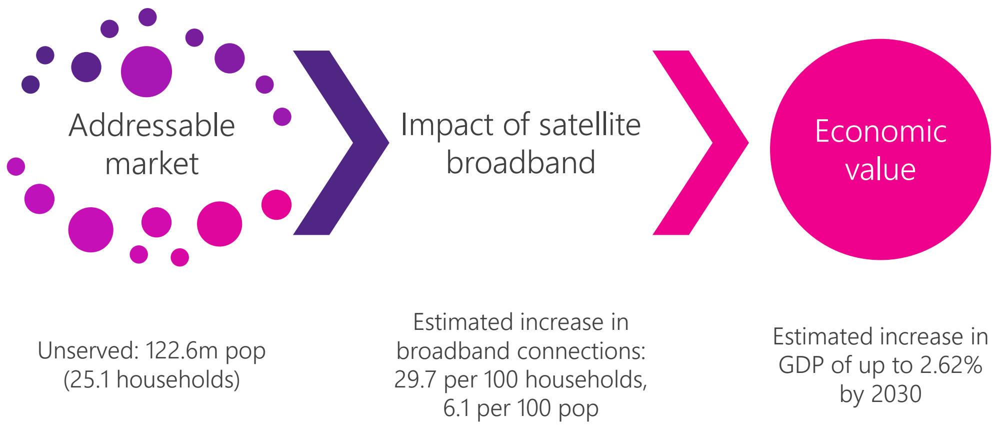
 

coverage available to at least 90% of the population by 2025 at a price of not more than N390 per 1GB of data[116].

### B.4.8 Potential benefits of 28 GHz for satellite broadband

There are several different types of benefits from the use of the 28 GHz for satellite service provision as discussed in Section 1.4 of this report. Below we provide high level estimates of the potential economic impact of satellite broadband provision in unserved and underserved regions for Nigeria.

**Figure B.8: Potential economic impact of satellite broadband in Nigeria**




It is estimated that increase in broadband adoption as a result of satellite coverage in unserved and underserved regions will contribute an increase in GDP of between 1.19% and 2.62% per annum by 2030.

In addition, there are potential economic benefits from new applications and connectivity services through ESIMs in the aeronautical and maritime sectors. Due to limited information, these benefits have not been assessed in this study. However, they should also be taken into consideration by policymakers and regulators when deciding on the allocation of the 28 GHz band.

## B.5 Rwanda

Compared to the other countries in this study, Rwanda is the smallest in terms of population. While its rural population is around 69%, its population density is amongst the highest in Africa. Fixed broadband adoption is very low, and 0.5% of fixed Internet subscriptions are still measured at a rate of less than 256 kbps. There is, however, extensive mobile broadband coverage, with 4G reaching 98% of the population in 2020 which is the highest among the other countries, yet 2G connections account for more than half the total mobile connections int the country.

66% of fixed broadband subscriptions are connected through fibre and as with the other markets, mobile broadband adoption has been growing in the last five years. As of 2021, 62.2% of the population have subscribed to a mobile broadband service compared to 46.4% in 2017. The average monthly fixed data usage per subscription is 454.2 GB per month which is significantly higher than the other African markets. In comparison, average monthly mobile data usage per subscriber is 1.2 GB as of 2020.

[116] https://www.nigeriacommunicationsweek.com.ng/fixed-broadband-the-next-big-thing-for-nigeria/

**Figure B.9: Status of broadband market in Rwanda[117]**

| Indicators | Value | Source |
|---|---|---|
| **Economic and demographic** | | |
| Population (million) | 13 | ITU |
| Households (million) | 3.9 | ITU |
| Proportion of rural population (%) | 69% | World Bank |
| Labour force participation (% of total 15+ population, 2019) | 84.1% | World Bank |
| GNI per capita (current USD) | 780 | World Bank |
| **Broadband indicators** | | |
| 4G mobile broadband coverage (% population) | 98% | ITU |
| Mobile broadband subscriptions (% population) | 43% | ITU |
| Mobile broadband adoption, unique subs (% population) | 62.2% | GSMA |
| Mobile broadband data usage per subscription (GB per month) | 1.2 | ITU |
| Mobile spectrum supply, all sub-6 GHz and sub-1 GHz (MHz) | 455.8 (185.8) | GSMAI, Plum analysis |
| Fixed broadband adoption (% households) | 0.5 | ITU |
| Fixed broadband ≥ 10Mbps (% households) | 71.1% | ITU |
| FTTH coverage (% homes passed, end-2019) | - | - |
| Fixed broadband data usage per subscription (GB per month, 2019) | 454.2 | ITU |
| **Prices** | | |
| Mobile broadband (voice and data, high usage, current USD) | 10.96 | ITU |
| Mobile broadband (% of monthly GNI) | 17.71% | ITU |
| Fixed broadband (entry level, at least 5GB, current USD) | - | ITU |
| Fixed broadband (% of monthly GNI) | 48.1% | ITU |

## B.5.9 Current situation in the 26 GHz and 28 GHz bands

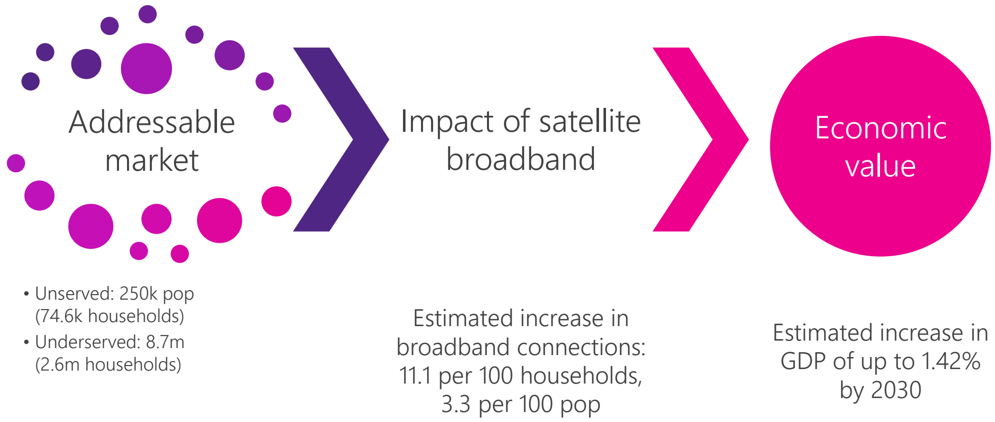
24-24.05 GHz is used for radiolocation (SRD) and amateur satellite users. 24.25-24.65 GHz is designated for FS (point-to-point links or FWA) and inter-satellite. While the 24.65-29.0GHz band is used for FS, FSS, mobile and earth exploration-satellite[118].

## B.5.10 Potential benefits of 28 GHz for satellite broadband

There are several different types of benefits from the use of the 28 GHz for satellite service provision as discussed in Section 1.4 of this report. Below we provide high level estimates of the potential economic impact of satellite broadband provision in unserved and underserved regions for Rwanda.

[117] Data for 2020, unless otherwise stated.
[118] https://rura.rw/fileadmin/Documents/docs/National_Frequency_Allocation_Table_02.pdf

**Figure B.10: Potential economic impact of satellite broadband in Rwanda**




It is estimated that increase in broadband adoption as a result of satellite coverage in unserved and underserved regions will contribute an increase in GDP of between 0.44% and 1.42% per annum by 2030.

In addition, there are potential economic benefits from new applications and connectivity services through ESIMs in the aeronautical and maritime sectors. Due to limited information, these benefits have not been assessed in this study. However, they should also be taken into consideration by policymakers and regulators when deciding on the allocation of the 28 GHz band.

## B.6 South Africa

South Africa is the country with the highest GDP per capita and the smallest proportion of rural population, at only 34%. Fixed broadband infrastructure is relatively more developed than in the other countries with 9.6% of households having a fixed broadband subscription. There is also broad mobile coverage with 4G reaching 96% in 2020.

Unlike the other countries covered in this report, fixed broadband adoption in South Africa has slightly declined between 2015 and 2020 and stands at 9.6% of households, in contrast with 10.9% five years ago. The country has the highest rate of mobile broadband adoption which as with the other markets has seen a significant growth – 68% in 2017 and 79.7% in 2021. Average monthly mobile data usage per subscriber is 2.0 GB, compared to 213.7 GB for monthly fixed usage per subscriber.

**Figure B.11: Status of broadband market in South Africa**[119]

| Indicators | Value | Source |
|---|---|---|
| **Economic and demographic** | | |
| Population (million) | 59.3 | ITU |
| Households (million) | 13.6 | ITU |
| Proportion of rural population (%) | 34% | World Bank |
| Labour force participation (% of total 15+ population) | 60.1% | World Bank |
| GNI per capita (current USD) | 6,010 | World Bank |
| **Broadband indicators** | | |
| 4G mobile broadband coverage (% population) | 96% | ITU |
| Mobile broadband subscriptions (% population) | 111% | ITU |
| Mobile broadband adoption, unique subs (% population) | 79.7 | GSMA |
| Mobile broadband data usage per subscription (GB per month, 2019) | 2.0 | ITU |
| Mobile spectrum supply, all sub-6 GHz and sub-1 GHz (MHz) | 528.25 (76.25)[120] | GSMAI, Plum analysis |
| Fixed broadband adoption (% households) | 9.6% | ITU |
| Fixed broadband ≥ 10Mbps (% households) | 65.3% | ITU |
| FTTH coverage (% homes passed, end-2019) | - | - |
| Fixed broadband data usage per subscription (GB per month, 2019) | 213.7 | ITU |
| **Prices** | | |
| Mobile broadband (voice and data, high usage, current USD) | 22.34 | ITU |
| Mobile broadband (% of monthly GNI) | 5.55% | ITU |
| Fixed broadband (entry level, at least 5GB, current USD) | - | ITU |
| Fixed broadband (% of monthly GNI) | 4.7% | ITU |

## B.6.11 Current situation in the 26 GHz and 28 GHz bands

The 26 GHz band is used for fixed (microwave link) services, and the band is available on an ad hoc radio coordinated basis.

The 28 GHz band is currently not available for use as it is being replanned[121]. However there are a number of existing users in the band, running point-to-multipoint microwave links on a regional basis.

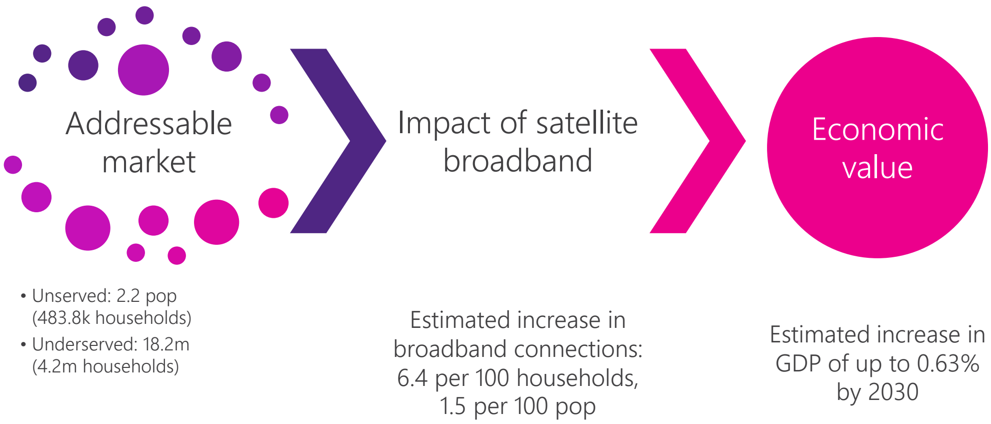
[119] Data for 2020, unless otherwise stated.
[120] Spectrum assigned during the spectrum auction ended March 2022 are not included as these are still in the process of confirmation
[121] https://www.icasa.org.za/legislation-and-regulations/spectrum-usage-and-availability-q1-2019

### B.6.12 Potential benefits of 28 GHz for satellite broadband

There are several different types of benefits from the use of the 28 GHz for satellite service provision as discussed in Section 1.4 of this report. Below we provide high level estimates of the potential economic impact of satellite broadband provision in unserved and underserved regions for South Africa.

**Figure B.12: Potential economic impact of satellite broadband in South Africa**




It is estimated that increase in broadband adoption as a result of satellite coverage in unserved and underserved regions will contribute an increase in GDP of between 0.26% and 0.63% per annum by 2030.

In addition, there are potential economic benefits from new applications and connectivity services through ESIMs in the aeronautical and maritime sectors. Due to limited information, these benefits have not been assessed in this study. However, they should also be taken into consideration by policymakers and regulators when deciding on the allocation of the 28 GHz band.