STARLINK

7 October 2025

Managing Director
Eastern Caribbean Telecommunications Authority (ECTEL)
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Re.: Starlink's reply to ECTEL Consultation Paper on Recommendation to Amend the License Classification Notice to include Non-Terrestrial Networks and Services License and the Telecommunications Fees Regulations for Point-to-Multipoint Wireless Services

Dear Sir(s):

Reference is made to the Consultation paper issued by the Eastern Caribbean Telecommunications Authority (ECTEL) titled Recommendation to Amend the Licence Classification Notice to Include Non-Terrestrial Networks and Services Licence and the Telecommunications (Fees) Regulations of the ECTEL Member States for Point-to-Multipoint Wireless Services (the "Consultation").

Starlink appreciates ECTEL's recognition for the need to establish smart, future-forward regulatory frameworks for Non-Geostationary Satellite Orbit Systems (NGSOS) that are already connecting the Caribbean, including during times of disruption caused by natural disasters or in remote areas where terrestrial networks are too difficult or expensive to deploy.

Starlink believes that ECTEL's proposed regulatory framework is well-suited to this need and addresses some of the most pressing regulatory issues involving NGSOS, including:

- The need to establish a regulatory fee framework consistent with the dimensions, reaches and social connectivity embedded in the new NGSO technologies,
- The immediate solutions necessary to start deploying Direct-to-Device (D2D) services as part of the regular NGSOS offerings that are already deployed and tested in several parts of the world[1],
- The need to differentiate emergent NGSO systems from legacy satellite technology and services and
- The need to build up flexibility in the national spectrum charts to ensure access to the higher spectrum bands that these satellite constellations will use to provide service.

[1] See. https://www.starlink.com/us/business/direct-to-cell?srsltid=AfmBOop8Ywcnl0CxkcAFpM6G-sDL_tshWedKFBZKO-URyrQKSTYA5F_8

SpaceX supports this regulatory update as the first global NGSO network and emphasizes that this technology will also be used by other companies in the future, so it is essential to bring the regulation of this transformative technology up to date.

Starlink would like to emphasize the importance of ECTEL taking into consideration the following:

1. Starlink offers two comments relative to ECTEL's proposed license fees for non-terrestrial networks:

    a. To eliminate confusion and doubt, ECTEL needs to clarify that its members should only charge the regulatory fees mentioned in Table 5 of the Consultation, and that this amendment replaces in its entirety the fees contained in Table 3 and Table 4 of the Consultation. This will reduce the possibility of additional "hidden" regulatory fees that would burden business growth and affordability. Such additional fees would be out-of-line with global best practice if ECTEL already intends to apply a 3% annual tax on license renewals.

Licence Code	Description	Licence Fees		
		Application	Initial	Annual
NNS	Non-Terrestrial Networks and Services	XCD 500.00	XCD 5,000.00	3.0% of Gross Annual Revenue, except that the minimum fee shall not be less than XCD 5,000.00

Table 5: Proposed Amendment to Schedule 2 of Telecommunications (Fees) Regulations for ECTEL Member States to include Class (NNS) Licence.

    b. To promote business sustainability and ensure continuity and affordability of service provided to end users, ECTEL should adjust the 3.0% annual license renewal fee to 3.0% of **Net** Annual Revenue, rather than Gross. This would align ECTEL's framework with global best practices.

2. To maintain regional competitiveness and incentivize innovation, ECTEL members need flexibility to authorize use of spectrum on a non-exclusive, non-interference, non-protection basis outside of regular spectrum classifications, even on a temporary basis. Providing the regulator and/or Minister the flexibility and discretion to approve spectrum use, enables rapid adoption of new technologies and continued focus on network quality, that otherwise may be hindered by a lengthy, and oft years long process, to amend spectrum allocation tables and supporting requirements.
3. Regulatory reports, although not addressed in the Consultation, should be simplified and standardized. Starlink considers that the ECTEL Recommendation should include a new exhibit in the license providing that local Regulators should only request minimal reports on an annual basis.

As recommended in the Consultation, Starlink is enclosing with its reply to the paper “How to Price Satellite Spectrum” published in November 2024 by National Economic Research Associates (NERA) which outlines best practices for determining spectrum regulatory fees for next-gen satellite systems.

Sincerely,

Kaitlyn Fleming

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Enclosures:

1. Richard Marsden, Hector Lopez, Julien Martin, et al. “How to price satellite spectrum”, National Economic Research Associates, 1 November 2024

How to price satellite spectrum

A NERA report prepared on behalf of
Starlink, a SpaceX company

1 November 2024

Project Team

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Executive Summary

Non-geostationary orbit (NGSO) satellite constellations are transforming the landscape of internet access worldwide. NGSO operators provide internet connectivity worldwide including in remote areas that have been historically unserved by terrestrial providers. For example, SpaceX's Starlink is already providing service in more than 110 countries, including remote regions of the United States and Canada, and underserved areas in Kenya and Mozambique.

However, ineffective spectrum pricing schemes threaten to frustrate realization of the universal connectivity promised by large-scale NGSO constellations and the socioeconomic benefits that come with it. Many countries operate legacy spectrum pricing regimes that fail to account adequately for the shared nature of satellite spectrum, the broad scope of NGSO networks, and the large bandwidths required to provide consistent broadband access at scale.

In a survey of 23 countries, we found that:

- there is no global consensus on how to price access to spectrum for satellite services, with the result that global providers must navigate huge variety and complexity in rules;
- only a handful of countries have updated their satellite spectrum pricing to account for the entry of mass market NGSO services;
- many countries use legacy pricing formulas that result in absurdly high fees when applied to constellations with thousands of user terminals and many gateways; and
- some countries use complex, ambiguous pricing structures that make it difficult for operators and regulators to understand and therefore agree on fee levels.

The prices levied for NGSO satellite spectrum access currently in effect in our survey countries range from less than one cent per head of population to more than $16,000 per pop. We found that countries with prices up to around three cents per pop (net present value over 20 years) – equivalent to annual total payments of around 2,800 USD PPP per million people – have attracted early NGSO entry, meaningful and service penetration, and gateway investments. With very high spectrum prices, entry becomes unviable, leading to NGSOs either skipping some countries or attempting the slow, uncertain task of trying to negotiate arrangements with regulators that circumvent fee regulations.

We found that heterogeneity in price levels is the product of disparate spectrum pricing regulations rather than any differences in socioeconomic situations between countries. In fact, many of the countries with the lowest prices – such as Germany and the United Kingdom – are well developed economies with niche markets for satellite broadband access. And many of the countries with unduly high prices are developing economies with large, underserved markets whose population would benefit most from wide access to a low-cost, easy-to-use satellite broadband service.

Fees for NGSO spectrum use should be set administratively because they use shared use bands where scarcity is not a current concern and market mechanisms are therefore not applicable. As illustrated in Figure 1, we recommend that regulators adopt simpler fee structures, with low fixed fees for NGSOs operating both service links (i.e. using spectrum to communicate between satellites and user terminals) and gateway feeder links (i.e. using spectrum to communicate between satellites and earth stations). Fees for spectrum should reflect costs of spectrum management, not revenue targets. Some variation in fees to discourage congestion in lower satellite bands and gently incentivize migration of traffic to higher bands may promote long-term efficient use of the spectrum.

Figure 1: Summary of recommendations for setting spectrum access fees for NGSOs

Service Link Fees

- **Adopt a uniform fixed fee for unlimited number of service links** to maximize incentives for NGSOs to grow and service deprived communities
- **Avoid fees that scale with bandwidth** as these discourage efficient use of wide bandwidths where spectrum is not congested
- **Avoid fee structures that scale unduly with the number of user terminals** as these deter operators from adding subscribers
- **Avoid duplicate fees for deploying in higher bands**, as these deter operators from deployment decisions that prevent future congestion in the Ku band

Gateway (Feeder Link) Fees

- Adopting **a low fixed fee for single or multiple gateways** based on cost recovery pricing principles should be the default approach
- **An additional fee may be applicable where local congestion is a concern**
- **Avoid complex fee structures** that put a high burden on NGSOs to supply and update information on technical parameters, such as number of antennas
- Set a **low nominal fee for access to Q, E, V and W bands** to gently encourage adoption of these lesser utilized bands, which will become more important as more satellite services expand

Overall fee level for NGSOs

- **Fee charges for spectrum access** should **reflect cost of spectrum management**, not revenue targets
- If a government desires to raise additional revenues tied to a service, it should use transparent consumption taxes based on a low % of net revenues
- **Aggregate spectrum fees** for deploying service and gateways should ideally **not exceed** a 20-year NPV of **US 10c per pop**
- Pricing structures that result in **fees up to around US 3c per pop** have been particularly effective in enabling NGSO operators to grow services

1. How the satellite industry uses spectrum

The satellite industry is one of the two largest users of radio spectrum for commercial purposes, the other being terrestrial mobile networks. Like mobile, satellites operators rely on many different frequency bands, with the choice of band driven by available ecosystems, which in turn are influenced by the technical characteristics of particular bands, including signal propagation and bandwidth capacity. Whereas mobile deployment is primarily focused on spectrum below 6 GHz, the satellite industry is more dependent on spectrum above 6 GHz.

For national regulators designing a pricing regime for access to spectrum used by satellites, it is relevant how each type of satellite system and associated services use designated frequency bands. In this section, we introduce the different types of satellite systems, noting in particular the different capabilities of satellites deployed in Geostationary Earth Orbit (GEO) versus those in non-Geostationary orbits (NGSO) - including those in Low Earth Orbit (LEO). We highlight the frequency bands that these satellites typically use to communicate with Earth and the services that they provide. And we describe the network architecture that satellite operators deploy, observing the more complex architecture associated with new broadband and mobile satellite services that make use of constellations of LEO satellites, such as those deployed by SpaceX's Starlink service.

We conclude by highlighting three key features which regulators should consider when setting prices

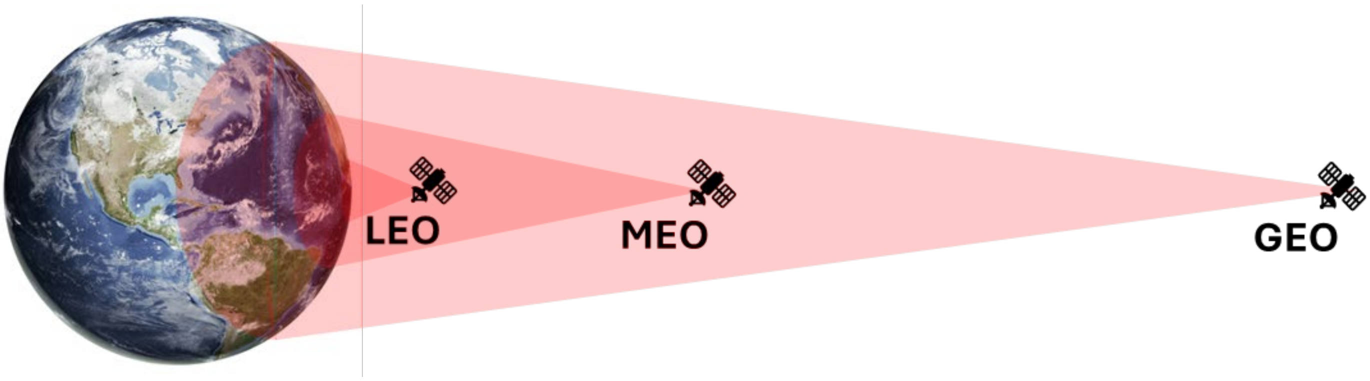
1. the role of NGSO satellite constellations providing universal broadband;
2. the shared nature of the spectrum used by satellite operators; and
3. the increasing use of higher frequency bands by satellite operators.

The level and structure of fees for satellite spectrum should be set in a way that supports these features. Any other approach will tend to delay or prevent individual countries from realizing the associated benefits, with harm focused on people and companies located in rural and remote areas where the costs of deploying terrestrial networks are prohibitive.

1.1. Different types of satellites and associated services

Most communication satellites use one of three types of orbit[1], as illustrated in Figure 2:

Figure 2: Illustration of positioning and ranges of LEO, MEO and GEO satellites



- **Geostationary Earth orbit (GEO).** GEO satellites orbit the earth at a distance of 35,786 km, allowing them to maintain a stationary position over a specific point on Earth. They have very large coverage areas with the capability to focus capacity on specific locations. Owing to their distance from earth, signals are subject to higher latency than closer orbits. These satellites are large and relatively expensive to launch. In the past, GEO satellites accounted for the majority of satellites, but launch activity is now focused more on LEO. They remain widely used for communications services where seamless and reliable connectivity is important, such as maritime and aviation safety services and some forms of government use.
- **Medium Earth orbit (MEO).** MEO satellites orbit at 2,000 km up to 35,786 km, with a typical orbit time of 2 to 8 hours. Relative to GEO, they offer reduced latency, making them suitable for Global Positing Systems (GPS) and other navigation systems. MEO constellations provided an early, relatively low cost solution for provision of lower latency, high bandwidth connectivity to remote areas, offering better performance and capacity than GEO, while covering a large area using fewer satellites than LEO. However, the latency and bandwidth they can provide is inferior to the large LEO constellations now being launched.
- **Low Earth orbit (LEO).** LEO satellites operate between 160 and 2,000 km from the earth, with an orbit time of between 1.5 to 2 hours. LEO constellations can provide very low latency, high bandwidth performance. For example, the first generation Starlink constellation operates at an orbit of 550 km with a latency of ~20-30 milliseconds (ms) versus 600+ ms for a GEO satellite. This performance makes LEO satellites suitable for home and enterprise broadband solutions wherever a good fixed or mobile connection is inconvenient, unreliable or unavailable. However, to deliver consistent performance in any given area, it is necessary to frequently hand over connectivity across satellites, as each one moves in and out of range. New launch

[1] There are also satellites that use a highly elliptical orbit (HEO) designed to provide connectivity to polar regions that are outside the range of conventional GEO satellites. Like GEO, this approach has higher latency.

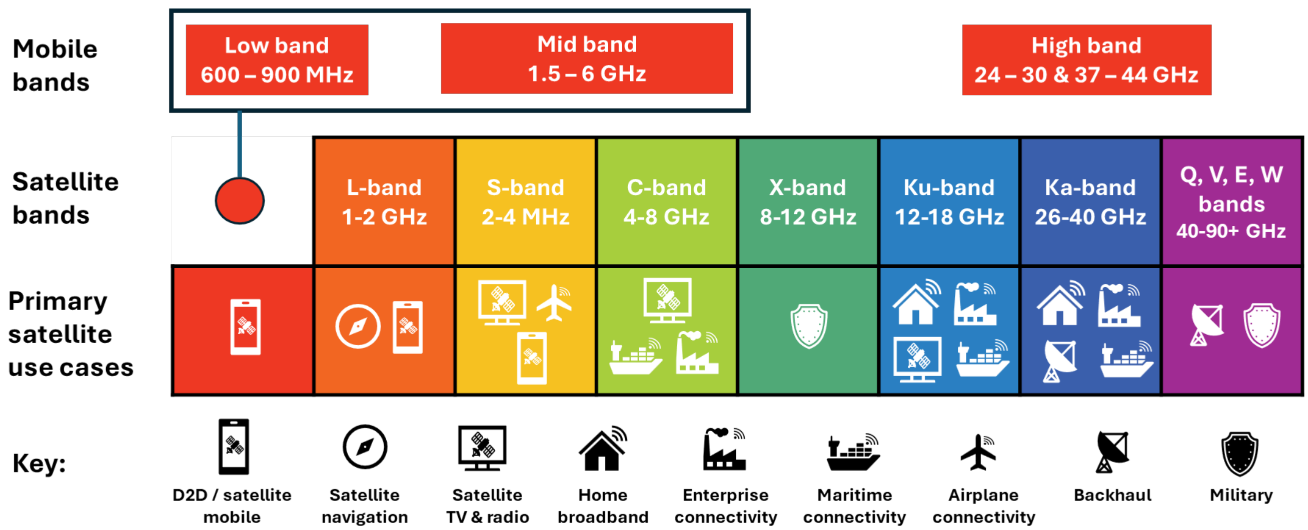
technology and the development of small LEO satellites has made such deployments increasingly cost effective.

1.2. Satellite frequency bands and services

Satellites make use of a wide range of frequency bands. As in terrestrial services, there is a trade off in performance between lower and higher frequencies. Lower frequencies propagate better, enabling wide area coverage and consistent performance in poor weather conditions. Higher frequencies offer much greater bandwidth, so can provide higher capacity and data speeds, but signals are increasingly vulnerable to interference from clouds and rain.

The major bands used by satellites and their primary satellite use cases are illustrated in Figure 3. The variation in primary use cases in large part reflects preferences for signal reliability versus higher bandwidth and throughput. For example, GPS is deployed in the L-band because navigation requires service consistency but uses little data. Backhaul of signals between satellites and earth stations via 'service links' is generally done using higher bands, such as Ka, owing to availability of wide bandwidth. Military use is often focused on the X band because it provides a compromise between reliability and bandwidth.

Figure 3: Satellite frequency bands and their primary use cases



Source: NERA

Spectrum allocations are broadly coordinated at an international level through the ITU. International coordination is particularly important for satellites, as satellites cover wide areas traversing international boundaries. In the commercial sector, the business case for satellites often depends on providing services to many countries. A satellite may serve a particular user, country or world region, or it could be part of a constellation serving most or all of the planet.

Satellites operate using frequency ranges identified by international agreements, as they are in the ITU's Radio Regulations. To provide services in specific countries, they also require authorization to use specific frequencies to communicate with user ground terminals (via service links) and gateway earth stations (via feeder links). These authorizations are the purview of national regulators, and users must typically follow an application process and pay annual fees for them. National regulators observe ITU recommendations when issuing access authorizations, but they ultimately decide whether to grant access or not to specific bands based on their national priorities and availability.

An authorization to use spectrum within a satellite band is typically for shared use access, with many operators using the same frequencies on a coordinated basis. This is different from the prevailing model for licensing terrestrial mobile, where mobile network operators (MNOs) acquire spectrum licenses that grant them exclusive rights to use specific frequency ranges in a specific geography. This difference reflects the different interference profiles of the two industries. Most (but not all) satellite use cases can coexist provided they coordinate technically to ensure that simultaneous satellite links use separate frequency channels or otherwise do not overlap. In contrast, mobile operators have designed systems that primarily require frequency or geographic separation to manage interference.

This difference in access models is also reflected in differences in associated property rights. Mobile rights, because they are limited and exclusive, and usually granted for long periods (e.g. 20 years), are inherently scarce. These characteristics confer significant value, which may be reflected in high prices paid in primary auctions and secondary trades of mobile spectrum licenses. Although satellite spectrum is also limited, as it is shared it is inherently less scarce and much less valuable because it is typically possible to add new authorizations on a coordinated basis. Reflecting this, most authorizations lack significant property rights: most satellite users pay annual fees and benefit from a (very high) expectation of renewal every year, but licenses do not confer exclusivity and are not tradable. As we will explain, certain uses of satellites to support mobile networks do require access to exclusive spectrum, and these are more suited to the spectrum license rather than the annual authorization model.

The usage fees paid for satellite spectrum authorizations are the subject of this report. In some countries, satellite providers may also require a separate license to provide services such as home or industry broadband connectivity. In this report, we do not directly consider prices for service licenses but they are a relevant consideration when assessing the overall fee burden on satellite operators.

The primary frequency bands relevant to the pricing of commercial satellite spectrum licenses are set out here:

Band	Frequencies	Description
L	Portions of 1.5 – 1.7 GHz	Portions of L-band frequencies between 1.5-1.7 GHz are used for mobile satellite services (MSS), such as those provided by Iridium and Inmarsat. They require exclusive access to relatively small bandwidths and can only provide low bandwidth services, such as voice and 2-way messaging.
S	Portions of 1.9 – 2.7 GHz	Portions of the S-band are used in some countries for satellite radio (e.g. Sirius XM at 2.3 GHz in USA) and television (e.g. Indonesia 2.5 GHz). Other portions have been identified for air-to-ground (A2G) and mobile satellite service (MSS), for example the EU-wide allocation of 2x15 MHz, split between Eutelsat and SES.

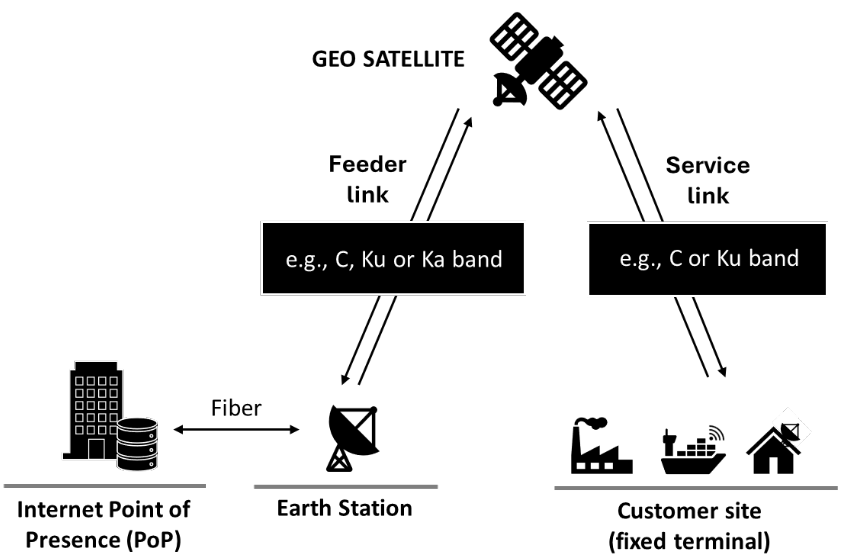
C	3.7 – 4.2 & 5.9 – 6.4 GHz	C-band was the first frequency band for commercial telecommunications satellites with downlink at 3.7-4.2 GHz and uplink at 5.925 to 6.425 GHz. Signals can cover wide geographic areas and generally require large ground equipment for reception. C-band is used for fixed satellite services (FSS) including distribution of television signals and provision of broadband to land and maritime users. In many countries, parts of the band have been repurposed for terrestrial mobile. C-band remains important for television and satellite broadband links in countries subject to high rain fade.
Ku	Portions of 10.7-14.5 GHz	The Ku frequencies used for uplink and downlink vary by ITU world region. This spectrum is the most intensively used satellite band worldwide. It allows for higher transmission frequency over smaller geographic areas and can be received with smaller ground equipment, making it suitable for FSS service links to subscribers, including television and broadband connectivity for home, industry and maritime users. Scope to connect smaller user receiving terminals makes it at attractive band for mass market NGSO broadband services using LEO constellations, such as Starlink.
Ka	Portions of 18-40 GHz	Use of the Ka band by satellites has grown rapidly in recent years, as satellite operators exploit the available wider bandwidths to improve capacity. Like the Ku band, Ka spectrum is used to provide FSS, including both service and feeder links. For Starlink, it is the primary feeder link band. Looking forward, the Ka band may be increasingly used for service links, as it can support high-bandwidth services such as high-speed internet, video conferencing and multimedia applications, and small user terminals. However, signal loss owing to rain fade is a challenge is some parts of the world.
Q,V	Portions of 40-70 GHz	The Q (33-50 GHz) and V (40-75 GHz) bands lie at the lower end of the extremely high frequency (EHF) range, and offer greater bandwidths than lower frequencies. Including these bands for gateway feeder links can help ease predicted congestion in the Ka band for service link bandwidth, enabling higher overall throughput.
E,W	71-76 GHz & 81-86 GHz; other portions TBD	The E (60-90 GHz) and W (75-110 GHz) bands lie at the upper end of and immediately above the V band. Historically little used for satellite owing to propagation challenges, advances in antenna technology now allow for highly directive pencil beams to communicate with earth stations in favorable rain zones. The band is largely lightly used and offers exceptional bandwidth for feeder links. In 2020, SpaceX received conditional approval from the FCC to deploy Starlink Gen2 satellites using 71-76 GHz and 81-86 GHz.

Over the last decade, there has been escalating pressure from terrestrial mobile industry to gain access to frequencies historically designated to satellite. Notably, many countries have repurposed parts of the C-band for 5G mobile deployment; some countries have allocated mobile frequencies in the Ka (millimeter wave) for mobile; and the FCC is exploring repurposing some spectrum in the Ku band at 12 GHz for mobile. Pressure from mobile expansion has been a factor encouraging satellite migration to higher bands, as discussed in Section 1.4.

1.3. Satellite network architecture

A standard satellite network architecture for a single GSO satellite is illustrated in Figure 4. The satellite communicates with customer sites via a service link and relays signals to and from an earth station which is connected by fiber to an internet point of presence (PoP). Across a country or group of neighboring countries, a GEO satellite may only be connected to a single earth station. The satellite may support few or many customer sites, each with a single mounted terminal, depending on the service application. The network may be designed to work with any satellite frequency band, depending on service requirements. The service and feeder link may use the same frequency band, in which case they will need to use different frequencies within the band, or they could use separate bands. Feeder links are often deployed at higher frequencies than service links because they must handle consolidated traffic, so need more bandwidth, and earth stations can be designed to conform to higher technical specifications and may be positioned to avoid rain fade.

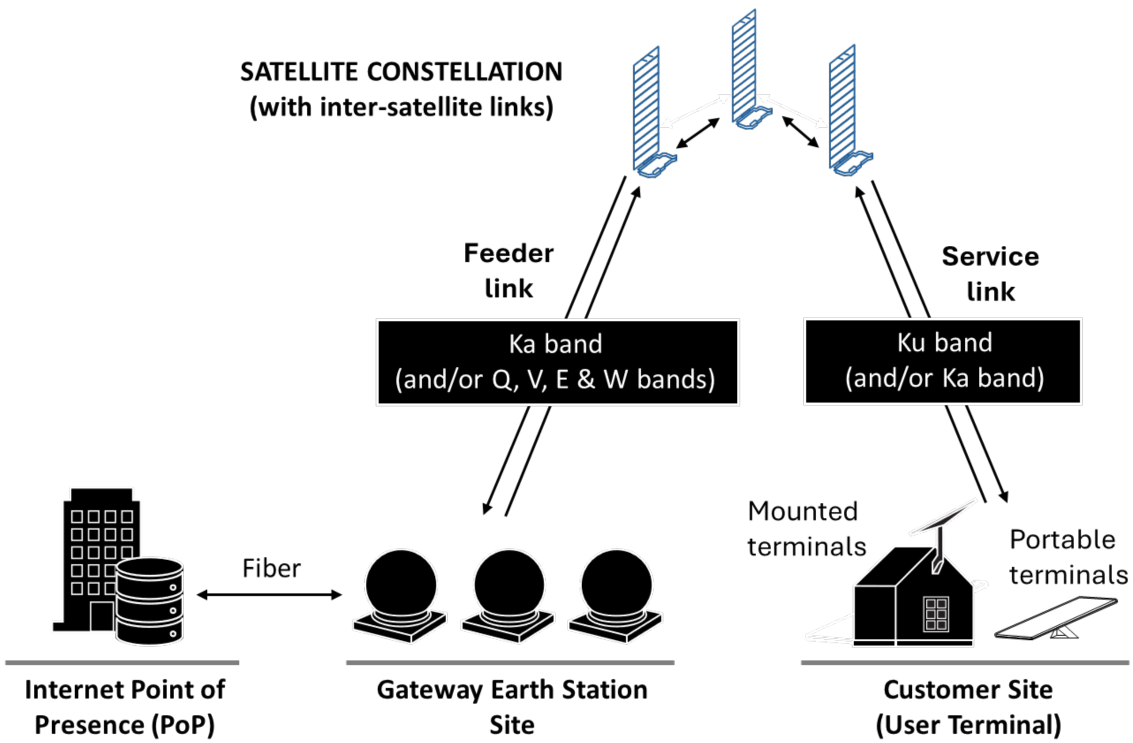
Figure 4: Standard network architecture for a GSO satellite



With the launch of NGSO constellations in LEO, this architecture is evolving. Figure 5 illustrates a typical network structure for a NGSO constellation. It consists of multiple, smaller satellites connected to each other with optical inter-satellite links. Each individual satellite has a smaller ground footprint than a GSO satellite, but, collectively, they can cover much more area. These networks are designed to service large numbers of customers via the service link. Although these networks are designated as FSS, some modern terminals (such as the Starlink User Terminals) are sufficiently small and light to be portable, so the difference with MSS is no longer so distinct. These networks are designed to support high bandwidth services, so service links are deployed in the Ka or Ku range, and feeder links use the Ka band or higher.

As networks grow, the traffic volume becomes too great to handle using single earth stations, so a successful NGSO network may require many gateway earth stations to manage capacity. However, operators have some flexibility with respect to where they site earth stations, as a gateway in one country may be used to offload traffic originating in another, a process that may be facilitated by the transfer of data in space through inter-satellite links.

Figure 5: Typical NGSO Architecture



A further difference between NGSO and GSO operators is the way they use frequency channels within satellite bands. With a GSO, the associated gateway and terminals are always pointing to the same place in the sky, so the signal direction is predictable. Other satellite users can then plan their own activity within shared use bands to avoid contention with these signals. However, with an NGSO, the pairing of earth stations or user terminals with satellites changes regularly, and the signal directions are constantly changing. Consequently, it makes sense for these systems to be frequency agile, shifting channels within the broader frequency band as necessary to avoid contention with the fixed position GSO signals and other agile NGSO signals. Accordingly, an NGSO deployment may require access to a broader bandwidth than a GSO, but this does not mean that it is using more frequency overall as, at any given time, it will only be using a subset of frequency channels across the wider range.

1.4. Key features and their implications for pricing

This is a very exciting period in the development of the global satellite industry, with many more satellites being launched than ever before and new and enhanced services becoming available. Every nation on earth stands to benefit from the improved connectivity solutions associated with this evolution of the industry.

Advances in connectivity will be realized most quickly in countries with welcoming regulatory environments. A vital element of a regulatory environment is the price levied for spectrum access for satellite operators.

We highlight here three key features that regulators must consider when setting prices:

1. **NGSO satellite constellations providing universal broadband availability.**

   The development of rural economies has long been held back by poor connectivity. In areas where fiber has not been deployed, many users still depend on legacy DSL and GEO services, which may be expensive and offer low quality. NGSO constellations are a gamechanger, providing good quality, high speed broadband at more affordable prices. As an indication of the potential of the service, consider that Starlink in Australia, which launched in 2021, surpassed 200,000 customers in March 2024. Potential for growth in developing countries where fixed broadband rollout is limited is higher still.

   Benefits from satellite connectivity are disproportionately associated with peoples living in rural and remote areas where the costs of deploying terrestrial networks are prohibitive. For example, the Starlink service has been widely adopted by first nation communities in remote parts of Canada and the United States, such as the Pikangikum in Ontario, Navajo in New Mexico, and Hoh in Washington State, facilitating homeworking, and access to e-health, online education, entertainment and other services. And in Africa, institutions in Kenya and Mozambique have deployed Starlink terminals to deliver connectivity to schools, driving student engagement and attendance rates.

   In areas where there were pre-existing fixed connections, availability of broadband via an NGSO introduces platform competition. It intensifies pressure on legacy fixed broadband providers to upgrade to fiber, so as to differentiate their services. And satellite provides options for instant connectivity for locations not on connected roads and for solutions that travel with customers via portable terminals. NGSOs also provide resiliency in emergencies when terrestrial networks fail; for example, Starlink terminals have been deployed in diverse situations including flooding in Brazil, wildfires in Canada, hurricanes in the Caribbean, an earthquake in Japan, a tsunami in Tonga, and a severed underseas fiber cable in Madagascar.

   From an economic and social perspective, universal fixed broadband is highly desirable as it can integrate rural and remote regions into national economies and accelerate economic growth. NGSO networks have the potential to be turned on in every country, with limited requirements for incremental infrastructure. The main barriers to this happening quickly are regulatory restrictions and high spectrum fees, as these deter NGSOs from prioritizing a country and/or lead to higher user prices that limit take-up of services. Simple, modest fee levels that are either fixed or scale modestly with growth encourage market entry and expansion.

2. **The shared nature of the spectrum used by satellite operators.**

   Satellite bands from C-band upwards work on a shared-use basis by managing interference with each other (and other services). Compared to terrestrial mobile operators, satellite operators have a much greater ability to avoid interference owing to the angular separation between satellites in the sky and the higher frequencies used. This difference between terrestrial mobile and satellite operators has profound implications for their ideal pricing schemes.

   Terrestrial mobile operators require exclusive access to spectrum because two operators cannot use the same frequency, in the same location, at the same time. Therefore, when pricing spectrum to these services, the price paid by one operator must reflect the opportunity cost of denying access entirely to all other operators.

   In contrast, two or more satellite operators can use the same frequency, in the same location, at the same time—as long as they have enough angular separation. Therefore, spectrum prices should reflect that granting access to one operator does not preclude other operators' use of the spectrum. Instead, satellite spectrum pricing should account for the marginal congestion produced by each operator and incentivize spectrum efficiency.

   As the number of NGSO satellites, earth stations and user terminals grows, bands such as Ku and Ka are becoming busier, but they are still far from being congested. One reason why congestion has been avoided to date is that new systems are increasingly frequency agile, being programmed to detect nearby use and find clear channels and transmission paths. This also underscores the need for access to broader frequency ranges in these shared bands.

   Frequency agility (small, steerable beams and frequency hopping capabilities) promotes spectrum efficiency, and so should be encouraged. However, some regulators use pricing formulas that charge based on the potential total bandwidth accessed. This is problematic in a shared use band because such fee structures incentivize satellite operators to stick to narrower ranges of frequency, thereby reducing agility, making congestion more likely and decreasing the ability to avoid or react to interference. Fees structures that charge a fixed fee regardless of bandwidth or charge on the basis of maximum bandwidth used at any particular time are more consistent with incentivizing, designing and implementing efficient systems.

3. **Satellite operators are increasingly embracing higher frequency bands.**

   Satellite operators are being both pulled and pushed towards higher frequency bands. The pull is coming from the potential to increase capacity and throughput by accessing large blocks of bandwidth in higher bands and separating feeder and service links over the same transmission path. The push is coming from the hunger of the mobile industry for more spectrum, which has claimed parts of the C and Ka band, and expressed interest in parts of the Ku band. While the potential for further displacement of satellite spectrum above 10 GHz appears low given the tremendous growth of satellite services in recent years, reallocations for 5G mobile have constrained expansion opportunities for satellite in some traditional bands.

The expansion of satellite to higher frequency bands, when supported by market dynamics, should be welcomed be regulators. In general, higher bands are progressively emptier, and there is often little or no opportunity cost to their use. Expansion to these bands frees up space in busier bands, thereby allowing other satellite use to expand. This is another factor why congestion in the Ka band has been avoided to date.

Regulators often charge fees on a per frequency band basis. A problem with this approach is that if per band fees are set too high, satellite operators may be deterred from deploying in multiple bands and from shifting capacity to higher bands. This risk could be mitigated either by charging one fee across related bands or ensuring that fees for adding capacity in higher bands are sufficiently modest that they do not deter this type of expansion.

2. Spectrum pricing for satellite bands

The four industry trends we identified in the previous section are being driven by a combination of technology change and market demand. The challenge for regulators is to create regulatory and pricing structures that support rather than impede this evolution in how we communicate via satellites. In this section, we consider the toolset available to regulators to price satellite spectrum, and the potential conflicts between a regulator's objectives and satellite operator's commercial preferences over pricing. Drawing on this analysis, we present a series of recommendations for best practice in the application of pricing tools for the different satellite services and frequency bands.

2.1. Spectrum pricing toolset

There are two modes of allocation and pricing of spectrum for commercial users:

- **Administrative.** Access fees are set by the regulator, with spectrum allocated directly to users. Depending on the fee regime and type of service, a user may face more than one fee.
- **Market.** Spectrum is awarded by auction, with the price determined by competition between bidders. Subsequently, spectrum may be traded or leased between operators.

For market awards, the regulator still has a role in setting fees for primary awards. It sets the reserve price in an auction. It may also charge an annual administrative fee to cover its costs, and application fees to register new users, trades and some forms of network deployment.

The applicability of each mode to a frequency band depends on the nature of the services that use the band. Market mechanisms are applicable to bands where there is scarcity and this scarcity is managed by limiting the number of licensees, usually through exclusive licensing (e.g. mobile) or, more rarely, limiting the number of shared-use licensees. Administrative mechanisms are applicable whenever there is no scarcity, as is typically the case in shared-use coordinated bands, or for any primary award where the regulator declines to use an auction.

Where prices are set administratively, there are a number of approaches that could be adopted to set fees:

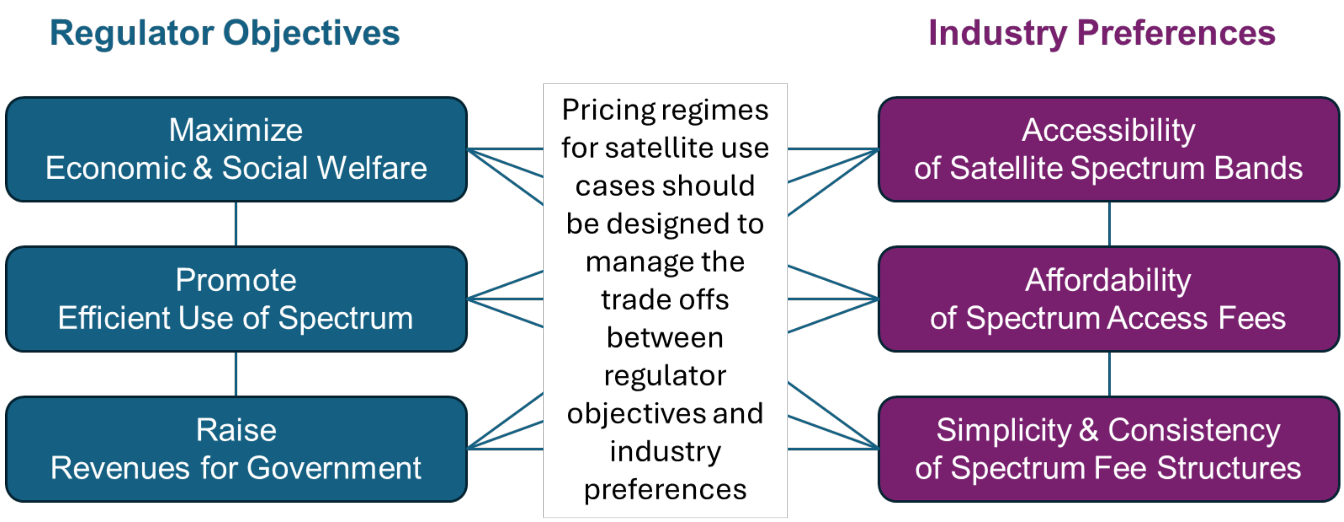
- **Nominal pricing** – Fees are set at a nominal level, sufficient only to maintain a register of users and deter non-serious applications.
- **Cost recovery** – Fees are linked to recovery of the regulator's spectrum management costs. This could be based on a detailed accounting of a regulator's costs (as in the United States) or – as may be more realistic for most countries – a rough approximation. For many services, where the regulatory management burden is low, cost recovery-based fees may in practice be indistinguishable from nominal levels. However, as broader spectrum management costs are common across services, there is flexibility here for regulators to cover a greater portion of costs from higher revenue services than lower revenue ones.

- **Incentive pricing** – Fees are linked to the opportunity cost of denying alternative uses from accessing the spectrum. In principle, this should be similar to the fee that would result from a hypothetical auction. Fees are typically calculated based on bespoke formulas tied to current and alternative usage parameters, and may be quite complex.
- **Premium pricing** – Fees are set at a higher level with the objective of raising money for the Government. Such fees may be based on an assessment of the licensees' ability to absorb costs without unduly deterring economic activity.

2.2. Regulator objectives and satellite operator preferences

When determining what pricing tool to apply to each satellite band and service, it is relevant to consider both the regulator's objectives and licensee technical requirements and preferences, and the trade-offs between them, as illustrated in Figure 6.

Figure 6: Managing the trade-offs between regulator objective and industry preferences



Source: NERA

All regulators should be mandated to maximize economic and social welfare, and promote the efficient use of spectrum. These two objectives are generally complementary, provided that efficiency is based on an analysis of the most cost-effective way of delivering services, and not just narrow technical efficiency. Regulators may also be expected to raise revenues, to cover their costs and potentially contribute to the State budget. Revenue raising is more problematic, as high spectrum fees can deter economic activity and lead to spectrum being used less intensively.

Satellite operators care primarily about the accessibility of frequency bands and the affordability of access fees. They have a secondary preference for simple, consistent fee structures that treat operators fairly across bands. Fees designed to promote economic & social welfare and encourage efficient use of spectrum should be broadly compatible with these preferences, although tensions may arise between operators with conflicting business models. Fees designed to raise revenues are more problematic, as depending on their level and structure, they may deter growth and inefficiently or unfairly favor some types of users over others.

2.3. Applying pricing tools to satellite services and bands

We now assess the applicability of these pricing tools to commercial satellite services in different bands. In developing our recommendations by service and band, we considered the following questions:

- *Does the service require exclusive use or can it use shared spectrum?*

  Exclusive use spectrum is typically sold by auction, with the price set by the market based on the opportunity cost of denying marginal users. Shared use spectrum is usually subject to administrative pricing because shared users may not impose opportunity cost on each other.

- *For shared bands, is the band congested or could it become congested in the future?*

  In bands with congestion, some degree of incentive pricing may be appropriate, to encourage marginal users to exit or migrate to other frequency bands that have more room. If bands are not currently congested but could become so in the future, then incentive pricing is not yet needed, but it may be appropriate to allocate a greater share of cost recovery pricing to pre-congestion bands than to bands with no anticipated contention so as to encourage migration to higher bands and head off future congestion.

- *For shared use satellite bands, are there alternative use cases incompatible with satellite spectrum that are being denied spectrum?*

  The identification of bands for use by satellite implies an opportunity cost which comes from the spectrum being denied to terrestrial use cases. In principle, there is a case for applying incentive pricing in bands where opportunity cost is higher, on the basis that higher prices will incentivize less efficient users to vacate the band. In practice, the shared use nature of most satellite bands makes them unsuitable for incentive pricing based on non-satellite use cases.

  There are several reasons why incentive pricing based on denial of non-satellite services is inappropriate:

  - In a shared use band, it is typically possible to add marginal capacity without causing harm to existing users. This adds value. However, increasing authorization fees would have the effect of pricing out marginal capacity. Unless there is an end goal of reducing or clearing a satellite band to make space for a higher value use, this is welfare destructive.

  - The frequencies used by satellites in each world region are designated at international level and the business case for commercial satellite services is based on having access to the same frequencies in multiple countries. This limits the scope for using pricing as a tool to drive change of use, as such change must be coordinated on an international regulatory basis.

  - Annual authorizations to use spectrum on a shared basis are inherently less valuable to an operator than exclusive use spectrum licenses, owing to the lack of scarcity and property rights. Even if an alternative use case were willing to pay more for the spectrum, that does not mean the associated services would offer more value to society. Any analogy to a hypothetical auction between competing use cases is inappropriate if willingness to pay is not reflective of social value.

  Notwithstanding these points, the potential to use the spectrum in other ways is still a relevant consideration when setting prices. When setting cost recovery prices, it is reasonable to weight prices towards bands that are more contended, on grounds of fairness across different services. For example, when setting fees for GSO earth stations in the Ku and Ka bands, Ofcom considers the hypothetical opportunity cost of the spectrum otherwise being used to deploy a terrestrial fixed link. This approach ensures a degree of consistency between pricing of satellite and fixed link spectrum access.

- *For services provided via shared use satellite spectrum, how strong is the business case for a particular service?*

  When considering how to distribute cost recovery based prices across different use cases and frequency bands, it is appropriate to consider the relative strength of the business cases. For example, satellite feeder links may be weighted similar to fixed links and higher than amateur use. Within satellite bands, it makes sense to weight more valuable low band frequencies above higher frequencies where deployment cases are more marginal.

Our recommendations are different for services in the Ku, Ka and higher bands, as these services use shared spectrum which is not currently congested. Accordingly, administrative pricing is appropriate. We generally recommend a cost recovery-based approach to setting fees.

Our specific recommendations for the Ku, Ka and higher satellite bands are as follows:

Ku band

The Ku band is a shared-use band that can support many users who are operating both service and feeder links. In many countries, it is increasingly busy but not congested, and there is still room for increases in the number of simultaneously active transmission paths, provided they are coordinated. Much of the current and projected increase in traffic will come from NGSOs providing ubiquitous broadband services, with high levels of adoption anticipated in areas without a quality fixed broadband service.

This structure is best served by an administrative fee regime based on cost recovery. This approach will result in modest but meaningful prices that in aggregate should cover the regulator's cost of managing the Ku band and make a broader contribution to the regulator's overall costs. Fees above this level are inappropriate because they may make the spectrum unaffordable for some satellite activity that could otherwise be accommodated, which would be contrary to the regulatory goals of raising welfare and encouraging efficient use of spectrum.

Notwithstanding this conclusion, it is foreseeable that with the growth in NGSOs, use of the Ku band in some locations could, in the medium-to-long term, become congested. At the point when this becomes a problem, either some incremental incentive pricing or market mechanisms could become relevant tools for rationing use of the band.

In the meantime, we recommend that regulators consider the flexibility inherent in cost recovery pricing to create gentle price incentives for marginal users to migrate activity to higher frequency bands. This can be achieved by setting somewhat higher prices and targeting a larger share of cost recovery from the Ku band than higher frequency satellite bands.

Legacy fees for Ku spectrum are often based around the traditional GEO business case, and some fee structures have many elements, such as bandwidth used, number of antennas, number of transmission paths and number of end-user terminals. Some regulations fail to distinguish between earth stations and consumer terminals. As illustrated in our examples in Section 3, such rules create a lot of complexity for NGSOs attempting to enter a new market, and in some cases may make entry or expansion commercially impossible. To avoid these problems, regulators should consider simplifying their fee structures and setting separate fees for NGSOs from GSOs.

On the service link side, incentives for entry and expansion can be best be achieved through:

- A modest but meaningful flat fee (“blanket license”) for provision of end-user services using the Ku band;
- Avoiding fees that scale unduly with activity, such as per terminal charges, as these deter growth and introduce unnecessary administrative burdens; and
- Avoiding fees that scale with the full range of bandwidth within the band that may be used over a cycle of operations (as opposed to maximum bandwidth used at any point in time), as this deters frequency agility and its contrary to promoting spectrum efficiency.

On the feeder link side, incentives for entry and expansion can be best be achieved through:

- Either a flat fee for deploying earth stations or modest fee per earth station, avoiding high fees that could deter adding stations; and
- Avoiding fees that scale with bandwidth, number of antennas or number of transmission paths, as these penalize NGSOs, discourage efficient use, and add complexity.

In a hypothetical future with more congestion where rationing became necessary, factors that may be associated with contention could become relevant when considering incentive pricing.

Ka band

The Ka band is a shared use band that is used for the same satellite services as the Ku band, but with a greater emphasis on feeder links. It is also increasingly busy but less intensively used than the Ku band. While it is conceivable that the band could eventually become congested in some locations in the long term, this point should be further in the future than for the Ku band.

Accordingly, the pricing structures proposed for the Ku band are also appropriate for the Ka band. Three refinements may be considered:

- It is appropriate to set fees for service access and for earth stations at a lower rate than the Ku band, so as to gently encourage migration of usage upwards, thereby pushing back the date when the Ku band may become congested. This difference can be achieved within the context of cost recovery pricing simply by attaching a lower price weight to the higher frequency range.
- An issue with levying a flat fee by band is that it may discourage operators from expanding services across multiple bands, even though this may increase efficient use of spectrum and ease congestion. This is relevant to NGSOs offering mass market broadband service who may improve capacity by separating service and feeder links. If fees are modest, this might be irrelevant, but otherwise the issue could be addressed by setting a single combined service fee for Ku and Ka bands, or offering a fee rebate to satellite operators that expand into both bands.
- Earth stations may use more than one frequency band. Charging an additional fee for adding the Ka band may deter this, which is undesirable. This could be addressed by charging a single fee per earth station, regardless of the number of bands being used, or charging a reduced fee for existing Ku users that add the Ka band.

As with the Ku band, these refinements are subject to the band remaining uncongested.

•Q, E, V and W band

The Q, E, V and W bands offer huge bandwidth but are currently much less used than the lower Ku and Ka bands, especially by terrestrial mobile and commercial satellite. The technology to use these bands is innovative but relatively expensive. There is no expectation that coordinated shared use by satellites will lead to congestion in the foreseeable future, especially given the tighter propagation characteristics of the spectrum, which facilitates sharing.

A key benefit of these bands is the potential for NGSOs to deploy huge bandwidths not possible at lower frequencies. It is therefore particularly important that regulators avoid fees based on bandwidth (such as per MHz or GHz used), as these may be prohibitively high and undermine the business case for using otherwise unused spectrum.

On both welfare and efficiency grounds, it makes sense for regulators to encourage satellite operators to use these bands for feeder links. Doing so could unleash higher capacity and ease or provide a remedy for congestion in lower bands. Given this upside, it would be appropriate to charge only nominal fees for deployment of feeder links in these bands, and only phase in cost recovery-based fees once the bands are more established. Alternatively, the bands may be included within a single earth station fee, so as to encourage satellite operators to add higher bands.

Our recommendations are summarized in Table 1.

Table 1: Applicability of pricing toolset to satellite services and spectrum bands

Service / band	Market	Nominal	Cost recovery	Incentive	Premium
Ku band	✗	Limited time to induce early NGSO entry	✓ (for GSO, and NGSO when established)	May be applicable in future	✗
Ka band	✗	Limited time to induce early NGSO entry	✓ (for GSO, and NGSO when established)	May be applicable in long term	✗
Q,E,V,W bands	✗	✓	May be applicable in long term	✗	✗

We do not recommend premium pricing for any band. Premium fees are inherently inappropriate in shared use bands: as the bands are generally not congested, premium fees would needlessly choke off marginal use cases, reducing welfare and spectrum efficiency as a result. If, in the future, these bands start to become congested, then incentive pricing is the appropriate tool to manage this.

If it is a government objective to raise additional revenues beyond those achieved with the recommended pricing tools, then this is best delivered through consideration of a simple low percentage tax on net service revenues. Such an approach provides equitable treatment across users and services and (provided the percentage fee is modest) should have the least negative impact on economic activity, as fees paid scale with commercial success. In contrast, if premium fees are linked to metrics associated with spectrum use or total customers, such as the number of earth stations, transmission paths, antennas, or user terminals, they may unreasonably discriminate against and deter specific types of service.

3. How to price the Ku and Ka bands

The Ku and Ka bands are currently the most important frequency ranges for NGSOs, being the primary bands used for fixed broadband service and feeder links. In this section, we report our findings from a broad survey of pricing rules adopted by spectrum regulators. We identify huge variation in the level, structure and complexity of fees associated with satellite use of the Ku and Ka bands. We highlight examples of effective fee setting, which has supported early NGSO entry and expansion, and also examples of bad practices that are preventing adoption of new satellite broadband services in specific countries. Finally, we consider what level of fee costs is appropriate for a generic NGSO service using the Ku and Ka bands. We observe that countries with the lowest spectrum fees have generally seen higher adoption rates of NGSO broadband connectivity.

3.1. Survey of approaches to pricing satellite use

There is huge variation across operators with respect to the level, structure and complexity of fees being applied to satellite operators in the Ku and Ka bands. Countries price spectrum using fixed fees and/or fees that scale proportional to the number of terminals, gateways, and the amount of authorized bandwidth. Some countries use all these types of fees, whereas others only use some. In some cases, the formulas are simple multiplications of a unit price and a quantity, and in others, the formulas consider complex calculations based on engineering parameters and/or socioeconomic variables. Many countries also charge a percentage of revenue, ranging from modest fractions of a percent to levels comparable to sales or value-added taxes.

We surveyed 23 countries across the Americas, Africa, Asia Pacific and Europe. We selected these countries to showcase the heterogeneity in pricing structures and levels in these regions. Table 2 lists the countries included in our survey and classifies them by foundational elements of their spectrum fees.

Specifically, we identify whether a regulator applies a fixed fee structure, and whether it sets fees by number of terminals, number of gateway earth stations or total bandwidth used.

- User terminal fees are typically straightforward unit fees per terminal or a blanket fee for unlimited terminals, but there are some countries that use volume discounts or fees that vary depending on the authorized bandwidth for user terminals.
- Gateway fees are generally structured as a unit price per MHz multiplied by the bandwidth authorized or as fixed fees per gateway but there are also examples of complex formulas that account for engineering and social variables.
- Bandwidth fees are also generally structured as a unit fee per MHz multiplied by the bandwidth authorized but do not normally increase when the number of user terminals or gateways increases.

We did not include revenue-based fees in our survey because these types of fees are analogous to consumption taxes and, hence, are independent of the cost of the spectrum.

Table 2: Main elements of fee structure for Ku and Ka bands in surveyed countries

Country	Fixed fee structures	User terminal fees	Gateway fees	Bandwidth fees
Australia	YES	NO	YES	YES
Bahamas	YES	YES	YES	YES
Barbados	YES	NO	NO	NO
Brazil	YES	YES	YES	NO
Chile	NO	NO	NO	NO
Colombia	NO	NO	YES	NO
Eswatini	YES		YES	NO
France	YES	0	YES	YES
Germany		0	YES	YES
Ghana	YES	0	YES	0
Haiti	0	0	0	0
Jamaica	0	0	0	0
Japan	YES	YES	YES	NO
Kenya	YES	NO	NO	NO
Mexico	NO	NO	NO	YES
Peru	YES	NO	YES	NO
Philippines	YES	NO	YES	NO
Qatar	NO	NO	YES	NO
Spain	NO	NO	NO	YES
Togo	YES	NO	NO	NO
United Kingdom	YES	NO	YES	NO
United States	YES	NO	YES	NO
Yemen	YES	YES	NO	NO

Our survey identified the following issues:

1. Only a few countries have updated their satellite pricing to take account of the network architecture and services associated with NGSOs.
2. Regulatory schemes designed for GSO networks are typically inappropriate to price large-scale NGSO constellations, and sometimes result in absurdly high notional fees. (We use the word 'notional' here because NGSOs simply will not launch services if fees are too high, but may look for workaround solutions, such as temporary fee exemptions).
3. There is no global consensus on pricing structures but countries that have updated their pricing structures to account for NGSOs are moving in the same direction.
4. Some countries use complex and ambiguous pricing structures that make it difficult for operators and regulators to agree on the fee levels.

We elaborate on each of these issues below.

NGSO specific pricing

In our survey, only the United States, the United Kingdom, and Ghana have pricing structures specifically designed for large NGSO constellations. The United States uses a blanket authorization and a modest fee per gateway. The authorization enables NGSO operators to use multiple frequencies irrespective of the number of user terminals. The UK currently charges NGSO operators based on the number of earth stations (currently GBP 500 per station). Ghana uses a structure similar to the United States, with a blanket authorization and a fee per gateway. Outside of our survey, we note that El Salvador has exempted NGSOs from spectrum fees for providing broadband services to the public.[2]

The remaining countries have pricing structures that do not properly reflect the development of NGSO services. Some countries, like Spain or Colombia, use 'all-purpose' pricing formulas that attempt to capture some inherent spectrum value. We find that this approach is generally ineffective in producing prices aligned with economic incentives as markets and technologies evolve much faster than formulas. Some other countries, notably Barbados and Eswatini, use pricing structures that capture different types of services e.g., VSAT, GPS, paging, etc. We find that this approach is becoming obsolete owing to changes in technology and market structure: it is typically not obvious how to categorize NGSOs under such formulas and resulting fee levels may be much too high to allow NGSOs to profitably pursue providing broadband connectivity to the unserved.

Inappropriate pricing for large-scale NGSO constellations

Many countries use pricing structures that scale with the network; for example, prices per MHz used, per user terminal, or per gateway. In some countries, these unit prices produce very different spectrum costs for GSO and NGSO operators owing to their differences in service, scale and business models. Most GSO operators require only a handful of gateways and user terminals to operate, whereas an NGSO offering residential broadband across multiple countries may deploy millions of terminals and require hundreds of gateways. For example, in the United States, a GSO operator may have around 10 gateways and 100,000 user terminals, whereas Starlink is targeting 100 gateways and several million user terminals.

Pricing levels for NGSO spectrum use range from justifiable to egregious depending on the country's approach to pricing. In theory, some level of price difference between GSO and NGSO may be economically justified in a situation where prices reflect opportunity cost (e.g. based on incentive pricing). In practice, the Ku and Ka bands are not congested, so incentive pricing is not (as yet) applicable. Price differences may be fair policy in countries using cost recovery, with gentle price differences promoting incentives to migrate traffic to higher frequencies that have lower fees. And they may be egregious in countries using premium pricing. In our survey, the largest differences in NGSO and GSO pricing arise in countries with premium pricing in terminal fees, followed by gateways.

[2] https://www.elsalvador.com/noticias/nacional/asamblea-legislativa-tarifas-de-internet/976876/2022/

Inconsistent structures and lack of consensus

Every country in our survey, albeit to varying extents, uses a different approach to pricing satellite spectrum. This situation may be contrasted with the mobile spectrum where there is a significant consensus on using spectrum auctions to price access. Structures vary from blanket authorizations to complex formulas accounting for usage and power. For example, the United States uses a blanket authorization and a modest fee per gateway, and Spain uses a formula based on the area covered, authorized bandwidth, the level of congestion, the type of service, the frequency used, the type of equipment, and the social value of the spectrum.

Each fee structure imposes different marginal costs on the expansion of a satellite network along some dimension. Economic principles tell us that to maximize social value generated from spectrum use, the marginal price imposed by the fee formula must be set at the level that balances the marginal social benefits and costs of using the spectrum. Fees that are too high will reduce the number of people who can enjoy satellite broadband services and increase the costs for those who have access. Fees that are too low will increase spectral congestion and reduce throughput for those connected. Given that there is no evidence of spectrum congestion or general throughput degradation, fees beyond cost-recovery are likely too high and reducing the benefits of NGSO services.

The four main types of fee structures impact users in different ways:

- **Fixed fee structures.** Fixed fees impose no marginal cost on network expansion. However, they can affect entry/exit decisions. Once paid, these fees represent sunk costs for companies and therefore do not affect economic decisions regarding network size – including user terminals, gateways, and bandwidth. Countries should favor these types of fees to accomplish their cost-recovery or premium pricing policies as entry / exit decisions are likely to be less elastic to price than network expansion. However, countries opting for premium pricing policies should consider the risk that overly high fees may deter entry and thus limit competition in downstream markets.
- **User terminal fees.** Fees based on the number of active user terminals directly increase the cost of service adoption. The marginal cost to society associated with the introduction of a new user terminal is minimal. Where terminal fees are applied, they are generally set way above this cost, so such fees act as a direct barrier to adoption.
- **Gateway fees.** Fees based on the number of gateway earth stations in a country directly increase the cost of service expansion. Gateways are necessary components to route traffic from user terminals to the internet. Introducing a new gateway has low marginal cost for a regulator, and adding a gateway typically will only modestly increase spectral congestion and coordination complexity in its surrounding area. Fees that reflect the costs of adding congestion and coordination can incentivize the appropriate location of gateways, whereas fees that deviate from these principles will distort their number and placement to the detriment of the service provided to consumers. Gateway fees also play a role in attracting investment relative to neighboring countries. In some circumstances, NGSOs have the ability to serve users in one country with gateways located in another country, creating missed investment and employment opportunities in those countries with unduly high fees.

- **Bandwidth fees.** These fees increase the cost of providing marginal Mbps of capacity to ease network congestion at time of peak use. High fees will deter operators from using additional bandwidth, reducing the network capacity. In principle, such fees might reasonably reflect the marginal cost of spectral congestion. In practice, as the Ku and Ka bands are not congested, bandwidth prices that exceed marginal costs deter efficient use of spectrum and negatively impact system capacity for consumers.

The heterogeneity in pricing structures and resulting differences in price levels is particularly unhelpful for NGSOs because of their global scale. Heterogenous pricing structures introduce incentives for NGSO operators to divert gateway investment and service to neighboring countries with comparatively lower prices. Similar to spectrum harmonization, greater harmonization in the pricing approach for spectrum access would encourage NGSO operators to position gateways in the most efficient locations rather than the cheapest ones, thereby maximizing satellite and spectrum utilization to increase social welfare.

Despite the heterogeneity, the three countries with specialized NGSO pricing in our survey (the US, the UK and Ghana) have moved in the same direction: blanket user terminal pricing, modest gateway fees, and opportunity cost bandwidth pricing (cost recovery where there is no congestion and incentive pricing where there is congestion).

Complexity and ambiguity

Complexity increases the administrative costs for both regulators and operators. Formulas that include individualized engineering and economic parameters are the most onerous as they involve the exchange of large and complex datasets, which may require specialized personnel on both sides. Formulas should be as simple as possible to achieve the regulator's goals. For example, consider gateway fees. In principle, a perfect price for a new gateway would reflect the marginal social cost associated with the congestion and coordination it imposes on other operators, plus the marginal administrative fees imposed on the regulator. In practice, calculating an individualized fee in this way is impractical as the costs of undertaking the engineering and economic analysis to calculate the fee would likely far surpass the benefits of accurately reflecting these costs.

In some countries, satellite spectrum fees depend on a multitude of parameters, including technical and socioeconomic inputs. In some instances, when the regulation is clear, evaluating the formula is a relatively straightforward exercise. This is the case in Spain. However, in some other instances, there is ambiguity with respect to the formula or its inputs. For example, in the Philippines, there are two variations of the formula used to calculate earth station fees, thereby creating uncertainty regarding the correct level of fees required for a gateway. In Colombia, the formula depends on the specific engineering parameters of each antenna in a gateway, increasing the level of involvement required by the regulator and the operator to determine the correct fees.

3.2. Examples of good and bad practice

In this section, we highlight some of the best and worst practices in satellite spectrum pricing, based on research we did in Summer 2024. The case studies show that satellite pricing requires effective policies in all three pricing dimensions:

- the level of fees directly impacts the entry/exit decision of NGSO operators;
- the structure of fees impacts the reach of the network and services; and
- the complexity of the fee formula affects the cost of doing business.

While it is desirable to get all three elements right, it is the level of fees that matters most, followed by structure and complexity. NGSOs can work through complex structures and adjust their networks in response to the fees so long as the overall level allows entry and continued operation.

We present our examples by region – with one good and one bad example per region. For each country, we present (top right of the relevant box) the cost of spectrum in purchasing power parity (PPP) dollars per person.

Americas

The Americas shows tremendous heterogeneity in pricing structures, ranging from the United States' NGSO-specific pricing structure to complex, expensive formulas in many South American countries. We highlight the United States and Mexico. The United States has one of the most attractive pricing structures for NGSOs based on our three categories, whereas the Mexico case demonstrates that a sensible structure is not enough to foster connectivity if the overall fee level is too high.

United States: Blanket licenses with modest gateway fees ***¢2.7 per pop***

The United States uses a cost-recovery framework to assess its regulatory fees, including fees for satellite spectrum. Currently, the administrative cost of managing space-related costs is distributed 60% to GSO systems and 40% to NGSOs. The allocation within GSOs is by satellite, and the allocation among NGSOs is by system – except for those with 20 or fewer satellites, which use a different category. The FCC charges the same fees to operators licensed in the United States and those licensed elsewhere.

In 2024, the share of the administrative cost recovered for each NGSO system is $964,200, and the share for each GSO satellite is $144,155. These fees increased from $347,755 and $117,580, respectively, in 2023, owing to the higher number of applications and proceedings related to satellite management in recent years. Each earth station has a flat cost of $2,610. These fees translate to a modest 3 cents per pop given the large size of the US market.

The United States uses a fee structure (cost recovery) and relative level (3 cents per pop) that we have identified as ideal for NGSO systems. Its fees recover the cost of managing the spectrum without limiting the number of NGSO systems that can enter the market. This price structure has facilitated the application of 2,835 NGSO systems between 2012 and 2022.

Mexico: High legacy prices set in law by Congress ***¢167.2 per pop***

Mexico codifies its spectrum fees in its federal law. Each year, the Ministry of Finance prepares a budget that includes these fees, which is voted on in Congress. This process has produced very high spectrum prices in most frequency bands and for most types of services. In recent years, the IFT, Mexico's independent telecommunications regulator, has actively lobbied Congress to consider reductions in some spectrum fees, but change is yet to come.

Mexican law uses a simple pricing structure: access to the Ku band requires a 214.47 MXN daily fee per MHz, and there is no codified fee for the Ka band. There are modest system and gateway fees. This structure is reasonably aligned to best practices; however, the fee level – which is more than 10X the equivalent per person charge in the United States – is much too high. The high fees are passed on to consumers, resulting in services being more expensive than countries with lower prices. This reduces consumer take-up and discourages NGSOs from marketing and promoting services to consumers.

Europe

Europe contains many examples of sensible levels of spectrum pricing but also some examples of legacy structures that deter NGSO entry and expansion. We discuss here the cases of the United Kingdom and Spain. The United Kingdom has been a leader in NGSO pricing, introducing an initial low fee for NGSOs to incentivize entry. In contrast, Spain provides an example of rigid. legacy pricing structures that inadvertently distort deployment incentives for NGSOs.

The United Kingdom: Modest blanket licenses and gateway fees ***¢0.3 per pop***

Ofcom moved quickly to incentivize NGSO operations in the United Kingdom. In 2021, Ofcom published statements setting out their approach to licensing NGSO systems in the Ka and Ku bands. In 2023, Ofcom added further details on license conditions to install and operate earth stations. Ofcom currently charges GBP 500 per year for each gateway and 200 pounds per year for each system. These fees have been set on a cost-recovery basis and provide access to portions of both the Ku and Ka bands.

With NGSO use now becoming established in the United Kingdom, Ofcom has indicated that it may transition to a form of administrative incentive pricing in the future. This could involve increasing the gateway fees to levels equivalent to prices charged for fixed links in equivalent frequencies, but the price will still be at a level consistent with cost recovery.

Spain: High fees set by law ***¢21.8 per pop***

Spain codifies its spectrum fees in its yearly budget using a general formula applicable to all bands and services. The formula considers the area covered, authorized bandwidth, the level of congestion, the type of service, the frequency used, the type of equipment, and the social value of the spectrum – with specific values for satellite services in the Ka and Ku bands.

In principle, the formula-based approach could be reasonable if the parameters used to calibrate the formula were set to represent cost recovery or incentive pricing. However, we observe that Spain uses premium pricing – making it one of Europe's most expensive spectrum fees, many times more expensive than those in countries like the United Kingdom or Germany. This has discouraged NGSO entry and expansion.

We note that Spain establishes its spectrum pricing at the level of law, creating a complex legislative process to update the formula.

Africa

Many countries in Africa charge high, revenue-based fees (ranging from 0.4 to 5 percent) in addition to spectrum-specific charges. We highlight two extreme cases in level and structure: Kenya and Eswatini. Kenya uses a mostly flat spectrum structure and a 0.4% revenue fee that produces reasonable prices in line with worldwide leaders. Eswatini uses gateways and terminal fees tied to uplink bandwidths that produce extremely high prices.

Kenya: Reasonable fees with simplified formula ***¢1.1 per pop***

Kenya uses a fee structure centered around services, such as aeronautical, fixed, mobile, and satellite. For satellite services, the fee is based on a simple unit price per bandwidth factor. The bandwidth factor is capped at eight for services using 10 MHz or more, which means that the maximum payment is eight times the unit price. This structure recognizes the minimal marginal cost of the shared large bandwidths used by satellite services. In addition, Kenya charges application fees for 15-year operational licenses.

Eswatini: High fees for gateways and terminals ***$16,787 dollars per pop***

Eswatini uses simple formulas for gateways and terminals based on a unit price per uplink MHz used. The unit price is around 120 dollars per MHz and applies to both gateways and terminals. This formula produces unreasonably high prices when applied to the large bandwidths used in satellite services and risks deterring most NGSOs from entering the market due to exorbitant upfront cost.

Asia-Pacific

Countries in the Asia-Pacific region use a wide combination of fee structures and revenue-based fees. We highlight two countries that use formulas to determine spectrum fees with drastically different results: Australia and the Philippines. Australia uses a complex formula that attempts to account for spectrum congestion using modest fees. The Philippines uses a very simple formula that produces very high prices.

Australia: Reasonable fees but complex formula ***¢8.2 per pop***

Australia uses a complex fee system, including fees for space and space receive licenses, bandwidth fees, and gateway fees. The gateway fees use different formulas for the uplink and downlink spectrum. Uplink spectrum is charged based on a price per MHz-Pop with respect to the population in the area where the earth station is located. Downlink is charged based on a price per kHz depending on the region's general population density.

While the formulas are complex, the pricing structure is reasonable with respect to economic principles, the fees are generally in the same vicinity as those countries using cost recovery, there is no marginal cost of adding terminals, and the marginal cost of adding earth stations is reasonable. While the formula is burdensome for NGSOs, ultimately the modest fee level has been the more important factor, with Australia seeing significant growth in take-up of NGSO services.

Philippines: Ambiguous regulations with high gateway fees ***¢459.6 per pop***

Spectrum fees in the Philippines are established in a regulation originally enacted in 1997. This regulation assessed fees using a relatively simple structure for gateways based on a unit rate and bandwidth in kHz. In addition, the NTC's Citizen's Charter adds the number of channels to the above formula. The unit price is around 30 dollars per MHz-channel, which represents a prohibitively expensive fee per earth station when considering that the typical NGSO gateway uses 500 GHz and dozens of channels. We find that the fee level in the Philippines is not aligned with the best principles of spectrum pricing, and is a barrier to NGSO entry.

3.3. Indicative prices

Given the heterogeneity of fee structures used by different countries, it is challenging to compare the actual prices being charged to satellite operators for use of the Ku and Ka bands. We address this by defining an illustrative NGSO network providing fixed broadband services to the public, and calculating the fees that would apply in each of our survey countries.

Specifically, we assume a large-constellation NGSO operator with the following profile:

- Access on a shared basis to 2,500 MHz of spectrum in the Ku band for terminals and 2,000 MHz of spectrum in the Ka band for gateways;

- 67% of the terminal bandwidth for downlink and 33% for uplink at the user terminals, and the reverse percentages for gateways;
- A penetration of 1.5% of each country's total households and an appropriate number of gateways to support the traffic associated with this user base. We assume that each gateway has a capacity of 20 Gbps. For reference, these assumptions imply about 2 million user terminals and 100 gateways in the USA and about 400,000 terminals and 20 gateways in the United Kingdom. For comparison purposes, Starlink currently has about 1.7 million users and plans to install 99 gateways in the USA.

We measure the net present value (NPV) of the cost of the spectrum over a 20-year period to account for the differences in payment structures over time. This addresses the fact that some countries have application fees, whereas others only have annual fees. We present costs on a per pop basis, in US cents per person. (We do not divide by the MHz used as would be done for exclusive use mobile spectrum, owing to the shared nature of the satellite bands.) We present our results in US dollars converted at Purchasing Power Parity (PPP) exchange rates to account for economic differences between countries.

For reference, Figure 7 presents the conversion between the 20-year NPV of spectrum fees on a per pop basis and annual fees per million population.

Figure 7: Conversion between NPV of spectrum fees on a per pop basis and annual fees per million population

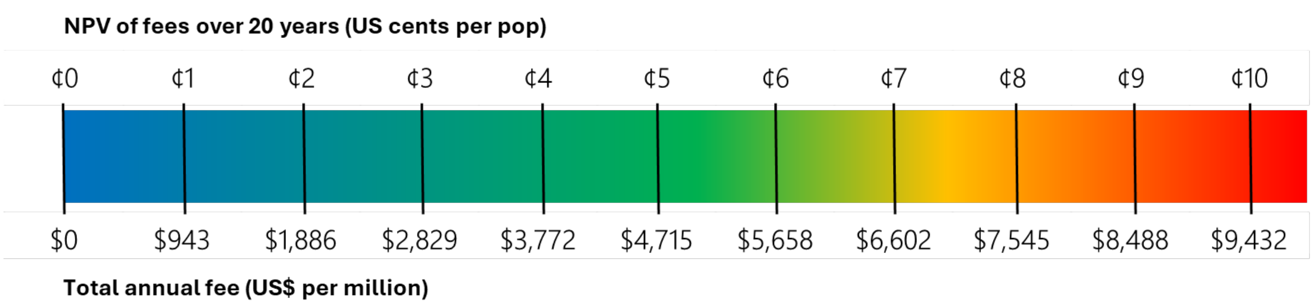
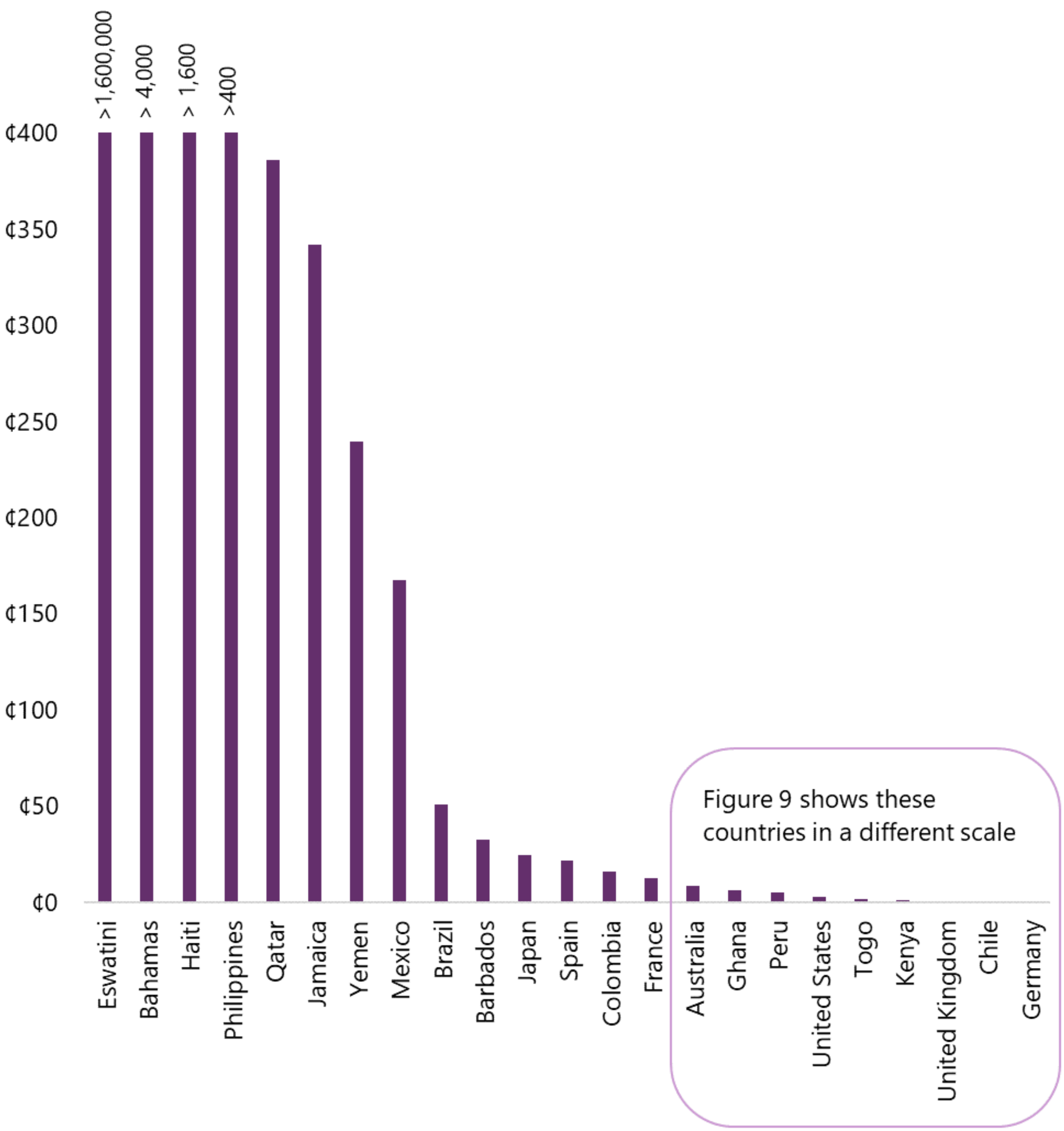


Figure 8 shows our estimation of costs for each surveyed country. The range of fees is extraordinary. In fact, the range is so wide that it is necessary to show a separate Figure 9 to illustrate variations between countries at the lower end of the scale – which still shows differences of two orders of magnitude. The extreme variation in prices is almost entirely driven by the regulatory approach to satellite pricing rather than the social and economic characteristics of the country or the scarcity/congestion of the spectrum. The fee levels in some countries are effectively prohibitive – deterring investment and service in the country.

We observe that countries with blanket authorization and/or modest per-unit fees have produced prices that have incentivized investment and service — for example, Germany, the United Kingdom, and the United States. As a reference, Starlink has about 1.7 million users in the United States, 96,000 in the UK, and 260,000 in Australia. In Kenya, Starlink captured 0.5% of the country's internet market in its first year of operating, reaching over 8,000 customers as of October 2024.[3]

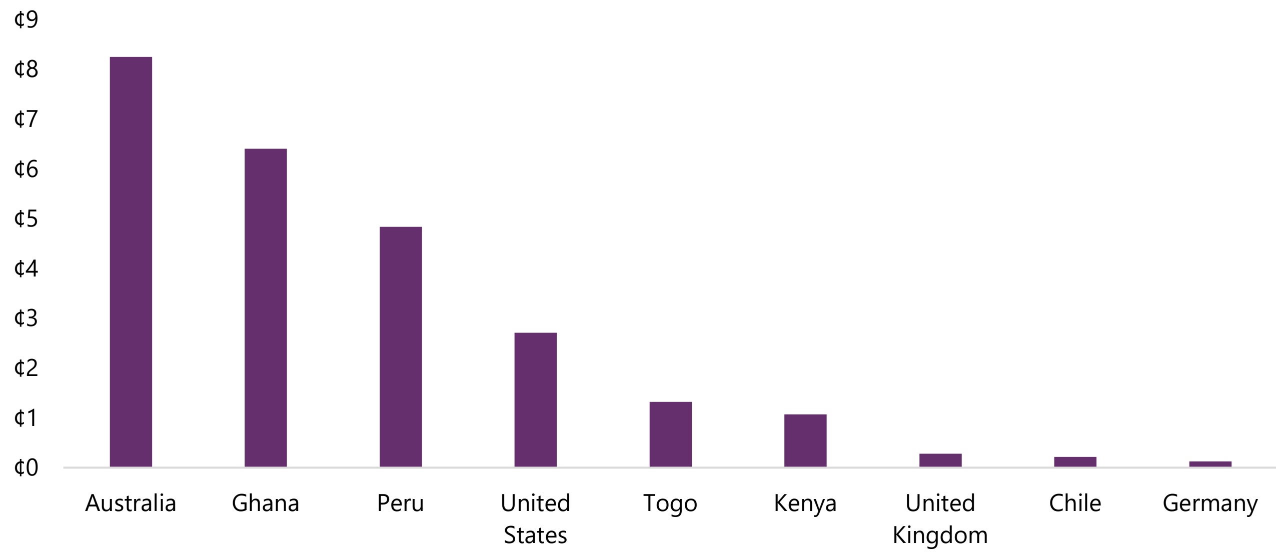
In contrast, countries with user terminal fees tend to produce the most prohibitive prices, followed by those with high unit prices for bandwidth. For example, Eswatini and the Bahamas both charge user terminal fees that have impeded service adoption.

Figure 8: Satellite spectrum costs in surveyed countries (USD PPP cents per pop)



3 Business Daily Africa, 14 October 2024, Starlink gains 0.5pc of Kenya's internet market in first year.

Figure 9: Satellite spectrum costs for countries with costs below 10 cents/pop (USD PPP cents per pop)



This survey has highlighted that many countries have fee structures that impose unreasonably high fees for spectrum access on NGSOs. In our opinion, a best practice approach is to set fee charges for spectrum access that are reflective of the cost of spectrum management, not revenue targets. If a government desires to raise additional revenues tied to a service, it should use transparent consumption taxes based on a low % of revenues, not impose excessive fees for access to shared spectrum.

Countries that have enjoyed early entry and growth in NGSO provision of mass market broadband services are generally those countries that charge modest overall fees. Notably, based on our generic NGSO profile, the countries in Figure 9 - which are charging fees with a 20-year NPV below 10 cents/pop (roughly below $10,000 per million population per annum) for combined service link and gateway fees - have generally enjoyed greater NGSO growth than the countries that only feature in Figure 8 – which appear to be engaging in revenue-driven pricing. We further observe that pricing structures that result in fees up to around US 3c per pop (PPP) have been particularly effective in enabling NGSO operators to grow services.

On this basis, we recommend that aggregate spectrum fees for a 'typical NGSO' deploying service and gateways should not exceed US$10,000 per annum or a 20-year NPV of US 10c per pop (PPP), and ideally should be set even lower.

4. Recommendations for NGSO spectrum pricing

There is both significant variation in pricing approaches towards NGSOs and staggering heterogeneity in price levels. This lack of harmonization is impeding the growth of the satellite industry because most countries have pricing regimes that are disconnected from the economics of NGSO operations.

A general problem is that many countries have rigid formulas and/or price levels and have not adapted quickly enough to the new services and technologies used by NGSO providers. Those countries that have recognized that NGSO constellations are different from GSOs and have adopted new fee structures – such the United Kingdom and the United States – have become leaders in NGSO development and service adoption. Even in countries like Australia—where fee formulas remain complex—overall modest fee levels have facilitated NGSO growth.

Fees for NGSO spectrum use should be set administratively—and ideally be based on a nominal or cost-recovery pricing approach—because they use shared use bands where scarcity is not a current concern. Market mechanisms are neither applicable nor appropriate for shared spectrum, discourage efficient spectrum, and further impose significant burden on regulators to define a fee structure and set fees at a level that promotes NGSO entry and growth.

Based on the evidence presented in this report regarding economic principles and our survey of international practice, we have developed a number of recommendations for how spectrum fees for NGSOs should be set. These are set out in Figure 10.

In summary, we recommend that regulators adopt simple fee structures, with low fixed fees for NGSOs operating both service links and gateway feeder links. Fees for spectrum should reflect costs of spectrum management, not revenue targets. Some variation in fees to discourage congestion in lower satellite bands and gently incentivize migration of traffic to higher bands may promote long-term efficient use of the spectrum. But the formulas to create variation in fees should not be complex and should avoid requiring regulators and operators to collate burdensome technical information.

Figure 10: Summary of recommendations for setting spectrum access fees for NGSOs

Service Link Fees

- **Adopt a uniform fixed fee for unlimited number of service links** to maximize incentives for NGSOs to grow and service deprived communities
- **Avoid fees that scale with bandwidth** as these discourage efficient use of wide bandwidths where spectrum is not congested
- **Avoid fee structures that scale unduly with the number of user terminals** as these deter operators from adding subscribers
- **Avoid duplicate fees for deploying in higher bands**, as these deter operators from deployment decisions that prevent future congestion in the Ku band

Gateway (Feeder Link) Fees

- Adopting **a low fixed fee for single or multiple gateways** based on cost recovery pricing principles should be the default approach
- **An additional fee may be applicable where local congestion is a concern**
- **Avoid complex fee structures** that put a high burden on NGSOs to supply and update information on technical parameters, such as number of antennas
- Set a **low nominal fee for access to Q, E, V and W bands** to gently encourage adoption of these lesser utilized bands, which will become more important as more satellite services expand

Overall fee level for NGSOs

- **Fee charges for spectrum access** should **reflect cost of spectrum management**, not revenue targets
- If a government desires to raise additional revenues tied to a service, it should use transparent consumption taxes based on a low % of net revenues
- **Aggregate spectrum fees** for deploying service and gateways should ideally **not exceed** a 20-year NPV of **US 10c per pop**
- Pricing structures that result in **fees up to around US 3c per pop** have been particularly effective in enabling NGSO operators to grow services

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