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Pricing of Satellite Complementary Ground Component

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1 Introduction

In 2009 the European Commission (EC) granted each of two operators, Inmarsat Mobile Ventures (Inmarsat) and Solaris Mobile Limited (since acquired by EchoStar), a pan-European authorisation to provide mobile satellite services (MSS) using spectrum in the 2 GHz band. As part of its decision, the EC set out that the operators should have the option of building a complementary ground component (CGC) alongside the satellite component using the same frequencies. Whilst the MSS authorisation was issued on a pan-European basis, Member States are required to issue and regulate CGC authorisations nationally (within certain bounds imposed by the EC).

The Commission for Communications Regulation (ComReg) in Ireland is currently considering its regulatory approach to granting a Complementary Ground Component authorisation to Inmarsat and/or EchoStar. Although ComReg consulted on this matter previously in 2009[1], delays to the roll-out of services means that no CGC authorisations have yet been granted in Ireland. With both operators now expecting to launch a satellite within the next year, and given the length of time elapsed since the previous consultation, it is considered appropriate to re-evaluate the approach and begin a new consultation process on the structure of a CGC authorisation.

As part of this process, ComReg is seeking to establish a suitable fee structure to be charged for operating a CGC network in Ireland. DotEcon has been commissioned by ComReg to provide advice and recommendations on the fees to be charged, taking into consideration ComReg's statutory obligations and preferences that the proposed fees or fee range should be:

- an annual fee for each individual base station installed;
- designed to encourage the efficient use of the radio spectrum;
- developed taking account of the current use of similar frequencies; and
- reflective of the likely opportunity cost of the relevant bands.

In this report we set out our considerations and approach to forming recommendations on a suitable fee structure, and present the results of our analysis and our recommendations.

[1] ComReg Document 09/96

1.1 Licensing of mobile satellite services

On 14 February 2007, the EC adopted Decision 2007/98/EC (the '2007 Decision'), designating the use of radio spectrum in the 1980 – 2010 MHz (Earth to space) and 2170 - 2200 MHz (space to Earth) frequency bands for the provision of mobile satellite services (MSS) on a pan-European level. The 2007 Decision defines mobile satellite services as "*systems capable of providing radiocommunications services between a mobile earth station and one or more space stations, or between mobile earth stations by means of one or more space stations, or between a mobile earth station and one or more complementary ground based stations used at fixed locations*"[2].

MSS systems may be used for a variety of telecommunications and broadcasting/multicasting services such as high-speed internet, mobile TV or public protection and disaster relief, and may help to improve rural broadband coverage within the EU.[3] The 2007 Decision sets out that MSS systems could include a complementary ground component (CGC), used to improve the availability and quality of the satellite services, discussed further below.

Following the 2007 Decision, the EC published Decision 626/2008/EC (the '2008 Decision'), setting out its plans for running a comparative selection process for choosing two operators authorised to launch mobile satellite systems on a pan-European level. In 2009 it published the results of the selection process in Decision 2009/449/EC (the '2009 Decision'), appointing Inmarsat Mobile Ventures (Inmarsat) and Solaris Mobile Limited (Solaris) as eligible applicants[4]. The two operators were each authorised to use 2x15 MHz of the 2 GHz spectrum for the provision of mobile satellite services. In particular

- Inmarsat was assigned the frequencies 1980-1995 MHz paired with 2170 – 2185 MHz; and
- Solaris was authorised to use the frequencies 1995 – 2010 MHz paired with 2185 – 2200 MHz.

Member States were subsequently required to ensure the two operators are able to use the frequencies assigned for operating a MSS (with CGC) in their respective countries. The MSS

[2] Decision 2007/98/EC

[3] https://ec.europa.eu/digital-single-market/en/going-mobile-satellite-services

[4] The EC determined that the two other applicants, ICO Satellite Limited and TerreStar Europe Limited, did not demonstrate the required level of technical and commercial development of their respective mobile satellite systems. They were therefore not considered eligible applicants.

authorisations may be rescinded at the national level, but only where one or both of the operators were to breach the terms and conditions set out in the EC Decisions.

The EU-wide MSS authorisations of Solaris and Inmarsat run for a period of 18 years from the selection decision (expiring in May 2027, and are subject to various pan-European and national coverage obligations:

- the proposed mobile satellite system shall cover a service area of at least 60% of the total geographical area of the Member States, from the time the provision of MSS commences;
- MSS shall be available in all Member States, and to at least 50% of the population over at least 60% of the total geographical area of each Member State by the time stipulated by the applicant, but in any event no later than seven years from the date of publication of the decision adopted by the Commission.

The 2008 Decision also sets out of obligations for the selected operators to meet a number of milestones, culminating in "*effectively providing the continuous commercial MSS within the territories of the Member States*" within 24 months of the selection decision. These milestones were not met by either operator; Solaris suffered a setback when its satellite suffered an anomaly that meant the S-band payload was significantly lower power than expected and unable to provide the required level of coverage, whilst Inmarsat did not launch a satellite before the deadline.

Solaris has since (in January 2014) been acquired by EchoStar, a global provider of satellite and video delivery solutions. Solaris Mobile Limited was renamed EchoStar Mobile Limited (EchoStar) in March 2015.

Following enforcement action taken by several Member States, the EC reset the timetable, giving the operators a new deadline for the launch or in-orbit manoeuvring of satellites by 1st December 2016. EchoStar is due to launch its (second) satellite in December 2016, although has stated it requires at least two months for in-orbit verifications of the satellite before commercial services can start. Inmarsat is expecting to launch its satellite by mid-2017, citing delays in establishing a launch date with launch provider SpaceX as the reason for missing the deadline; it announced in December 2016 that it would instead entrust the launch to Arianespace.

1.2 Complementary ground component

The MSS operators may deploy a complementary ground component (CGC) alongside the satellite system. This is a terrestrial

network of ground-based transmitters operating on the same frequencies as the MSS, which can be used, for example, to:

- ensure quality of service in areas where communication with the space station(s) cannot always be guaranteed (i.e. where satellite signals may be shadowed);
- provide additional capacity in traffic hotspots; or
- provide temporary coverage in disaster areas.

Despite the fact that the MSS component has been authorised at the European level, the task of authorising or otherwise licensing CGCs falls to national regulatory authorities such as ComReg within their respective jurisdictions. National authorisations to operate a CGC are, however, subject to a number of conditions, as set out in the 2008 Decision:

- "*operators shall use the assigned radio spectrum for the provision of complementary ground components of mobile satellite systems;*
- *complementary ground components shall constitute an integral part of a mobile satellite system and shall be controlled by the satellite resource and network management mechanism; they shall use the same direction of transmission and the same portions of frequency bands as the associated satellite components and shall not increase the spectrum requirement of the associated mobile satellite system;*
- *independent operation of complementary ground components in case of failure of the satellite component of the associated mobile satellite system shall not exceed 18 months;*
- *rights of use and authorisations shall be granted for a period of time ending no later than the expiry of the authorisation of the associated mobile satellite system*."[5]

Whilst Member States are required under the EC Decisions to provide the selected MSS operators with a national authorisation to deploy a CGC, there is no obligation on MSS operators to seek such an authorisation; where feasible, the coverage conditions linked to the MSS authorisation may be met using the satellite component only. This is relevant to the setting of CGC fees, as there may be a trade-off between setting fees at a sufficiently high level to reflect the long-run opportunity cost of alternative spectrum users and

[5] Decision No 626/2008/EC of the European Parliament and of the Council of 30 June 2008 on the selection and authorisation of systems providing mobile satellite services (MSS)

reducing incentives for efficient roll-out of services based on the CGC in the shorter term.[6]

MSS with CGC appears to have a range of potential applications. As well as offering options for standard mobile services (e.g. in areas not reached by terrestrial mobile networks, or for extra capacity in traffic hotspots), ideas for more innovative uses are beginning to emerge, such as provision of rural backhaul for the Internet of Things (IoT)[7]. Inmarsat intends to use hybrid satellite-terrestrial technology to create a European Aviation Network (EAN), providing in-flight connectivity to passengers on commercial airplanes across Europe, and there is potential for further unanticipated applications in the future. It is unclear how much incremental revenue such services might generate, but it is possible that they could contribute significant social value.

1.3 ComReg's previous consultation

ComReg previously consulted in 2009 on the appropriate regulatory approach to facilitating the development and deployment of MSS with CGC in Ireland.[8] That consultation focused primarily on technical issues and requirements, setting out the procedures for monitoring and enforcing coverage, as well as ensuring that there would be no interference with other frequency bands.

As part of that consultation process, ComReg used existing licence fees for 3G, GSM and Mobile TV services in Ireland to establish a proposed fee in the range of €1M to €2M per annum for an 18 year MSS with CGC licence. ComReg considered that "*any fees charged in relation to the MSS with CGC system could be adjusted on a pro-rata basis in proportion to the percentage coverage of the State*".

However, this consultation, including the proposed CGC fees, has been overtaken by the failure of the operators to meet the original

[6] This tension arises because of the approach taken to pan-EU licensing by the EU. In particular, the EC has not levied an opportunity-cost based charge on the MSS component, despite there being a good argument that this would have promoted efficient use of spectrum in the long-run. This leaves NRAs with the difficulty that although a charge at a similar level could be levied on the CGC so that a MSS licensee using the CGC would pay an efficient and fair amount for access to this spectrum, such a charge might discourage use of the CGC (as it is only payable if the CGC is used).

[7] For example, IoT technology may be applied to provide services to farmers for monitoring livestock, people and vehicles in their farms – see http://www.inmarsat.com/blog/cows-and-their-part-in-the-internet-of-things/

[8] ComReg 09/96

roll-out obligations and the subsequent change in timetable. As such, it is appropriate to reconsider the approach to setting relevant fees in light of current circumstances.

For example, we note that the prices for the 3G licences in Ireland were administratively set, whilst there was no demand for the Mobile TV licences. These comparators therefore offer little information about the actual value of spectrum and are of limited relevance for establishing suitable CGC fees on the basis of opportunity cost.

2 Key issues

This section sets out the key issues of principle that need to be considered when determining an appropriate level of spectrum fees for CGC use. We first briefly review the reasons that ComReg has typically sought to use opportunity cost pricing – often determined by a competitive process such as an auction – for spectrum licences, and then discuss the specific considerations relevant for the pricing of CGC authorisations.

There are good reasons for wide application of opportunity cost based pricing (where appropriate) as part of a consistent and predictable approach to spectrum pricing. However, allocation of the MSS spectrum by the EC without applying an opportunity cost based price now creates various complications. It is still relevant to consider the provision of long-run incentives for efficient use and allocation of this spectrum (i.e. beyond the term of the current licences) through opportunity cost based pricing, and to avoid any risks – even if hypothetical – of distorting competition in provision of services derived from spectrum. On the other hand, it is also necessary to weigh the possibility of disincentivising CGC deployment, as charges are only payable on use of the CGC, not on the MSS licence itself.

2.1 General approaches to spectrum pricing

Any spectrum fees set by ComReg should meet its overarching policy objectives set by legislation to promote competition, contribute to the development of the internal market, and to promote the interests of users. Overall, the legal framework places considerable emphasis on efficient use of spectrum, which is typically well-supported by charges based on opportunity cost, as far as possible applied consistently across bands.

In this context, the opportunity cost of spectrum usage refers to the value of the next best use of the spectrum. This is defined by the value of (and willingness to pay for) the spectrum to potential users other than those licenced to use the spectrum. If a potential user is not willing to pay this foregone value, then it is not efficient to award it spectrum, as there is an alternative user that could create more value from the spectrum.

Opportunity cost pricing can typically be expected to result from competitive market-based award processes, such as auctions. ComReg has used market-based awards where the circumstances are appropriate for such an approach to yield efficient allocation of spectrum. Auctions have been successful in a number of recent

awards in Ireland (such as the MBSA in 2012) and have now become the predominant methodology for spectrum award.

In competitive spectrum award processes, regardless of their format, prices for winners are typically determined by what prices losers are prepared to pay and so reflect opportunity cost for the specific licences awarded. Indeed, auctions can be thought of as processes that elicit information about opportunity cost. Equally, opportunity cost can be considered to be the market value for spectrum as established by a competitive process.[9] Using opportunity cost as the basis for setting fees establishes what could be considered a "fair" price for users to pay for the use of a scarce public resource.

Broad application ofopportunity cost pricing is supportive of the efficient allocation and use of spectrum in four main ways:

- First, if prices are administratively set at a level below opportunity cost, there may be competing demands for spectrum that need to be reconciled through administrative decisions. For instance, there could be calls from an alternative user for reallocation of spectrum in its favour, with such rent-seeking behaviour itself being a waste of resources. Avoiding such a situation is a key rationale for using competitive award processes that establish market prices for spectrum by resolving competing demands;
- Second, in the long-run spectrum prices based on opportunity cost provide appropriate price signals both to economise on spectrum use and to switch between different bands where possible in response to their relative scarcity. A predictable regulatory framework in which spectrum users can anticipate that the pricing of future spectrum bands will typically be based on opportunity cost should assist with efficient decision-making about spectrum use and associated investments in network equipment;
- Third, if spectrum charges are set at opportunity cost, this provides an incentive for an inefficient user of

[9] In practice market values depend on the context of the award process, including the licence conditions attached to the spectrum.

spectrum to return that spectrum to ComReg (who can then re-award it);[10]

- Fourth, if spectrum charges were set on an inconsistent basis for different parties, there is a danger of creating competitive distortions in downstream service markets (to the extent that operators pay substantially different amounts for similar spectrum).

Spectrum fees should also allow spectrum regulators to recover reasonable administrative costs. Such costs include:

- one-off costs of awarding spectrum and issuing licences;
- policing licence conditions; and
- monitoring and resolving interference problems.

In most cases, opportunity cost pricing can be expected to allow recovery of such administrative costs.

2.2 Opportunity cost pricing for MSS and CGC

We now turn to the specifics of how opportunity cost based pricing might apply to the MSS spectrum through charges for use of the CGC.

Short-run opportunity cost

This spectrum has already been assigned for MSS on a pan-European level, with Member States obliged to make it available for use by the two operators. The 2007 Decision states that:

> "*CEPT has concluded that the coexistence of systems capable of providing MSS and systems providing terrestrial-only mobile services in the same spectrum in the 2 GHz bands without harmful interference is not feasible in the same geographical area"* and sets out the condition that "*…where the 2 GHz bands are used by other systems, which are not capable of providing MSS, these*

[10] In theory, spectrum trading can provide similar incentives, in that if there is an alternative user of spectrum with a higher value, then the current licensee could profitability transfer or lease spectrum. However, the incentive to make such a trade is related to the foregone profit opportunity, which represents a notional loss to the licensee. In comparison, charging for spectrum at opportunity cost leads to an actual loss, which may provide a stronger incentive to give up spectrum that is not being efficiently used.

other systems should not cause harmful interference to nor claim protection from systems providing mobile satellite services".

MSS licensees are protected users, and it is not feasible to share the allocated spectrum with a ground-based user other than the MSS licensee. Therefore, in the short-run – prior to expiry of these licences - there is no practical alternative user other than the MSS licensee and the short-run opportunity cost of CGC is formally zero.

Long-run opportunity cost

Use for MSS essentially sterilises the spectrum for further use in the short-run. We can expect little, if any, impact from CGC fees on the efficiency of use of MSS spectrum in the short-run. However, this does not detract from arguments that fees for use of the spectrum should be set with long-term spectrum policy objectives in mind. Although pan-EU licensing for MSS might foreclose alternative uses of the spectrum in the short-run, spectrum pricing should provide appropriate signals for efficient spectrum use over longer horizons, anticipating eventual re-licensing and re-planning of spectrum.

Although there are currently no alternative users of the MSS spectrum, other than the MSS licensees, in the long-run these licenses will terminate and the spectrum will again become available for re-allocation. Difficulty in predicting what may happen at this stage lends importance to providing appropriate long-run incentives to facilitate efficient allocation, and respecting the broad principles that ComReg applies to spectrum in general.

Current use of similar frequencies (1800 MHz, 2100 MHz, 2.6 GHz etc.) in Ireland and elsewhere across Europe suggests that 2 GHz spectrum could be utilised for mobile network capacity or fixed wireless services. In particular, we note that the MSS spectrum concerned is adjacent to the IMT-2000 terrestrial frequencies and could be a natural candidate to expand the available spectrum for mobile broadband use in the future for either FDD or TDD systems in the 2 GHz band where it not already allocated for MSS/CGC use.

Assigning the spectrum to MSS with CGC use could hinder the possibility of reconfiguring the band for mobile use in the longer term. Therefore, it is arguable that setting fees for a CGC based on the opportunity cost of the whole MSS with CGC infrastructure is a reasonable approach. This recognises that if CGC infrastructure is deployed, then MSS with CGC services might be expected to make a future claim on use of the spectrum when licences are renewed, at which point allocating the spectrum for mobile and fixed wireless services would seem to be the most likely alternative uses. In this regard, the fact that this spectrum is currently assigned on a pan-EU basis is not relevant; anticipating the application of opportunity cost pricing gives appropriate incentives at the point that licence terminates. Such incentives are best maintained by generally

applying a consistent and predictable approach to pricing spectrum, with any deviation from this approach for a specific band needing to being justified by there being a sufficient benefit.

The fact that spectrum has already been assigned by the EC without applying opportunity cost pricing at the time of award does not mean that ComReg should now make an exception for this spectrum from its typical approach of seeking to set charges based on opportunity cost. Carving out particular spectrum bands or licences for exceptional treatment undermines the benefits of a consistent and predictable regulatory approach to spectrum pricing.

Measuring long-run opportunity cost

The prior decision to assign MSS authorisations on a pan-European level using a comparative award process means that ComReg has not run an auction process for this spectrum as it normally might. Without holding a competitive award process, establishing a good measure of opportunity cost can be difficult. It relies on having information about the value of spectrum to alternative users, which is typically known only by the users themselves and which they may not be freely (or accurately) willing to reveal (especially if it directly impacts on the determination any fees they might be required to pay).

In this case, it is necessary to form some methodology for establishing an *estimate* of opportunity cost based on the available information, which is subject to inaccuracy. Furthermore, the associated uncertainty means that the measure of opportunity-cost used will likely need to be a *conservative* proxy for the market value, due to the need for avoiding adverse effects from excessive fees.

Trade-offs with deployment incentives

Although the EC did not levy an opportunity cost based price on the MSS licences when these were awarded, it provided for NRAs to set charges for the CGC, with these charges only being paid if the CGC is used. Therefore, it is necessary to consider whether the level of charges might discourage use of the CGC. This leads to some conflict between trying to ensure that general principles of opportunity cost pricing are widely applied and at the same time not discouraging efficient use of the CGC for this particular spectrum. This tension is unavoidable given that the EC did not set an opportunity cost based charge for the MSS licence itself.

For the purposes of determining a reasonable level of charges for the CGC, it is relevant that ComReg has decided to charge on a per-site basis. This creates a trade-off between setting fees to reflect opportunity cost (thereby providing appropriate long-run price

signals) and reducing incentives to deploy sites. We return to this issue in detail in Section o below, considering various alternatives for how a CGC usage charge could be structured. Our overall conclusions reflect this concern about deployment incentives for the CGC, with our eventual recommendation being based on a conservative estimate of opportunity cost for this spectrum.

Although incentives for CGC deployment need to be considered, this concern should not override general arguments for opportunity cost based prices. Acceding to the argument that incentives to deploy a CGC could be weak under such charges and thus using this as a reason for reducing charges might be a poor precedent, as this encourages special pleading for moving away from opportunity cost pricing in the future.

Avoiding the risk of competitive distortions

The spectrum authorised for use by the MSS operators is adjacent to the 2100 MHz mobile band, and the bandwidth allocated to each operator (2x15 MHz), along with the availability of terminal equipment, means that the MSS spectrum could be exploited to provide services similar to those offered on existing terrestrial mobile networks. Such services could compete – at least at the margin – with mobile operators. This possibility is not excluded by the MSS licence, which allows for technology- and service-neutrality.

A concern – albeit a hypothetical one – is that the CGC fees should not be so low that they create a back door means to deliver services competing unfairly with existing mobile services by avoiding paying opportunity-cost based fees, especially, when the mobile operators are paying non-trivial prices for the use of similar spectrum.[11] At present mobile operators pay prices reflective of opportunity cost in most bands, as spectrum was allocated at auction, with the only significant current exception being the 2100 MHz band.

The 2100 MHz spectrum was awarded for 3G use by ComReg in a competitive process in June 2002, but not using an auction in the conventional sense. As a consequence, current fees for the 2100 MHz spectrum were not market-determined and cannot considered an indicator of the value of the 2100 MHz band in Ireland. However, ComReg has since changed its policy, and other key bands for providing mobile capacity have subsequently been awarded using an auction process. For example, the Multi-band Spectrum Award (MBSA) in Ireland in 2012 used a Combinatorial Clock Auction (CCA)

[11] We assert that this is a hypothetical consideration rather than a prediction of how MSS operators might behave.

format, which has an opportunity cost based pricing rule that explicitly sets prices based on the value of spectrum denied to losing bidders (based on bid amounts submitted). These spectrum bands represent the marginal cost of expansion by MNOs, and hence the fees paid for use of those bands can be considered relevant to the pricing of CGC usage.

We acknowledge that these considerations are by nature hypothetical. However, the principle is a very general one. If a current licensee pays less than opportunity cost for spectrum, there may be potential to distort competition with services provided by other parties paying opportunity cost. In contrast, pricing based on opportunity cost ensures equality of treatment with other spectrum in Ireland.

2.3 Incentives for roll-out

The level and structure of fees to be paid for a CGC authorisation may have a significant impact on the incentives for operators to make use of a CGC alongside the satellite component. Operators are under no obligation to deploy a CGC, and if the cost of doing so is too high relative to the additional revenue they would gain, they may choose to instead use only the MSS, even if that means providing services of a poorer quality.

The pricing structure of the license should therefore have the objective of not discouraging roll-out of a CGC where efficient to do so. We set out below a number of considerations regarding the fee structure and the potential impact on deployment incentives.

Per site vs. lump-sum charging

Two broad alternatives for a pricing structure are:

- to set a single fixed fee for using CGC at all (i.e. a national fee that would allow the operator to deploy as many base stations in Ireland as it likes with no incremental fee); or
- to set a per-site charge (i.e. an annual fee for every base station deployed).

The difficulty with a simple fixed charge at the opportunity cost for the allocated spectrum is that it potentially renders CGC operations unviable if they are of limited scale. Pricing off CGC applications is not (short-run) efficient as there are no alternative users that could be accommodated, and it is conceivable that some innovative CGC applications might yield modest revenue yet significant social value.

Seeking to avoid pricing off such limited uses suggests that per site licensing may be more appropriate for CGCs. However, this pricing structure creates a marginal cost to expanding the coverage of services, even though the short-run opportunity cost of the spectrum employed in doing so is effectively zero. This creates an incentive to minimise the number of sites deployed, potentially at the expense of quality of service or coverage.

It is important to note that the impact of per-site spectrum pricing may be quite different for different types of service. Ground-based aeronautical services may not be much affected by a per-site charge, as few sites are required.[12] In contrast, rural IoT backhaul, for example, may require many sites (each generating modest revenue), in which case a per-site fee could impact on the incentives to deploy sites. For such applications, there is tension between creating long-run incentives for efficient spectrum allocation and allowing for incentives to promote roll-out in the short-run.

Time profiled and non-linear charging

The trade-off between encouraging roll-out in the short-run and mitigating inefficient use of the spectrum in the long-term requires compromise. Nevertheless, it may be possible to improve the terms of this trade-off through more sophisticated pricing structures.

For example, charges could change over time - starting low and ramping up in real terms as time passes encourages early deployment and allows the fee to be more inline with true opportunity cost as licences approach renewal. However, this approach has some disadvantages:

- it is not clear if extensive early investment is necessarily desirable;
- the choice of time periods and discount is arbitrary – especially as there have already been considerable delays and uncertainty in deployment and launching of satellites;
- spectrum prices need to approach long-run opportunity cost sufficiently in advance of the end of the licence to provide appropriate incentives for planning future spectrum use at that point in time.

An alternative to a time-dependant structure could be to offer quantity discounts on a small number of sites. Pricing would be non-

[12] At the time of writing, Inmarsat expects to deploy 2-4 CGC base stations in Ireland.

linear in the number of sites and convex in the sense that per-site charges would be small if there are a relatively low number of sites, and increase if site-number exceeded specified thresholds. Therefore, if an MSS licensee deployed base stations on such a scale that it could, at the margins, compete with mobile services, it would subsequently be faced with appropriately high spectrum fees as to avoid competitive distortions. At the same time, the per-site price can be kept low for smaller scale deployments to avoid disincentivising building sites. This model has the advantage of being relatively straightforward for both ComReg and operators.

Geographical variation in charges

Satellite mobile provision and the MSS/CGC model has the potential to provide coverage in areas that are otherwise hard to reach, particularly in rural areas.

Ofcom, the UK telecommunications regulator, has proposed an approach that differentiates between rural and urban sites in their pricing, setting lower fees for areas with a lower population density. The motivation is to incentivise deployment of CGC sites in rural areas, rather than more valuable urban areas and so maximise long-run opportunities for spectrum sharing with other users (e.g. mobile operators).

This approach has some logic in that that there are good reasons to think that MSS and CGC services are much less relevant in urban areas where there are a variety of other fixed and mobile networks that can be used instead of satellite-based services for backhaul applications. For example, IoT backhaul applications would seem unlikely to require a satellite service in urban areas. However, the situation is somewhat less clear for aeronautical services, as there may be need to locate base stations close enough to airports (due to the density of flights) which may in turn be close to urban areas.

The theoretical basis for this approach is that pricing can reflect geographic variation in opportunity cost if demand for spectrum to supply mobile services in urban areas is higher. However, this raises the concern that it is difficult to estimate appropriate differentials, not least as it depends on long-run and very hypothetical considerations, such the possibility of spectrum sharing in limited geographical areas.

Furthermore, to the extent that MSS licensees might be able to avoid deploying CGC in urban areas and tolerate degradation of the MSS service, they would in any case have an incentive to form geographically limited spectrum sharing arrangements with, say, mobile operators. It is not clear that there is much incremental incentive provided to form such arrangements by using a geographically differentiated pricing structure for spectrum.

In addition to the per-site license structure, Ofcom has proposed to offer a parallel license at a flat fee. Inmarsat has the choice between the aero-specific 'Network 2 Access' License and standard technology neutral 'Spectrum Access' fee. Similarly, Malta has offered two different licenses for the different uses.

These approaches are more in line with the non-linear per-site charging approach we outlined in the previous subsection. In particular, this approach ensures that per-site charges can be modest for small-scale deployments, without creating the possibility of a large-scale deployment that could unfairly compete with other users of spectrum paying much higher charges.

Overall, we do not see strong arguments for geographically differentiated pricing, as it would appear that most of the benefit of this approach in terms of not disincentiving deployment of rural sites could in any case be achieved with non-linear per-site charging which is much simpler.

Charging for spectrum in use

Another possible approach is to charge for MHz occupied. This may have attractive long-term properties as it should lead to spectrum only being used for services sufficiently valuable to cover its cost, potentially freeing spectrum for other users where efficient to do so. However, it is inefficient in the short-run as there are no alternative users that could be accommodated by minimising the spectrum that Inmarsat or EchoStar are willing to use. We thus recommend charging on the basis of spectrum allocated rather than spectrum used.

2.4 Proposed approach to pricing

In order to proxy for the opportunity cost of the 1980-2010 MHz and 2170-2200 MHz spectrum, we need to benchmark spectrum for mobile capacity bands that are typically awarded national licenses and that are technically similar to our relevant spectrum. This value then needs to be converted to a per-base station site to be applicable to the MSS/CGC conditions. We undertake these calculations in Section 3 below.

If seeking to maximise roll-out incentives without favouring MSS licensees in a way that would allow them to compete unfairly on the mobile services market, the most straightforward way to calculate an appropriate per-site fee is to divide the full national license value by the number of CGCs required to compete with existing mobile services. Using a figure smaller than this number of CGC base stations would lead to higher per-site prices that would impact

deployment incentives. Conversely using a larger number reduces the per-site price and so may distort relative competitive abilities.

In Section 3.4 we divide an estimated value of a national licence by the number of base stations that a typical mobile operator might deploy across Ireland. Realistically, this is likely to exceed the number of CGC base stations that an MSS licensee might (hypothetically) need to compete at the margin with terrestrial mobile services. However, using smaller number of base stations results in a higher per-base station price. Given that the MSS licensees only have a limited amount of spectrum available to compete with, and considering the potential social value of extensive CGC deployment, there seems little benefit in pushing the per site price up by assuming a smaller number of sites, given that this risks disincentivising CGC deployment. Therefore, our approach gives regard to the issue of ensuring that there is no unfair competition with mobile operators and that general principles of opportunity cost based pricing are following, but at the same time seeks to set a conservative per site charge that maintains reasonable deployment incentives.

Additional considerations stem from the possibility of employing more sophisticated pricing structures; using greater than inflation price increases to square roll-out incentives with long-run opportunity cost pricing, or a tiered discount if few sites are deployed in order to encourage rural backhaul applications. However, we consider that the additional complexity of these charging structures (which each involve a greater number of parameters to be set) is not justified given that a reasonable compromise between the objectives in play can be obtained with a simpler linear per site charge.

3 Benchmarking

3.1 Which bands?

Frequency bands that are technically and commercially most comparable to the MSS/CGC frequencies would serve as the most appropriate benchmarks. The MSS/CGC frequencies are adjacent to the main 3G band in Europe (1920-1980 MHz/2110-2170 MHz) as well as TDD Band 34 (2010-2025 MHz) both of which has been reserved or licensed for UMTS/IMT since 1999, though the spectrum in TDD Band 34 remains largely unused in Europe as well as most of the rest of the world.

There is a degree of overlap between the services provided by MSS operators and that provided by mobile and fixed wireless operators. MSS operators provide various forms of electronic communication services though in areas that traditional operators may not be commercially incentivized to cover. Therefore, the services provided by MSS operators are arguably comparable to that provided by mobile and fixed wireless operators and we would expect spectrum bands that provide mobile capacity to be the most relevant benchmarks.

Frequency bands around the 2100 MHz range where the MSS/CGC frequencies are located are considered capacity bands. These bands do not have the propagation reach of low frequency bands (sub-1GHz) and hence are typically not of comparable value to sub-1GHz spectrum. In comparison, there is typically more spectrum available in these higher frequency bands that is utilized to boost network capacity. Therefore, other capacity bands around 2 GHz would be suitable candidate bands for benchmarking MSS/CGC spectrum value. These include:

- L band (1452-1492 MHz) – An EC decision in 2015 harmonised this frequency for wireless broadband supplementary downlink use in the EU.[13]
- 1800MHz/1900 MHz – The 1800 MHz in Europe and Asia Pacific or 1900 MHz band in North America and some Latin America countries are established mobile

[13] Commission Implementing Decision (EU) 2015/750 of 8 May 2015 on harmonising of the 1 452-1 492 MHz frequency band for terrestrial systems capable of providing electronic communications services in the Union (notified under document C(2015) 3061), Official Journal of the European Union L119/27.

bands. The 1800MHz band is now the most widely used LTE FDD band in the world.

- 2100 MHz/AWS – The 2100 MHz and AWS (1700/2100MHz) bands were used to provide 3G services traditionally, though the equipment eco-system for LTE FDD is growing.
- 2300 MHz – This band is allocated to the fixed and mobile services on a co-primary basis in Europe and has been identified by the ITU for IMT and is currently used for wireless broadband applications in a number of jurisdictions including the US, China and India. This band is also the most widely used LTE TDD band.
- 2600 MHz – This band comprises LTE FDD band 7 and LTE TDD band 38, both widely used for LTE.

The 3.4-3.8 GHz band is also a capacity band. However, the use of this frequency range for mobile services is relatively new, the equipment eco-system remains immature. This means that the auction benchmarks in this band may not fully reflect the value for this spectrum for wireless broadband use. In addition, there is an unprecedented amount of spectrum available in this band, which has not been available in other bands to date. This band has also been earmarked for 5G, which may create demand for large contiguous blocks to deploy high bandwidth services. Overall, the supply and demand conditions for this band may affect the value of spectrum in this band in unpredictable ways. Therefore, we consider it would be prudent to exclude this band as a candidate band to benchmark the value for MSS/CGC spectrum.

3.2 Relevant comparators

The price of spectrum licences paid at auction can provide an indication of market value of spectrum concerned. In the case where the strongest losing bid determines the price paid by the winners, the market price reflects the opportunity cost of spectrum concerned. When comparing spectrum licence prices across different jurisdictions, it is important to adjust prices to a common basis. Therefore, in our analysis before, we will:

- Express prices in per MHz per head of population terms: This corrects for population and size of spectrum endowment differences and is a common metric used to compare licence prices in different jurisdictions;
- Calculate the present value (PV) of the stream of fee payments associated with the licence, as in some cases national regulatory authorities allow the licence fee to be paid in instalments. Additionally, annual fees are

also charged on top of the headline auction prices in some jurisdictions;

- Adjust prices for differences in licence terms using a PV adjustment assuming a constant annual profit stream from holding spectrum.14 We will normalise prices to that of a 10-year licence term - we estimate that the MSS/CGC licences that are valid until 13th May 2027 are likely to have a similar term-length remaining when the CGC authorisations are issued by ComReg in 2017.
- Express prices in 2017 Euros – we will convert licence prices from local currency to Euros using a Price Purchasing Parity (PPP) exchange rate. Using a PPP exchange rate accounts for price differences between countries and is not as prone to speculative fluctuations as market exchange rates. Licence prices are first converted to USD using PPP rates based in USD. We then adjust for inflation using US Consumer Price Index (CPI) data and express prices in 2017 terms. Prices are then converted to Euro using the Ireland-US PPP rate.

We use a discount rate of 9% for all PV calculations. The Weighted Average Cost of Capital (WACC) of an Irish Mobile Operator in 2014 was calculated by ComReg to be 8.63%.[15] Further, we note that the WACC for an international satellite operator ranges between 7.5%-10.5%.[16] Therefore, we will use a discount rate of 9% for NPV

[14] Assuming a constant annual profit stream from holding the spectrum, a licence with duration T_2 is adjusted into a licence with duration T_1 as follows:

$$L_{T_1} = L_{T_2} \times \sum_{t=0}^{T_1-1} \left(\frac{1}{1+r}\right)^t \Big/ \sum_{t=0}^{T_2-1} \left(\frac{1}{1+r}\right)^t$$

[15] ComReg, 2014, Cost of Capital, Response to Consultation and Decision, ComReg Document 14/136 & D15/14.

[16] Nordicity's report for Industry Canada in 2010 on the Study on the Market Value of Fixed and Broadcasting Satellite Spectrum in Canada, calculated the WACC of Canadian and International Satellite companies (including EchoStar) to be between 8%-10% (http://www.studfiles.ru/preview/2266739/page:5/). This is consistent with the WACC applied in more recent valuations of Inmarsat and EchoStar's businesses. For instance:

- Credit Suisse uses a WACC of 7.6% for Inmarsat (https://doc.research-and-analytics.csfb.com/docView?language=ENG&source=emfromsendlink&format=PDF&document_id=806506970&extdocid=806506970_1_eng_pdf&serialid=goPa5%2fPwbVkJ7WRWBglZmPTswBuVXGFSGRcVbHoZO7Q%3d)
- Jefferies uses a WACC of 7.9% for Inmarsat (https://www.jefferies.com/CMSFiles/Jefferies.com/files/InmarsatClearerandBluer.pdf)

(footnote continued)

calculations. Our calculations are not particularly sensitive to the rate used.

Even with the above adjustments, there are likely to be differences in market conditions that remain that could have an impact on licence prices. Therefore, it is important to focus on benchmarks from auctions that are most relevant. We would expect to place greater weight on:

- European benchmarks – there is a considerable consistency in regulatory policy across Europe, therefore, we would expect greater uniformity in market condition across Europe compared to the rest of the world. Nonetheless, other developed economies are also likely to be a good benchmark for Ireland;
- Recent benchmarks – recent benchmarks are more likely to be informative of the present value of spectrum as current market conditions and technical developments are considered by operators valuing spectrum in these auctions. This is particularly important for spectrum bands that have only recently been harmonized for wireless broadband use – higher equipment cost due to the lack of a mature equipment eco-system and economies of scale are likely to increase investment uncertainty and cost of network deployment;
- Competitive benchmarks – the more competitive the auction, the more likely final auction prices are likely to reflect opportunity cost of the spectrum concerned. In contrast, if the auction is not at all competitive and licences are awarded at reserve prices then the auction price is unlikely to reflect opportunity cost of spectrum unless reserve prices were set in line with market value of spectrum. However, even if market value was considered by the national regulatory authority (NRA) when setting reserve prices, a conservative view of market value is typically adopted to ensure that no efficient demand is choked off. Therefore, these benchmarks are likely to understate the market value of spectrum. In general, we would expect competitive

- Lenos Trigeorgis and Sophocles Loulianou assume a WACC of 10.6% for EchoStar in their study on "Valuing a high-tech growth company: the case of EchoStar Communications Corporation" published in the European Journal of Finance.

auctions to provide a more accurate view on market value. We define a competitive auction to be one where the licence price for at least one lot exceeded the reserve price for that lot.[17]

Just as it is important to focus on benchmarks that are comparable to Ireland, care has to be taken to exclude benchmarks that are not relevant. For instance, we note that auctions that occurred around the time of the telecoms bubble in 2000 might have inflated licence prices that are not relevant to current market conditions. More generally in our analysis, we will systematically identify outliers within the sample and exclude these. Outliers are observations that are far removed from the rest of the sample. We use two common methods to identify outliers:

- observations that lie more than three standard deviations away from the sample mean are considered outliers;
- observations that lie beyond the outer fence are considered outliers, where the outer fence is defined as three times the interquartile range from both the 1st and 3rd quartiles.

3.3 Results

In this sub-section, we will present benchmarks for each relevant frequency band category and deduce conservative value estimates. Prices are that of a 10-year term, presented in per MHz per head of population terms in 2017 Euros as detailed above.

Auction prices are calculated as weighted averages – each licence price is weighted by the product of the licence endowment (in MHz) and population covered by the licence. This means that a larger licence (in terms of MHz and/or population covered) sold in an auction will have a greater sway on the average price of the auction.

We will also present band specific sample average prices for each band category – these are calculated as simple average with each

[17] Nonetheless we note that the fact a licence price exceeds reserve price does not necessarily mean that the auction was fully competitive or that the licence price would reflect market value. In such cases, the extent to which an auction is competitive depends on factors such as the design of the auction and the approach taken to minimum prices. In particular, where reserve prices are set low and distant from market value, the gains from strategically reducing demand to close the auction are higher, creating greater incentives to do so. In such cases, even though final licence prices do exceed reserve prices, the auction result may not be fully competitive and final prices may not reflect competitive market value.

auction holding equal weight within the sample. We will derive band specific value estimates based on these sample averages or where the sample is small, such as in the case of L band, look at individual auction prices.

The results presented in this report are estimates generated at a specific point in time, based on the data available at the time (such as the sample of historic awards, and estimates of population levels and PPP exchange rates) as well as country and award specific parameters (such as license duration and the appropriate discount rate). Data may be subject to revision over time and the relevant parameters could vary depending on the specific nature and requirements of the study. As such, the results for particular bands may differ across various benchmarking exercises, and those presented here may therefore not align precisely with those published by ComReg in previous or future benchmarking reports.

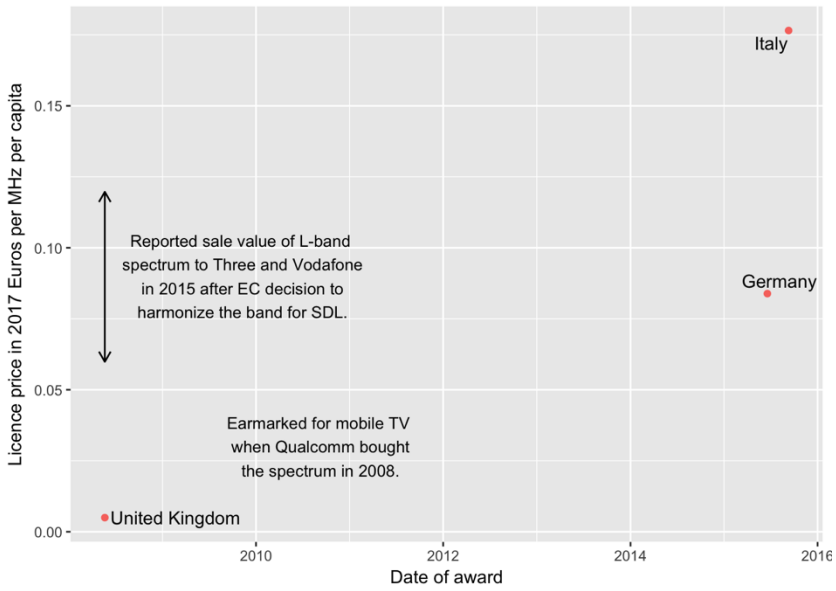
3.3.1 L band (1452-1492MHz)

There are only three L band benchmarks available, the:

- UK auction in 2008;
- German multiband auction in 2015 which included the sale of L band spectrum; and
- Italian L band auction in 2015.

The prices achieve in these auctions in detailed in Figure 1 below.

Figure 1: L band auction benchmarks



The UK auction price is significantly lower than that in Germany and Italy. The UK auction in 2008 occurred before the EC decision to harmonize the band for supplementary downlink use. At the time of

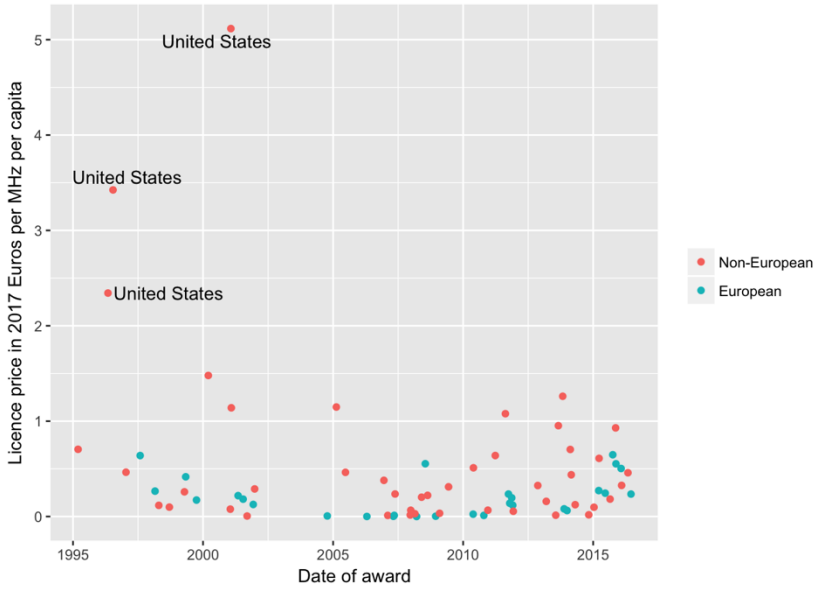
the auction in 2008, the spectrum was designated for mobile TV use by Qualcomm. However, after the EC decision in 2015, Qualcomm sold its L band spectrum to Vodafone and Three. The official sale value was not disclosed but has been reported to be between £100m to £200m in total. This translates to a per MHz per population value of €0.06 to €0.12, which is comparable to the values achieved in the German and Italian auctions, both of which took place after the EC decision.

Licence prices exceeded reserve prices by 120% in German auction and 0.4% in the Italian auction; however, reserve prices in the German auction were considerably low and the premium over reserve in the German auction does not necessarily indicate that the bids for L band spectrum were particularly competitive. Nonetheless, considering that these auction prices are also consistent with the reported traded value of the Qualcomm spectrum, we would consider that these benchmarks would provide a reasonable estimate on L band value. Overall, these benchmarks suggest that a conservative value estimate for L band spectrum to be around €0.07.

3.3.2 1800 MHz and 1900 MHz

We have a sample of 73 1800 MHz and 1900 MHz auctions. Figure 2 shows prices achieved in these auctions. There were a couple of US auctions in the late nineties and early 2000 where Personal Communication Service (PCS) spectrum in the 1900 MHz band sold for high prices. These auctions have been identified as outliers within our sample. There were also a number of non-mobile spectrum auctions such as that of DECT frequencies.

Figure 2: 1800MHz and 1900MHz auction benchmarks



Excluding the outliers and non-mobile spectrum auctions, the sample average is €0.35 per MHz per head of population. Most of the auctions within this sample took place pre-2004 or post-2006 and the spread of prices in these two periods are similar. Indeed, looking at the average price of auctions from the last decade yields a similar average of €0.32. Another noticeable trend is that the prices achieved in European auctions tends to be lower than non-European auctions - the average price of European-only auctions is €0.26. When restricting the sample further to competitive auctions only, the sample averages are higher (see Table 1 below). This is consistent with our expectation that competitive auctions should yield auction prices that are likely to more closely reflect market value of spectrum.

Table 1: 1800 MHz and 1900 MHz sample averages

	All	Last decade	European
Mobile auctions	0.35	0.32	0.26
Competitive mobile auctions	0.40	0.37	0.30

Overall, the available benchmarks suggest an estimate of 1800/1900MHz value to be around €0.25. We note that the reserve price for 1800 MHz spectrum in the Multiband Spectrum Auction (MBSA) in Ireland was €0.17[18]. The MBSA was competitive with final prices exceeding reserve prices by between 70%-160%.[19] This would suggest that €0.25 falls within the likely range of bids for 1800 MHz spectrum in the MBSA. Therefore, a value estimate of €0.25 for 1800 MHz spectrum would seem suitably conservative for the Irish market.

[18] For a 1800MHz lot in Time Slice 2 (reserve price is €4.13 million and annual Spectrum Usage Fee is €0.54 million)

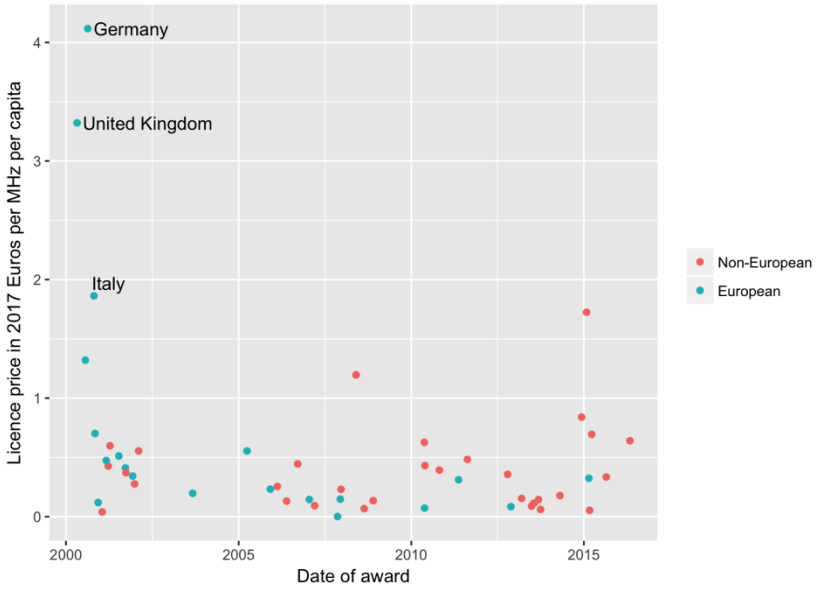
[19] The Irish operators paid the following premium over reserve prices (difference between headline price paid and reserve price over reserve price) for their respective spectrum package won:

- H3G: 71%
- Meteor: 160%
- Telefonica: 125%
- Vodafone: 138%.

3.3.3 2100 MHz and AWS

2100 MHz band in Europe, the Middle East and Asia-Pacific as well as AWS band in North and South America were traditionally used for 3G though has gradually been used more recently for LTE. A good number of 3G auctions, particularly in Europe took place at the turn of the millennium, hence prices in some of these auctions were likely inflated by the telecoms bubble then. We note that the UK, German and Italy 3G auctions have been identified as outliers within the sample. Excluding these outliers and non-mobile awards, the sample average is €0.384 which is similar to that in the 1800 MHz and 1900 MHz sample.

Table 2: 2100 MHz and AWS benchmarks



Looking at auctions in the last decade yields a similar average price of €0.36. In particular, we note that the majority of these auctions are non-European auctions, many of which in the last decade, achieved higher prices than the European auctions. Across the entire period however, the sample of European-only auctions yields a similar average price of €0.35. Like the case with the 1800/1900 MHz sample, restricting the samples further to competitive auctions only yield higher average prices, though only slightly so as many of the 3G auctions were competitive.

Table 3: 2100MHz and AWS sample averages

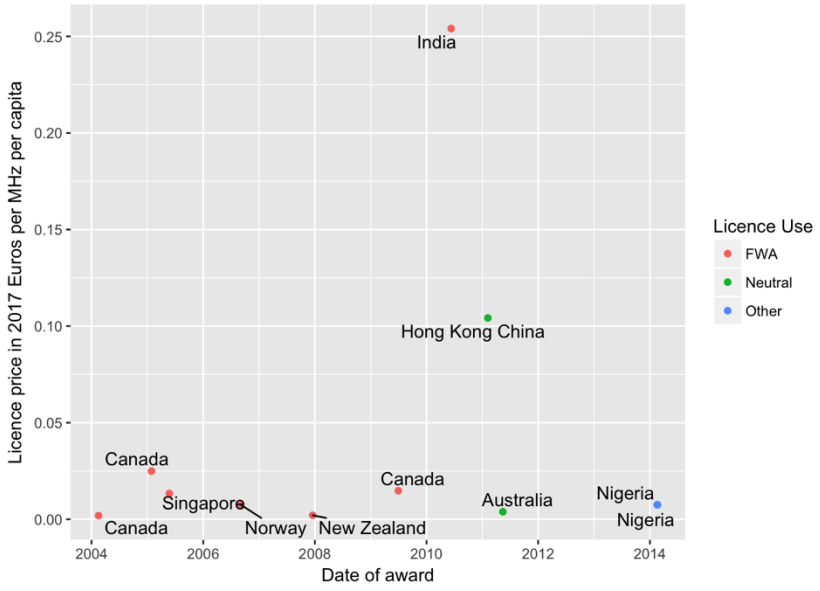
	All	Last decade	European
Mobile auctions	0.38	0.35	0.35
Competitive mobile auctions only	0.40	0.38	0.39

Overall, the 2100 MHz and AWS auction benchmarks would support a value estimate of around €0.35 for spectrum in this band. We note that in 2002, Vodafone, O2 and Hutch paid on average of €0.51 for their 3G spectrum licences while Meteor paid €0.47 in 2003 for its 3G licence. This lends support to the value estimate of €0.35 for 2100 MHz spectrum in Ireland bring suitably conservative.

3.3.4 2300 MHz

The sample of 2300 MHz auctions is relatively small – consisting of just eleven awards. Most of the available auctions are non-European auctions, there is also a lack of recent spectrum auctions with the most recent benchmarks being a couple of Nigerian auctions in 2014. There are two auctions that achieve significantly higher prices than the rest of the sample – India in 2010 and Hong Kong in 2011. Some of the operators who won spectrum in these auctions announced plans to use the spectrum to provide wireless broadband services. Nonetheless, both these auctions are outliers within the sample. Excluding these outliers, the sample average is €0.009.

Table 4: 2300MHz auctions

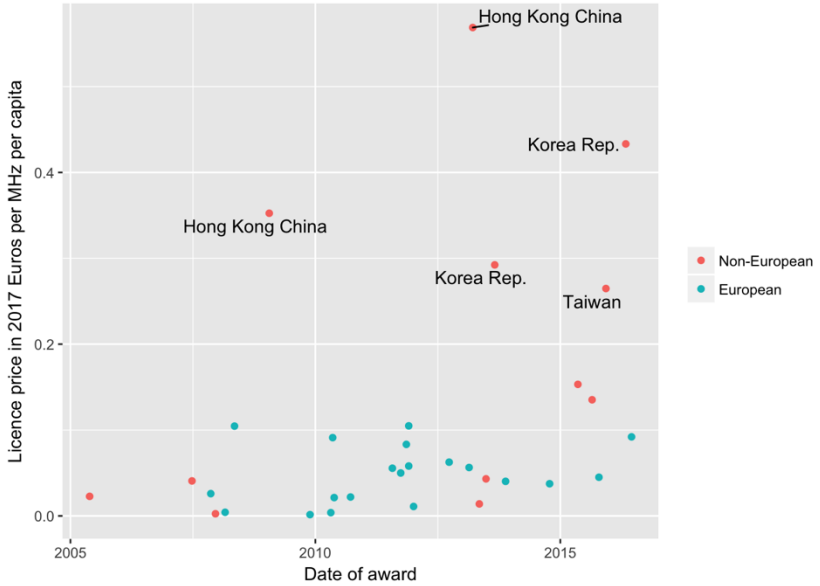


Most of the 2300 MHz spectrum auctioned was designated for FWA use – these auctions took place some time back (pre-2010). We would expect more recent auctions to better reflect the value of spectrum for LTE use, though there are few benchmarks available to inform this value. Overall, we consider that the available benchmarks are only able to provide a floor value estimate for 2300 MHz spectrum of €0.01 – in reality we expect the value of spectrum in this band to exceed this floor value.

3.3.5 2600 MHz

The 2600 MHz band has been allocated via auction internationally since 2005, with a number of countries assigning this spectrum for fixed wireless or WiMAX use. In Europe, the band was only harmonised for mobile use in 2008.[20] The Hong Kong auctions in 2009 and 2013 and Korean auction in 2016 are outliers. However, we note that 2600MHz spectrum has sold for high prices in other developed economies in Asia – namely in South Korean and Taiwan.

Figure 3: 2600 MHz auctions



Overall, the sample average excluding the three non-mobile auctions pre-2007 and outliers is €0.072. The average for European-only auctions is significantly lower at €0.049. The majority of the 2600 MHz licences in our sample sold for in excess of reserve prices, hence the sample composition of competitive-only and all auctions overlap to a large degree. Reserve prices for 2600 MHz auctions also tend to be low as there was a trend of using low but non-trivial reserve prices, particularly in Europe. Therefore, while many of the auctions ended with prices in excess of reserve, these auctions might not have been fully competitive and final prices may not closely reflect market value for spectrum. As all available 2600 MHz mobile auctions took

[20] Commission Decision of 13 June 2008, "on the harmonisation of the 2 500-2 690 MHz frequency band for terrestrial systems capable of providing electronic communications services in the Community (notified under document number C(2008) 2625)", Official Journal of the European Union, 2008/447/EC.

place in the last ten years, we will not present separate average figures for auctions in the "Last decade".

Table 5: 2600 MHz sample averages

	All	European
Mobile auctions	0.072	0.049
Competitive mobile auctions	0.065	0.046

In general, paired 2600 MHz spectrum sold for higher prices per MHz than for unpaired 2600 MHz spectrum. Arguably, this may be in part motivated by greater clarity over the technological and equipment eco-system development for FDD rather than TDD use when 2600 MHz spectrum was first auctioned for mobile use. Restricting the sample to paired spectrum only, the average price is €0.108. In comparison, the average price for unpaired spectrum is €0.052, approximately half of the average price for paired spectrum. This relationship also holds for the European sample, though the average price of unpaired spectrum is closer to the average price of paired spectrum.

Figure 4 Paired and unpaired 2.6 GHz awards

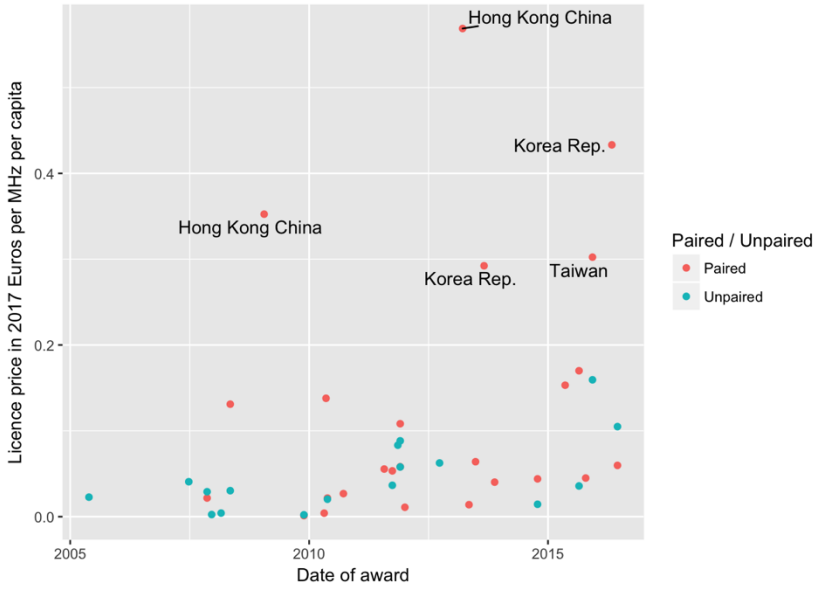


Table 6: 2600 MHz sample averages broken down into paired and unpaired spectrum

All		European	
Paired	Unpaired	Paired	Unpaired
0.108	0.052	0.051	0.045

On the basis of the benchmarks, we consider that an estimate of the value of 2600 MHz spectrum is €0.05 for paired spectrum and €0.04 for unpaired spectrum would be appropriate.

3.4 Converting to a per-site price

Table 7 below provides a summary of the value estimates for each band categories suggested by the international auction benchmarks.

Table 7: Overview of benchmark values

Band	**Value estimate (€ per MHz per pop.)**
L band	€0.07
1800/1900 MHz	€0.25
2100 MHz	€0.35
2300 MHz	€0.01 (lower bound only)
2600 MHz - Paired	€0.05
2600 MHz - Unpaired	€0.04

The 1800 MHz and 2100 MHz samples are the most robust, with cross-checks available in the Irish context to verify these value estimates. The value estimates for 1800 MHz and 2100 MHz[21] are substantially higher than those for L band, 2300 MHz and 2600 MHz. This is expected to some extent as 1800 MHz and 2100 MHz have superior propagation characteristics to 2600 MHz spectrum, the 2600 MHz equipment eco-system is less developed than for 1800 MHz, and the auction benchmarks could only provide a lower bound on the likely value of 2300 MHz spectrum. In the case of L band, the lower value might reflect that the more restrictive use of this band –

[21] We note that the 2100 MHz benchmark is higher than the 1800 MHz benchmark, whereas these bands are close in frequency and both mature for mobile use, suggesting they might have similar value to operators, at least in the long run. This difference occurs because early 2100 MHz awards in Europe were relatively expensive, in particular the Dutch 3G auction in 2000 (prices in the German, UK and Italian 3G auctions were also relatively high, but have been classified as outliers and are not included in the sample).

for downlink use only - and that there remains considerable investment uncertainty in utilizing this spectrum for mobile use given the equipment eco-system is still relatively immature.

The benchmarking results suggest that fees in the range of €0.05 - €0.35 would be suitable. We consider that given the proximity of the MSS spectrum to the 2100 MHz band, the 2100 MHz benchmark of €0.35 is likely to be the most directly relevant for estimating the opportunity cost of the 2 GHz MSS/CGC spectrum. However, the uncertainty over the potential use of the spectrum as well and the need to consider the impact on rollout incentives suggests that taking a more conservative approach would be appropriate. On that basis, and taking account of the implied range of fees, we consider that €0.25 would be suitable price point. This value is approximately equal to the overall benchmark for 1800 MHz prices, which is also a relevant benchmark for MSS spectrum. Basing a fee for MSS spectrum on the lower 1800 MHz benchmark also avoids the potential worry that prices of 2100 MHz spectrum may have been inflated around 2000/2001, when 3G licences were first awarded (though auctions such as the UK and Germany 3G awards that were particularly affected by the TMT equity bubble around that time have been excluded as outliers). This approach should also yield a fee for MSS that is sufficiently conservative to encourage CGC rollout, but high enough to prevent unfair competition with mobile services.

Since the benchmark results provide value estimates for national licences, we also need to convert those into per-site CGC fees. We understand that, on average, a mobile operator in Ireland would have circa 2,200 sites providing mobile services using the 800 MHz, 900 MHz, 1800 MHz and 2100 frequency bands. This is informed by ComReg's recent mobile network modelling exercises (Section 2.1.1 and 5.7 of Documents 15/62b and 16/09 respectively).

If we are seeking a level of the per-site fee that is sufficiently high to prevent the hypothetical possibility of distorted competition against mobile operators, then we also need to consider the possibility of a more limited service offering, say focusing in urban areas and to a limited number of subscribers. It is arguable that it might be possible to offer such a service on a smaller number of sites than the full 2,200 used for a full mobile network. However, calculating a per-site price on the basis of a smaller number of sites raises the price; this could then have the undesired effect of discouraging CGC deployment.

In Table 8 below we present a range of fee levels (calculated using a discount factor of 9% and assuming a 10 year licence term) that would arise on the basis of different value estimates and assumptions on the relevant number of base stations for converting into a per-site fee.

Table 8: National and per-site fees

Fee/MHz/Pop	National fee per annum (€)	Fee per site per annum (€)		
		2,200 sites	1,100 sites	550 sites
0.05	1,010,829	459	919	1,838
0.10	2,021,658	919	1,838	3,676
0.15	3,032,488	1,378	2,757	5,514
0.20	4,043,317	1,838	3,676	7,351
0.25	5,054,146	2,297	4,595	9,189
0.30	6,064,975	2,757	5,514	11,027
0.35	7,075,805	3,216	6,433	12,865

As discussed above, we consider a suitable price to be €0.25 and the relevant number of sites is 2,200. This implies that an annual fee per site of approximately €2,300 is appropriate for the CGC authorization fees. As these assumptions are all quite conservative, there is little need to consider further discounting to address concerns about disincentivising CGC roll out.

There is a reasonable case for higher fees (on the basis of the 2100 MHz benchmark being the most appropriate reference point) at around €0.35, rather than the proposed €0.25. If ComReg were to take that approach, given the uncertainty around the use of MSS with CGC and the need to avoid disincentivising CGC roll-out, it may then be desirable to use a non-linear pricing structure and apply a discount on this fee level for smaller networks, provided that it does not risk distortion to competition with the mobile network operators. As discussed above, the discounting approach is attractive as it better balances the issues of not creating distortions with regard to mobile networks against not discouraging CGC roll out.

Competing at the margin with mobile operators would not require deployment of as many base stations as the mobile operators (since competing at the margin does not require national coverage, and the satellite component of the network means fewer sites are likely to be required in any case). Nevertheless, with sufficiently few sites, we would not need to be concerned about the issue of fairness of treatment relative to mobile operators. However, there is significant uncertainty and a lack of evidence over what would be an appropriate discount to apply, and at what threshold (number of

sites) that discount should apply. As such, we do not see any good reason to deviate from the simpler approach of applying a uniform price per site, at a clearly conservative price point that should offer a reasonable balance between not discouraging rollout, and allowing for competition at the margin with mobile operators at a level that suitably represents opportunity cost and avoids competitive distortions in the mobile market.

4 Charges in other EU states

As part of this study, we conducted a review of the approach to setting MSS and/or CGC fees in other EU member states. Given the somewhat unique characteristics of the MSS 2 GHz licenses, and the degree to which member states are free to independently set CGC fees, it is unsurprising that in practice there is significant variation in policy across the EU, with substantial diversity in both the level and the type of fees charged. Inmarsat's plans to use CGC for aeronautical services has added further complexity; some member states (such as the UK, Malta and Greece) have chosen to adapt their current legislation, whilst others have not yet indicated any intention to do so.

Of the 27 member states (i.e. not including Ireland), 16 charge, or plan to charge, a fee based on the number of CGC base stations deployed (with or without a separate MSS fee). Amongst those countries that charge per site, there is substantial variation in the level of fees, with annual fees per site ranging from €432 per year in Slovakia to €21,978 per year in Portugal.[22] . Unsurprisingly, per-site CGC fees also tend to be lower in countries where there is a high corresponding MSS fee (such as in Slovakia and Hungary).

Table 9 gives an overview of the policies applied by different EU member states. The information has been sourced from a combination of:

- In the first instance, responses to a questionnaire sent by ComReg to BEREC;
- the findings of a 2016 consultation on MSS and CGC fees undertaken by the Greek NRA EETT[23];
- NRA websites and national legislation; and
- a study prepared for the European Commission by OLSWANG LLP on MSS authorisation regimes in EU member states.[24]

[22] It should be noted that in some cases licence conditions apply that might affect the value of the spectrum and the level of fees to be charged. For example, prices are generally lower if licence conditions require CGC stations to be used only as a repeater, as in Slovakia

[23]http://www.eett.gr/opencms/export/sites/default/admin/downloads/Consultations/RadioCommunications/Mss_aero_CGC.pdf

[24] "MSS authorisation regimes, authorisations and enforcement in the EU Member States", SMART 2013/0013, OLSWANG LLP (2013)

Table 9: Comparison of fee structures across Europe

Member State	Description
Austria	Monthly spectrum fee: €581/400KHz. The corresponding annual fee is €522,900.
Belgium	CGC fees: €1,500 per base station per year. Administrative fee for registering an electronic communications service: €546 (capped at €1,092 if registering more than one service). Additional fee based on yearly turnover: €510 - €150,000
Bulgaria	MSS fees: BGN 100,000 (€51,000) per year. CGC fees: BGN 400,000 (€204,000) per year if a CGC is deployed (regardless of number of sites). Issuance fee: BGN 5,000 (€2,500) Annual control fee: 0.2% of gross revenue (if revenue > BGN 100,000).
Croatia	MSS is under general authorisation – no specific fee. CGC fees: HRK 1,500 (approx. €200) per MHz per year for each CGC station.
Cyprus	CGC fees: €2,500 operational fee per year per site. General administrative fee: €10,000 per year (covering the whole authorisation).
Czech Republic	CGC fees: CZK 3.2 million per 2x1 MHz per year = CZK 48 million (€1.8 million) for 2x15 MHz per year (Nationwide authorisation for CGC, valid for 5 years with potential for extension.) CGCs should only be used as repeaters. Issuance fee: CZK 3,000 (approx. €110) for registration with NRA.
Denmark	Annual fees (as of 2016): • Usage fee: DKK 600 (€80) • Spectrum fee: DKK 56,405 (€7,500) per MHz for a licence with nationwide coverage. The Greek consultation document suggests there are plans to change the fee structure to €12,000 per CGC site per year (for a 2x15 MHz authorisation), capped at approx. €226,000 in the case that the operator deploys more than 19 sites.

Estonia	No charges have been fixed for MSS with CGC as of yet. There is currently a general fee for complementary land components of €1,730 per site per year.
Finland	CGC fees: €13,991 per base station per year. (Annual CGC fees are determined by a formula based on geographical coverage, application and bandwidth used.)
France	CGC fees: €8,010 per CGC base station per year.
Germany	One-time authorisation fee: €3,000 (covers both MSS and CGC).
Greece	MSS fees: €7,500 per year Annual CGC fees: • €7,500 per base station per year for CGCs that are to be used for aeronautical purposes; otherwise • €30,000 for every block of 10 CGCs (whether the block is complete or not). Administrative fee: €440 per year. Fees will be reviewed every 3 years.
Hungary	CGC fees: • Frequency usage fee: HUF 112,500,000 (€359,000) per month (€4,308,000 per year). • Station fee: HUF 15,000 (€50) per month (€600 per year). These fees are based on the rules applicable to mobile services for the purpose of service provision. Annual market surveillance fee: 0.21% - 0.35% of revenue. There are plans for amending the Fee Decree to establish a special fee structure for use of MSS with CGC for aeronautical services (as envisaged by Inmarsat). This will be a monthly per CGC station fee of HUF 0.5 per KHz time bandwidth used by the station.
Italy	If CGCs are used as simple repeaters: • Spectrum usage fee: €22,200 per year. • Administrative fees per year: 1. €2,220 for up to CGC 10 sites; 2. €5,500 for up to 100 CGC sites; 3. €11,100 for over 100 CGC sites. If CGCs are used as base stations: • Spectrum usage fee: €7,216,171 per year for each 5

	MHz block. • Administrative fees: €127,000 per year.
Latvia	No fee for the authorisation. Annual fee of 0.2% of turnover for general regulation. €400,000+ for electromagnetic compatibility control.
Lithuania	MSS fees: LTL 14,083 (approx. €4,100) / MHz (for E-S link only) per year for nationwide coverage. CGC fees: LTL 14 083 (approx. €4,100) / MHz per year for nationwide coverage. (Unclear whether these fees apply separately for MSS and CGC).
Luxembourg	CGC fees: • Number of stations less than 10: €2,000 per station per year. • For more than 10 stations: €6,000 per year for each additional station in excess of 10. Annual fee of 0.9% of revenue.
Malta	MSS fees: €2,000 in the first year, €1,000 per annum thereafter. At the time of writing, CGC fees are yet to be established with proposals currently included in a consultation process for a CGC licencing regime. The MCA proposes CGC fees that are dependent on the type of service provided: • Licence fees for aeronautical CGC services: €13,000 per annum (independent on the number of sites deployed). • Fees for service neutral CGC services: 1. Year 1 to year 5 of licence term: €33,000 per 2x5 MHz (€99,000 per 2x15 MHz) per annum 2. Year 6 to licence expiry (May 2027): €98,000 per 2x5 MHz (€294,000 per 2x15 MHz) per annum.
Netherlands	CGC fees: €10,865 per base station. 4% annual fee.
Poland	No fees for the MSS authorisation. Annual spectrum usage fees for providing mobile satellite services: • 12,000 PLN for earth to satellite • 40,000 PLN for satellite to earth

	• Total: 52,000 PLN (€11,746). CGC fees: PLN 250 (approx. €60) per MHz per year per municipality covered.
Portugal	CGC fees: €21,978 per year for each base station (using 2x15 MHz). Allocation of rights to use frequencies: €700 A revenue-based fee is also charged, dependant on level of revenue, but not a percentage of revenue.
Romania	MSS fees: €3,600 per annum. CGC fees: €240,000 per 2x1 MHz per year (€3,600,000 per year for a 2x15 MHz licence), or €60,000 per MHz per year for unpaired spectrum.
Slovakia	CGC fees: €36 per month (€432 per year) per base station, if it only used as a repeater (otherwise fees for land mobile networks apply). 0.08% of revenue
Slovenia	Formula given in legislation dependant on amount of bandwidth used and geographical coverage. It is given by F=B*C*E*Value, where B is a parameter determined by frequency, C dependant by bandwidth, E by coverage and 'value' is a number set by their telecommunications act (0.49 for 2016). This gives €29,400 per year for a national licence.
Spain	Annual spectrum usage fee: €74,000. CGC fees: €2,500 - €3,500 per site.
Sweden	Annual Fee of €85,000, which is not MSS/CGC-specific. 0.0045% of revenue supervision fee
United Kingdom	No MSS fees. CGC fees (for two types of available licence): • Spectrum Access 2 GHz Licence: 1. National licence 2. £554,000 (€640,000) per 2x1 MHz per annum (independent of number of sites) 3. Translates into £8.31 million (€9.87 million) per 2x15 MHz per annum • Network 2 GHz Licence:

1. Licence to cover pre-defined regions (50x50km grid squares)
2. Annual fee per 2x1 MHz for each bases station, depending population density at location of the base station: £64,000 (€74,000), £8,025 (€9,200) or £825 (€950)
3. Translates into £960,000 (€1.11 million), £120,375 (€138,000) or £12,375 (€14,250) per 2x15 MHz per annum per base station

The two charts below show the proposed fees for Ireland relative to the fees charged elsewhere (only for countries where the fee structures allow for reasonable comparisons to be made[25]):

- Figure 5 shows the proposed annual per–site CGC fee for Ireland (€2,300) alongside per-site CGC fees charged by other EU member states. In this case, other fees that cannot be attributed to individual sites (one-off administrative fees, annual fees that cannot be broken down into a per-site value etc.) are not included. In addition, where a range of fees might apply (e.g. in Luxembourg) we show the highest possible values in the chart.
- Figure 6 shows the proposed equivalent annual fee for a national CGC licence in Ireland (€5.06 million, assuming 2,200 sites) alongside national authorisation fees charged by other EU member states (where applicable), expressed in €/pop. In this case, we include other annual fees if possible and where deemed applicable (e.g. if there are separate fees for MSS and for CGC, but they are both annual fees for a nationwide authorisation, we include both).

[25] Note that we have not always been able to include all applicable fees in the values reported e.g. where revenue-based annual fees are charged, or where one-off fees apply. This means that in some instances the fees used for comparison are below what the operators would pay in reality and, therefore, understate the fees relative to the proposals for Ireland.

Figure 5: Comparison of per-site CGC fees

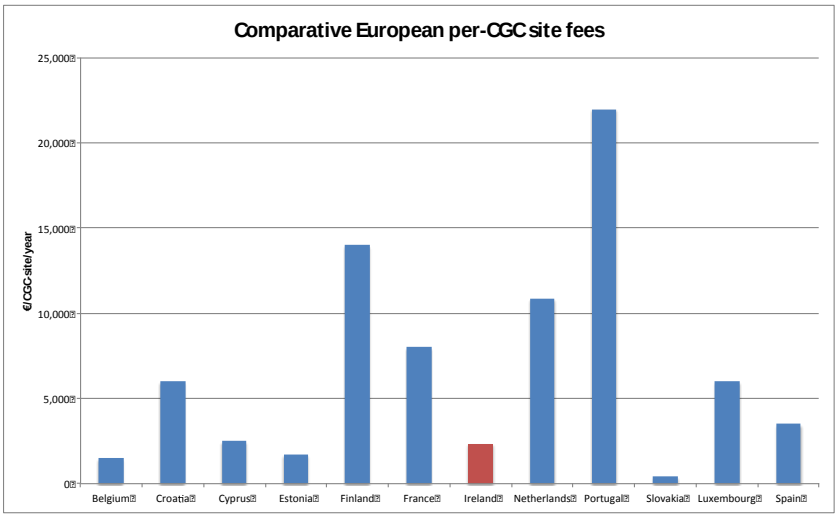


Figure 6: Comparison of national MSS with CGC authorisation fees

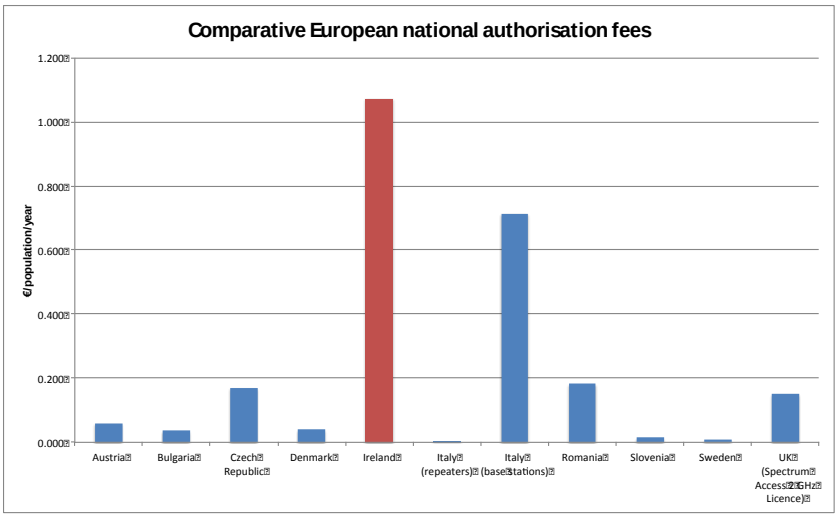


Figure 5 shows that the per-site fees proposed for Ireland are at the lower end of per-site fees charged elsewhere in Europe. On the other hand, Figure 6 shows that were a MSS licensee to deploy a similar number of base stations as that used in a typical terrestrial mobile network, the total cost would be high compared with the annual fees charged for national authorisations in other countries. This is consistent with the dual objective that aims to ensure operators deploying a network large enough to compete with mobile operators will need to pay fees that approximately represent opportunity cost (to prevent unfair competition), whilst fees for smaller networks are sufficiently low to avoid disincentivising deployment.

5 Conclusions and recommendations

The European Commission Decision 2007/98/EC granted two operators, Inmarsat Mobile Ventures and Solaris Mobile Limited (now EchoStar) a pan-European authorisation to provide mobile satellite services (MSS) using the 2 GHz spectrum, with the right to broaden and enhance services using complementary ground components (CGCs). The MSS license was issued on a pan-European basis, but Member States must grant CGC authorisations individually subject to a number of conditions. This report has considered how to determine the level and structure of CGC authorisation fees in Ireland.

ComReg previously consulted on this issue in 2009. However, considering the time elapsed and changes to timetabling it is appropriate to reconsider the best approach to setting the relevant fees. Statutory obligations and preferences dictate that the fees ComReg sets should satisfy its policy objectives to promote competition, contribute to development of the internal markets and to promote the interests of its users. The proposed fees should be: in the form of an annual fee for each base station, designed to encourage efficient use, take the current use of similar frequencies into account and be reflective of the opportunity cost of relevant bands.

The concept of opportunity cost, as defined by the value of the best alternative use foregone, is widely used to price spectrum licenses as to best promote efficiency. Typically, opportunity cost pricing is achieved by the use of auctions; ComReg has expressed a preference for using such market-based methods in its own decisions. Incentives for efficient use and allocation of spectrum will be enhanced by predictable and consistent application of opportunity cost pricing principles wherever applicable.

The relevant 2 GHz MSS and CGC license does not, however, lend itself easily to such methods – Inmarsat and EchoStar have sole use of this spectrum, creating some challenges in determining the appropriate opportunity cost as there are no alternative users until the expiration of the license in 2027. This renders the short-term opportunity cost formally equal to zero, and yet pricing on this basis (i.e. setting CGC fees of €0) is not desirable as it can lead to a variety of inefficiencies both in allocation and use of spectrum, including the hypothetical possibility of unfair competition with mobile operators.

Instead, we use a broader view of opportunity cost to determine prices by instead focusing on commercially and technically similar spectrum for benchmarking. This approach is desirable as it avoids setting a poor precedent for future pricing and fosters incentives for

efficient spectrum use in the long-run when the current MSS license expires.

However, as well as these long-term efficiency considerations, distorting incentives in the short-run should be avoided. Specifically, the 2 GHz band is adjacent to 2100 MHz spectrum band used to provide mobile services. The MSS fees must therefore balance two competing incentive considerations:

- Although a purely hypothetical concern, an MSS licensee may have the ability to provide a service using the CGC that competes at the margin with terrestrial mobile services. If CGC charges are not set adequately high this could be achieved at a discount, risking a distortion of competition.
- The 2007 Decision permits the use of CGCs, but does not require it. CGC deployment might yield high social value when extending coverage to locations that would otherwise be without, such as rural areas. Fees should therefore also not be so high as to significantly discourage deployment, especially in these regions.

In view of the tension created between encouraging CGC deployment whilst mitigating any future inefficiency in spectrum use or allocation, several options for pricing are considered. In the broadest terms, there is the decision between a flat and per-site fee structure:

- A flat fee for any number of CGCs has the advantage of avoiding roll-out disincentives, but may risk pricing off limited-use applications that have high value but low revenue potential;
- a per-site fee avoids this problem and is considered more suitable, especially given that there are no alternative users to accommodate.

Nevertheless, a per-site fee increases the marginal costs of roll-out and so has potential consequences for deployment incentives. There are a number of possible ways of mitigating this disincentive without creating a risk of competitive distortions:

- A conservatively set uniform price that is expected to provide a suitable balance, by being sufficiently low to keep small-scale CGC deployment feasible and attractive, but high enough such that fees for larger-scale networks sufficiently reflect opportunity cost to prevent unfair competition with terrestrial mobile services.
- Time profiled charging – for example, fees increasing over time. This incentivises early deployment and allows the fee to align with true opportunity cost as the license approaches renewal but is nevertheless a

somewhat arbitrary approach, especially when considering the already much-changed timetable.

- A fee structure non-linear and convex in number of sites. Low initial charges avoid depressing roll-out whilst high fees once a certain number of sites have been built disincentives mobile service provision. This approach has the additional advantage of being relatively straightforward to structure and implement. However, given the uncertainty over potential use of the spectrum it is unclear precisely what the most appropriate discount structure and level should be.
- Geographical variation charges, such as those proposed by Ofcom in the UK, should incentivise deployment of stations in (cheaper) rural sites. This creates considerable complexity in classifying regions, and much of the benefit of incentivising rural deployment can be achieved via a simpler non-linear pricing structure.
- Charging only for spectrum in use has attractive long-term implications as it encourages efficient allocation, but is inefficient in the short-run as there are no gains to minimising the amount of spectrum MSS licensees use.

Our proposed approach to pricing is to use technically and commercially similar spectrum to benchmark a total value for the national 2 GHz license. This figure must then be converted to a per-CGC fee as a starting point for fee levels. To do this, we divide the national license value by the (upper-bound) number of base stations necessary for MSS licensees to provide a competing mobile service. Although in practice fewer base stations may be needed to deploy a mobile service, proposing a conservative fee is appropriate to ensure roll-out incentives are not strongly suppressed. The resulting figure reasonably balances encouraging CGC deployment and avoiding competitive distortions.

The most relevant comparator bands are the L band (1452-1492 MHz), 1800/1900 MHz, 2100 MHz/AWS, 2300 MHz and 2600 MHz bands. These bands are technically and commercially most comparable to MSS/CGC spectrum. Emphasis is placed on European, more recent and competitive awards.

The result of benchmarking and per-site conversion exercises suggests an annual fee per-site of approximately €2,300 is appropriate for the CGC authorisation fees. We consider this suitably conservative to encourage deployment, but also high enough such that large-scale CGC deployment could only be achieved at a cost that suitably represents opportunity cost, and so avoids competitive distortions in the mobile sector in addition to setting a favourable precedent to future pricing decisions.

There might be an argument for higher fees based on the upper end of the range of benchmarking results, although that would increase the risk of discouraging small-scale deployment. In that case it might be attractive to use a non-linear fee structure with a discount for small networks (where there is little chance of unfair competition with the mobile market) in order to keep small-scale deployment feasible. However, there is considerable uncertainty over the use and value of the spectrum, and we do not see any compelling evidence to suggest that this alternative price structure would be more appropriate or effective than the proposed uniform pricing structure.