Body of European Regulators for Electronic Communications

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BEREC report on practices on spectrum authorization, award procedures and coverage obligations with a view to considering their suitability to 5G

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Content

1. Introduction

As 5G technologies are being developed, European countries are considering the granting, amendment or renewal of frequency licences which could accommodate these technologies. It is also possible that 5G might be deployed using unlicensed spectrum.

The design of the selection procedures for spectrum licences and the conditions attached to these licences may have consequences on the structure of national mobile markets (either by enhancing competition or by limiting it).

The Radio Spectrum Policy Group (RSPG) has already produced report RSPG16-004 on Efficient Awards and Efficient Use of Spectrum, which provides a comprehensive analysis of different types of awards, discussed the trends and best practices, as well as how to address them in view of the objectives set and of the market context. This report was, however, concluded in the beginning of 2016 and based on information gathered in 2015.

In order to pave the way to 5G, the present report provides National Regulatory Authorities (NRAs) with an updated compilation of practices with regards to the market-shaping aspects of spectrum licence granting, amendment or renewal in the following bands harmonized for electronic communication services by the European Conference of Postal And Telecommunications Administrations (CEPT) and the European Union (EU): 700 MHz, 800 MHz, 900 MHz, 1500 MHz, 1800 MHz, 2100 MHz, 2300 MHz[1], 2600 MHz FDD, 2600 MHz TDD and 3400-3800 MHz (see Appendix 1).

This report focuses first on the features of past spectrum awards that have been conducted by the competent authority in each country (being the NRA or another entity) and on the rationales that drove competent authorities to make decisions regarding spectrum awards and licences. It provides some considerations about the choice and design of the award mechanism (section 2), the competition measures (section 3), the band structure and band bundling (section 4), the licence scope and conditions (section 5) and the coverage obligations (section 6).

It is to be noted that the considerations provided are reflecting what is the most common outputs of past recent spectrum awards and do not necessarily reflect best practices in this matter.

It finally provides some insights on future spectrum authorisation, award mechanisms and coverage obligations for 5G (section 7).

1.1. Authorisation regimes applied for ECS bands

Each Competent Authority makes decisions on spectrum management in accordance with the objectives and rules decided by the EU and national regulations.

[1] The 2300 MHz is harmonised at CEPT level only.

The so called ECS bands – frequency bands used for electronic communications systems – are harmonised in Europe (EU mandatory and CEPT voluntary harmonisation). The technical conditions are set on a common level but the authorisation process is managed on a national level. Harmonisation and standardisation enable economies of scale in manufacturing, and lower costs for radio equipment and transnational services. Setting minimum restrictive conditions (only those required to facilitate efficient spectrum use) enables uses with maximum societal benefits.

Decisions made by the Competent Authority responsible for the usage of ECS bands contribute to how various stakeholders can develop their business plans, both nationally and internationally. One of the challenges within spectrum management is coping with the ever increasing demand for spectrum and its new applications and technical solutions. Development of new radio with an increasing number of technical concepts like Internet of Things (IoT), 5G, beamforming, cognitive systems, active antennas and other more or less spectrum consuming applications facilitates a potential of a great number of new use cases, with relevance to an increasing number of businesses like verticals. This can be a challenge for the authorisation process. Spectrum should be administered in such a way that it provides the most efficient and effective level of use, to the extent that this promotes innovation, the development of technology and a broader range of wireless services.

There are three fundamental ways to authorise the use of spectrum:

- Through the central planning of frequency bands and assignments of frequencies to various stakeholders and various areas of use;
- Through awarding rights of use (auctions, beauty contests, etc.);
- Through common access (license exemption, general authorisations).

Spectrum was traditionally managed through central planning of frequency bands and assignments by Competent Authorities. However, the introduction of technology and service neutrality and market mechanisms has superseded this and now these principles provide the framework for spectrum management.

The answers to the first questionnaire mentioned in the introduction show that all competent authorities have used individual rights of use as an authorisation regime for the harmonised ECS bands and will do so in coming award procedures (as far as any information about that is given).

Therefore, the report focuses mainly on the award of individual rights of use.

1.2. Source material for the report

In addition to the reports mentioned above, the information provided in this report is based on information gathered from two questionnaires circulated to BEREC members in 2018:

- The first questionnaire focused on the authorisation regime applicable for operators to access spectrum resources to deliver electronic communication services (ECS), on the features of past spectrum awards and on considerations for future awards. 29 NRAs[2] answered this questionnaire.
- The second questionnaire was dedicated to coverage obligations that have attached to existing frequency licences and that could be attached to future frequency licences, in particular in the bands where 5G technologies will be rolled out. 26 NRAs[3] answered this questionnaire.

The information provided in the report is mainly based on "nominated award procedures" which correspond to examples of previous or planned awards that NRAs considered relevant in their answers to the first questionnaire. Most nominated award procedures are auctions that have already been conducted for the 800, 900, 1800, 2100, 2600 and 3400-3600 MHz bands. Although not as often, some nominated award procedures are more recent awards and/or procedures that are being planned. In this case, and besides spectrum previously auctioned that was not awarded because for which there was no sufficient demand, the bands at issue are primarily the 700 MHz band bundled, in some cases, with the 3400-3800 MHz band and, fewer times, with spectrum in the 1500 MHz and 26 GHz bands.

In addition, the report also provides some statistical information about past spectrum awards which is based on the characteristics of 283 award procedures[4] for individual rights of use of spectrum in ECS bands that are currently in place and the awards competent authorities are currently designing. The number of award procedures for each NRA and each band can be found in Appendix 2.

[2] European Union (EU) NRAs from Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Malta, Netherland, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden and United Kingdom and non EU NRAs from Montenegro, Norway, Serbia, Switzerland and Turkey.

[3] EU NRAs from Austria, Bulgaria, Croatia, Czech Republic, Denmark, France, Germany, Greece, Hungary, Ireland, Latvia, Malta, Netherland, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden and United Kingdom and non-EU NRAs from Former Yugoslav Republic of Macedonia, Montenegro, Norway, Serbia, Switzerland and Turkey.

[4] For the purpose of this section a spectrum award is defined as an assignment procedure of exactly one frequency band (e.g. procedures during which 3 bands were awarded count for 3 awards).

2. Choice and design of the award mechanism

Competent authorities use three main ways in which competent authorities may award spectrum:

- through auctions, competitive procedures, in which candidates make monetary bids for spectrum rights;
- through beauty contests, another type of competitive procedure in which competent authorities rank candidates in regard to specific indexes;
- and on a first come first serve basis.

Competent authorities might also design hybrid mechanisms combining characteristics of these three mechanisms.

As shown in the distribution of award mechanisms below (Figure 2), auctions are the most commonly reported chosen award mechanism in every band identified; their predominance is even more notable in recent awards in the 800 MHz and 2.6 GHz bands for example. Beauty contests come in second and are still chosen for recent awards.

However, competent authorities do not always use competitive mechanisms to award spectrum: first come first served is sometimes reported as the chosen method in bands such as the 1500 MHz, 2300 MHz or 3400-3800 MHz, which have not been assigned for mobile services in many countries as of yet and in earlier awards. This method has been used for 800 MHz and 2600 MHz FDD spectrum awards in one country when the supply of spectrum was sufficient to meet the demand.

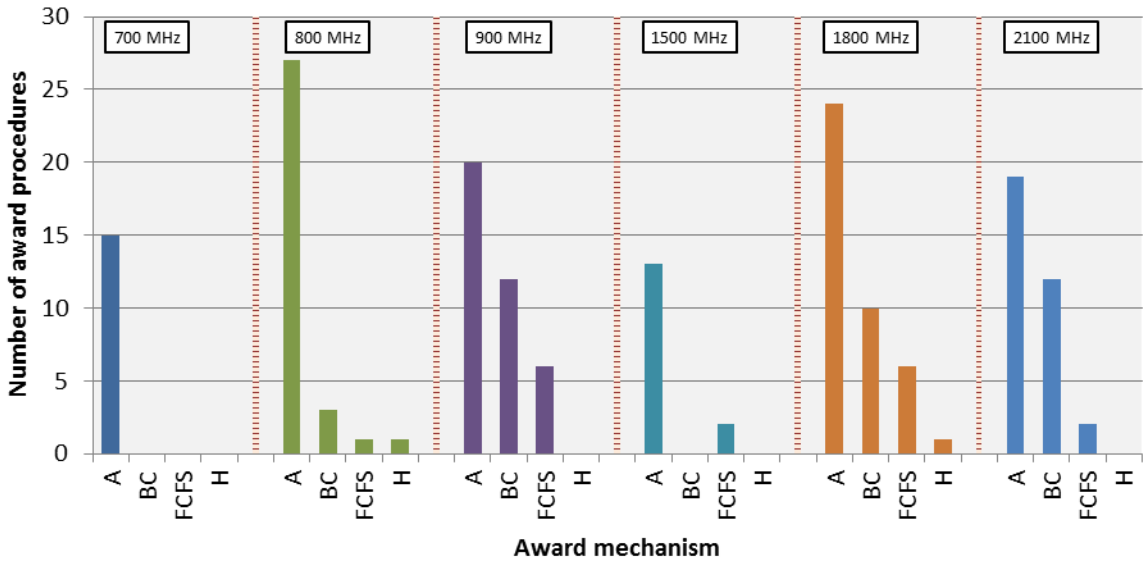

Figure 1: Distribution of reported award mechanisms in the 700 MHz, 800 MHz, 900 MHz, 1500 MHz, 1800 MHz and 2100 MHz bands (out of 283 awards reported by 29 competent authorities). A: auction, BC: beauty contest, FCFS: first come first serve, H: hybrid

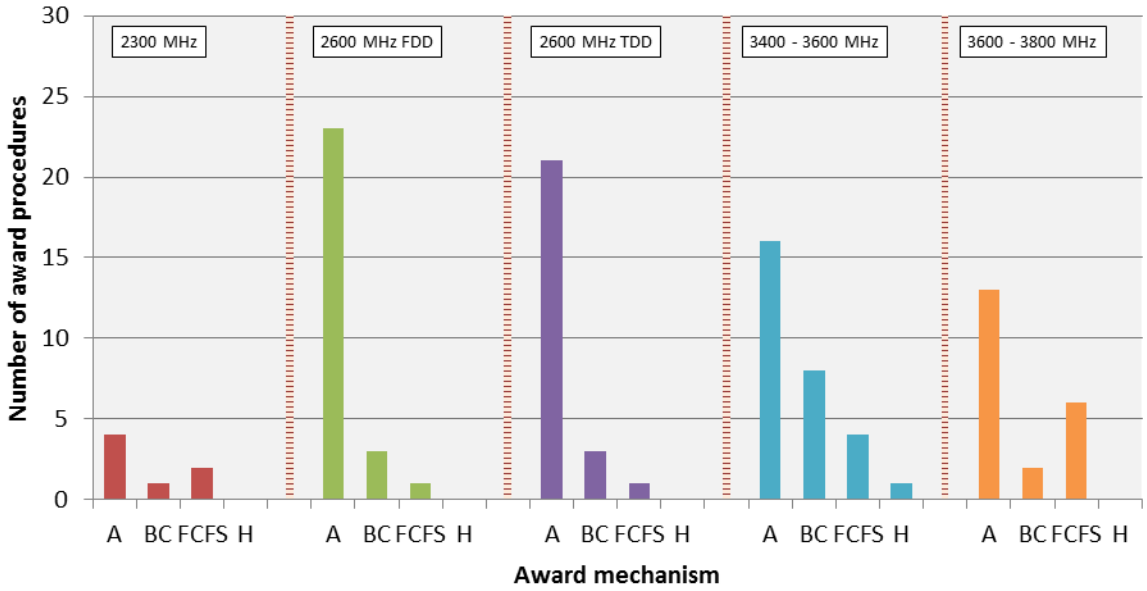

Figure 2: Distribution of reported award mechanisms in the 2300 MHz, 2600 MHz FDD, 2600 MHz TDD and 3.5 GHz (out of 283 awards reported by 29 competent authorities). A: auction, BC: beauty contest, FCFS: first come first serve, H: hybrid

This section provides the following considerations taken by competent authorities when they design spectrum awards:

- The objectives of the awards;
- The choice of auction format or the selection criteria for beauty contest or for hybrid procedures;
- The challenges they may face in conducting the award.

2.1. Award objectives

According to the RSPG Report on efficient awards, identifying and articulating public policy objectives is a strategic part of a well-designed award. It is important to be clear about what the Member State wants to achieve and this will then help to inform the award design and other related decisions.

BEREC asked NRAs to mention recent award procedures and to bring to light the objectives they have set as well as the market situation and the considerations that have been relevant for the design of the award procedure. The responses show that almost all award procedures mentioned by NRAs and for which relevant information on that subject has been provided, have been driven by certain objectives (approx. 90%). Only a few awards might be purely driven by legal provisions.

From the responses to the first questionnaire mentioned in the introduction, four main objectives can be identified that are common for the majority of the nominated award procedures (see table below):

- The most prevalent objective is competition on the downstream market as a means to promote consumer welfare. It has been an objective for the design of approximately 80% of the nominated award procedures.
- Efficiency follows in second place. Either economic or technical efficiency aims have been relevant for approximately 60% of the nominated award procedures.
- In third place is coverage (relevant for 55% of the nominated award procedures).
- The fourth main objective is innovation. This has been a relevant objective for the design of almost 50% of the nominated award procedures.

Main objectives	**Description**
Competition (consumer welfare)	- Preserve level of competition - Lower barriers to market entry - Foster market entry
Efficiency	- Efficient use of spectrum - Efficient assignment of spectrum - Selection of the most efficient operators - Selection of the operators that value the spectrum the most (assuming that the companies with the highest private values for the spectrum will be those that can use it to generate the highest value for society) - Ensure economic efficiency - Avoidance of winner's curse - Ensure technical efficiency (such as the assignment of contiguous spectrum blocks for broadband services)
Coverage	- Coverage - Connectivity - Broadband penetration - Regional development
Innovation	- Innovation - 4G development - 5G development - Conditions for further development of the ICT sector and promoting national development
Other objectives and considerations for designing the award procedure	- Promoting business opportunities - Adequate revenues - Information society strategies - Prevent collusion and strategic bidding - Creating investment and jobs - Legal standards (objective, non-discriminatory and transparent procedure) - Fairness - Freedom of choice - A practically and efficiently executable auction process - Making spectrum available in a timely manner

Table 1: Objectives of award procedures

Although some of the objectives are largely common, there are also national variations. For example, in some member states one of the objectives is to ensure a reasonable return on the spectrum assets. However, for the majority of member states generating revenue is not included as an objective.

2.2. Choice of an appropriate auction format

Several auction formats have been used for awarding spectrum in Europe. The most common ones are simultaneous multiple round ascending auction (SMRA), combinatorial clock auction (CCA) and sealed bid auction. As already highlighted by the RSPG report on efficient awards, there is no one-size-fits-all. Each of the formats has advantages and disadvantages. The choice of the most appropriate format depends on the objectives and the market circumstances. This section describes these parameters more in details.

Market circumstances are a key criterion for the design of the auction whereby demand side factors as well as supply side factors matter:

- Typical supply side factors are the amount of spectrum available, the number of lots and the homogeneity/substitutability of those lots.
- Typical demand side factors are the number of participants (relative to the supply), the specific competitive situation on the downstream markets and the degree of heterogeneity of demand that matter.

It is one of the main targets of an efficient award procedure to optimally match demand and supply. In this context flexibility and freedom of choice are mentioned several times. A certain degree of flexibility in the design of the award (lot structure, categories, etc.) seems to be crucial not only for ensuring an efficient distribution and use of spectrum but also for the implementation of the principle of service and technology neutrality where applicable.

A third group of design considerations can be classified under efficiency considerations. The purpose of the award is to setup a sound market mechanism in order to foster an optimal and efficient distribution/use of the scarce resource “spectrum” and to produce market prices. This again might require some flexibility in the auction to provide bidders with sufficient freedom of choice so that they can buy a portfolio of spectrum that suits them most.

A possibility to increase flexibility is by selling smaller pieces of spectrum. In fact, many NRAs prefer smaller lot sizes because it is perceived that small granularity provides bidders with the maximal freedom of choice (see chapter 4.2). This might raise concerns about different risks in the auction. If bidders have synergetic valuations for bundles of spectrum blocks they might face aggregation risks in the auction. The presence of such aggregation risks might lead to the choice of a format that allows package bidding. If lots are substitutes, bidders need some flexibility in the auction in order to avoid substitution risks and to acquire the most valuable block given the relative prices in the auction. Also the risk that spectrum could become fragmented is regularly addressed. Price transparency and discovery could help bidders to overcome common value uncertainties (winner’s curse risk). Finally, NRAs are concerned about strategic bidding and gaming.

A fourth group of considerations refers to the acceptance of the design by market players and the practicability of the format. In this context, high transparency, simplicity or fairness can well be associated with the acceptance of a particular design. A quick and simple solution is likely to be chosen if transaction cost should be kept low.

Class	Design considerations mentioned by NRAs
Reach objectives	- Put emphasis on objectives of the award - Setup a competitive process in order to reach the objectives
Market circumstances	- The amount of spectrum and the number of blocks available - The homogeneity of blocks that are on sale (are they close substitutes or not?) - The number of participants and the specific competition on the market - The heterogeneity of demand (will the spectrum only be used for mobile services or for other services such as fixed wireless access services as well?) - The number of participants in relation to the spectrum available (flexibility to ensure an efficient assignment) - Market and technology development (flexibility to ensure services and technology neutrality)
Efficiency considerations	- Setup a market mechanism in order to foster optimal and efficient use of a scarce resource and to produce market prices. - Flexibility with maximum freedom of choice (ensure an efficient assignment/use of spectrum, allow operator to buy package that suits them most) - Presence or absence of aggregation risks (e.g. in connection with regional licenses) - Substitution risks and better control of options in the auction - Common value uncertainties (Winner's curse risk) - Fragmentation risks (risk that non-contiguous spectrum is assigned to operators) - Incentives for bidders to engage in a pro-competitive manner in the award procedure and to not engage in strategic bidding and gaming (e.g. strategic demand reduction, collusion, bid-shading, eligibility-parking or price-driving) - Price transparency and discovery
Acceptance and practical considerations	- High acceptance of the auction format - High transparency - Easy to understand and clarity - Low complexity - Quick solution - Simple solution - Fairness (equal opportunity by each bidder) - Result of public consultations

Table 2: Design considerations mentioned by NRAs (The information provided by NRAs does not allow deriving robust conclusions about the circumstances and considerations that might determine the choice of a certain auction format)

2.3. Choice of selection criteria for beauty contests and hybrid mechanisms

Less than 10% of the nominated award procedures are beauty contests or hybrid procedures (mix between beauty contest and auction). Determining appropriate and proportionate selection criteria that correspond with the objectives is a crucial part of the design of a beauty contest. In their answers to the questionnaire NRAs specified the following selection criteria in connection with the nominated procedures:

- Coverage
- Number of base stations
- Financial bid for the license
- A commitment to provide MVNO access
- Impact on market competition
- Investment
- Job creation
- Project consistency and credibility
- Business plan consistency and credibility
- Contribution to digital regional development (coverage commitments)
- Contribution to stimulating the market with affordable products
- Declaration of providing so called “social Internet” (lower prices for Internet access)

Some NRAs state that the main source of these criteria are the award objectives, of which coverage (especially in rural areas) and competition seem to be the most relevant ones. Apart from those, the financial bid seem to play an important role.

2.4. Challenges

Preparing and conduction an award procedure is a complex and challenging project, which may include the following tasks:[5]

- Setting the award objectives
- Conducting a competition and market analysis
- Conducting a technology development analysis
- Options analysis for the award design
- Product design (lot structure, license duration, etc.)
- Defining market shaping instruments (e.g. spectrum caps)
- Specific design of the auction or of the beauty contest
- Conducting consultation processes

[5] A list of tasks can also be found in the RPSG report RSPG16-004 on Efficient Awards and Efficient Use of Spectrum.

- Developing and testing software
- ICT planning for the electronic auction system
- Drafting and publishing documents (e.g. information memorandum)
- Defining the process and planning the support for the auction
- Ensuring security and reliability
- Organizing bidder trainings and mock auctions
- Conducting the auction or beauty contest itself
- Post award processes (such as the publication of results, the monitoring of the long term effectiveness of the award)
- Parallel assignment of spectrum expiring at different times aiming at the simultaneous expiration of the new spectrum awarded

Challenges have been mentioned in connection with approximately 20% of the mentioned awards. They are listed in the following table.

Design and preparation	- Novelty of the auction format or the award method (hybrid mechanism) - Implementation of a rather complex format such as the CCA - Many challenges due to the fact it was the first auction - Balance different objectives of the award procedure (e.g. investment, competition and revenues) - Build the electronic auction platform - Complexity of the auction rules - Applying rigorous qualification criteria (beauty contest)
Auction	- Tacit collusion - Long lasting auction - Lack of demand - Unsold spectrum
Complaints by bidders	- Complaints about high prices - Complaints about spectrum caps - Complaints about asymmetric prices
Others	- Keep existing users in the same position in the band - Interaction of award procedure with ongoing mergers - Execution of several parallel procedures - Different expiration dates (spectrum that is renewed) - Post award litigation

Table 3: Challenges in connection with award procedures

3. Competition measures

This chapter sets out any competition measures that the spectrum awarding authority took into consideration when designing the award procedures. Generally, the design of the selection procedure can have an impact on competition, particularly how the market structure will look like after spectrum was assigned – i.e. it can determine the number of mobile operators and whether other operators than mobile network operators can also enter the market and offer mobile retail services to end users, such as MVNOs. It therefore may make sense to address specific competition concerns, e.g. whether the existing market structure is already prone to market foreclosure or should market entry of new operators be incentivized or facilitated to allow for more diverse offers at the retail level. But even if there was effective competition in the mobile market, a new award procedure could change the existing market structure toward more market concentration without incorporating any safeguards in the selection mechanism.

Competent authorities may use several measures to safeguard competition and to address competition concerns:

- Spectrum caps are used to restrict the maximum amount of spectrum a bidder is allowed to buy. A spectrum cap can be imposed on a single band or it can be imposed on a group of bands (combined cap). Spectrum caps can be symmetric for all bidders or asymmetric with a tighter or loser cap for certain bidders.

- Spectrum can be set aside or reserved for certain bidders or group of bidders (e.g. for new entrants). The other bidders would not be allowed to acquire reserved spectrum.

- Wholesale access obligations can facilitate market entry of mobile network operators (e.g. national roaming and access obligations to sites and masts and other critical infrastructure that cannot be replicated by other operator) and MVNO / service providers to allow competing at the retail level.

3.1. Competition concerns

Competition concerns were perceived by most respondents. Those concerns relate to extreme asymmetric spectrum holdings and distribution of spectrum, foreclosure strategies particularly towards smaller operators or new entrants without spectrum holdings, tacit collusion leading to collective dominance, strategic bidding (e.g. operators bid for more spectrum than they need) or spectrum hoarding. Some respondents have taken measures in order to ensure a non-discriminatory award procedure, or to increase consumer demand. In one Member State the objective is to have a certain number of MNOs to ensure competition. One NRA assessed asymmetry of spectrum holdings with regard to the usability within a specific timeframe and concluded that very asymmetric spectrum holdings of immediately useable spectrum could adversely affect competition in the period before the 3.4 GHz band became useable.

3.2. Spectrum caps

Spectrum caps have not been used in all countries. One NRA reported that the reason for not applying a spectrum cap is when the demand is low. In fact, some NRAs did not set spectrum caps at all or imposed caps only on reserved spectrum that were to be auctioned.

Still, spectrum caps are commonly used by many countries and Table 7, Table 8 and Table 9 in appendix 3 display the spectrum caps that were actually imposed by the NRAs - particularly the spectrum caps employed in each band, the number of countries and the percentage rate of the spectrum caps for each band and for combined bands.

As shown by the tables, spectrum caps are not limited to specific bands, and they are either set per band or combined across several bands. Spectrum caps are quite commonly applied in the 800 MHz band at 20 MHz (2×10 MHz) in ten countries. They are mostly applied uniformly, but in some countries spectrum caps are being differentiated between operators:

- for instance, the incumbent operator could be only entitled to have a lower cap compared to its competitors (e.g. 40 MHz, and 80 MHz for the other operators).
- In another case, a distinction was made between 2G/3G and 3G only operators.

In some cases, spectrum holdings are limited by a combined cap when the spectrum holder acquired spectrum in several bands. Spectrum caps are in some cases also employed area-wise, such as for instance in specific regions.

Consideration on the percentage of the maximum amount of spectrum that operators are allowed to obtain during the award procedures (see 7, Table 8 and Table 9 in appendix 3) showed the following:

- the lowest caps for paired spectrum were set in the 900 MHz band, where the caps start at 9.6 MHz (2×4.8 MHz), which amounts to acquiring a maximum of only 13.7% of the available amount of spectrum in that band. At the same time, the 900 MHz band exhibits the widest percentage range of spectrum caps, spanning from 13.7% to 75%.
- The 2600 MHz band also shows quite a range owing it to unpaired spectrum, where the cap starts at 5 MHz, amounting to only assigning 14.3% of the available spectrum in that band (due to only 70% of the available spectrum being awarded in that country).
- In the other bands, more spectrum was available for each operator within the cap range, for instance in the 700 and 800 MHz bands. Spectrum holding is limited at approx. 33% or 50% of the whole amount of spectrum in those bands.
- The amount of spectrum is less limited in the higher frequency bands, except for the 2600 MHz band.
- The highest caps were set in the combined bands with more than two bands combined and those combined bands which include almost all spectrum bands, allowing operators to acquire higher amounts of spectrum.
- Some of the very low spectrum caps are due to a lesser amount of spectrum awarded than actually were available.

In most countries, there are no provision to limiting the amount of spectrum a licensee can retain during the entire duration of their licence, i.e. the spectrum caps are only employed during the award procedure and are not applied for the duration of the license (for instance

during spectrum trading). In a few countries, provisions are in place, such as an annual review of spectrum caps. These provisions are sometimes included in the national frequency regulation, where for instance a review of the regulation would limit the license duration and where a license duration of more than 10 years would require the NRA to review the spectrum holding.

3.3. Spectrum reservation

Spectrum was reserved only in a few cases and concerned the 700, 800, 900, 1800 or 2100 MHz bands. One NRA is currently considering spectrum reservation in the 700 and 2300 MHz bands. Spectrum is being reserved both for new entrants and operators with spectrum holdings, as well as for operators with a market share of 15% in the retail market (could be both new entrants and MNOs with spectrum holdings) and lot-wise, i.e. reserved spectrum would in such a case be assigned to one lot where there is demand for spectrum. The main reason for reserving spectrum is to ensure competition and to secure the supply of mobile services.

3.4. Other competition measures

As to other measures to address competition concerns, half of the respondents did not consider it necessary to impose any measures. Some NRAs are considering implementing competition measures for future award procedures.

Where NRAs have implemented competition measures, the most common were national roaming (in some cases limited for a specific period), access obligations for MVNOs, sharing agreements or extended duration of coverage obligations for new entrants. One NRA added an obligation for operators to provide a specific service to the public to mitigate high market prices. In one country competition measures were rejected by the court. In another country the two merging MNOs were required to surrender some of their sites.

4. Band-bundling and band structure

This section provides a review of the reasons put forward by competent authorities for deciding on the bundling of different bands in a single award or not as well as rationales for defining the lot structure of the awarded spectrum.

4.1. Reasons for multiband or single band awards

The majority of the respondents have already conducted a multiband award and the decision to bundle the bands into a single procedure have been based on the following benefits:

- to facilitate new entrants in the market by allowing access to an appropriate set of bands for the implementation of a new complete network (e.g. by awarding complementary bands, such as coverage and capacity bands);

- to allow for more flexibility, thus being able to suit different business models and/or by allowing bidders to react to prices and bids taking into account potential complementarity and substitution across bands;
- to provide the opportunity for operators to be awarded spectrum in bands that will allow them to both provide proper coverage and adequate capacity;
- general benefits in terms of improving competition and of using spectrum efficiently.

Some also referred that the option for a multiple band award was supported on advice from experts and on the responses received in the course of the public consultation process.

Most of the reasons listed above were mentioned by several respondents and also a few MS that have not undergone a multiband award provided similar views about the rationale that could drive them to conduct such a type of award.

The list of benefits is indeed similar to the conclusions gathered in the RSPG Report on Efficient Awards and Efficient Use of Spectrum (RSPG16-004)[6] and the motivation from the MS's side and recognition from market players of those benefits have not changed significantly since 2016.

In summary, the reasons commonly recognized by many of the respondents are both technical and/or market oriented as well as of an organizational nature (i.e. streamlining the award procedure for both market players and Competent Authorities).

Conversely, there are also spectrum managers that prefer to release the spectrum as soon as it becomes available. Again, this has also been noted in the RSPG Report dated from 2016 and the highlight was that in either option it is important to "ensure a steady flow of spectrum to the market in order to respond to market developments or technological changes to ensure that innovation is not hindered".

[6] See item 5.6 of this Report.

4.2. Band structure

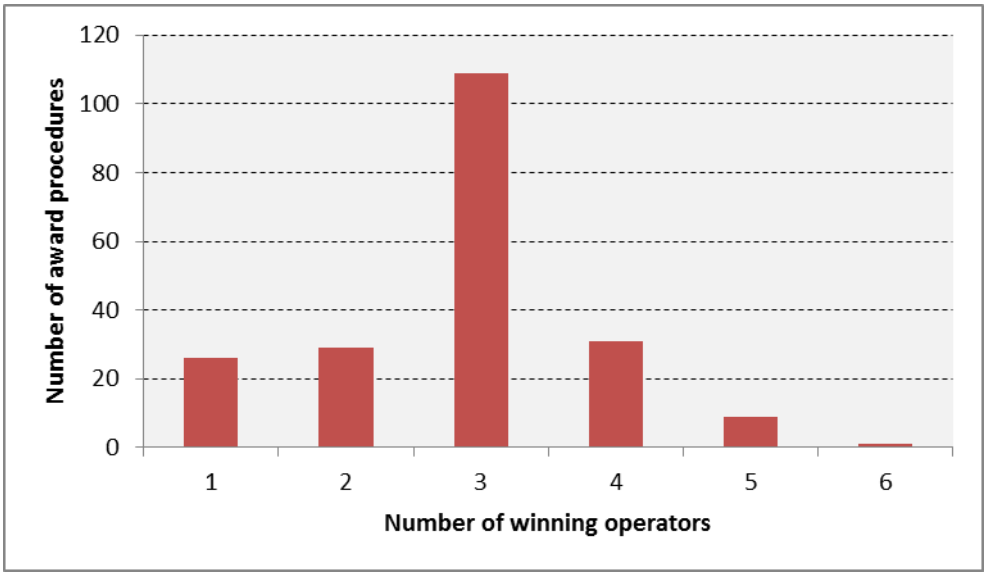

Figure 3: Distribution of the numbers of winners of national spectrum awards (out of 207 awards reported by 29 competent authorities)

Most awards being competitive in nature, they lead to a variety of results in terms of assignments sizes, band structure and number of successful candidates, depending on factors such as the amount of spectrum available or the number of operators in a country.

As shown by the distribution of the number of winners (fig. 2), a significant majority of award procedures end up with 3 winners. Cases where there is only one winner are limited to bands that have not been frequently awarded such as the 2300 MHz, 2600 MHz TDD and 3400-3600 MHz bands.

More than half of the award procedures reported in the questionnaire resulted in an equal distribution of the awarded spectrum. However, there are some notable cases in which the resulting band structure is significantly asymmetric with an up to 7/1 spectrum quantity ratio between assignments

In regionally assigned bands (see section 5.2), NRAs have reported up to 20 winners of regional licenses in a single award. These licensees sometimes coexist alongside operators with national licenses in the same bands.

The lot size may also influence the number of winners and is an important element in the design of the award. Therefore, the questionnaire also focused on the considerations for using a specific lot size. The considerations mentioned in the replies can be summarised as follows:

- Allow market players as much flexibility as possible

  Most of the respondents perceive that small granularity provides bidders with the maximal freedom of choice, while the issue of contiguity can then be addressed and guaranteed through the award design (assignment stage). In addition, assuring that spectrum is licensed on a technology-neutral basis is also an objective which can be achieved by defining lot sizes that allow market plays as much flexibility as possible. In most cases,

pursuing flexibility leads to choosing the smallest usable block size (see further detail on item 2.2, session regarding *Choice of an appropriate auction format*).

- Technical considerations

  Most of respondents indicate that lot sizes follow the technical harmonisation.

- Linkage between lot size and obligations

  Without prejudice to other lot sizes being settled in accordance with the rationale mentioned above, in some awards lots are defined with different sizes and are given different obligations accordingly. For example, some competent authorities apply specific coverage obligations to one of the lots and that lot size is determined in order to suit meeting those obligations (normally this lot is wider than the remaining).

- Safeguarding competition

  It was mentioned that blocks may be sized in order to foster that the number of winners be equivalent to the number of operators considered optimal. In order to pursue this objective, besides defining the size of the blocks, spectrum caps will also have to be applied. E.g., if the number of blocks is equal to the number of operators considered optimal and that is done by defining equally sized blocks, in the award design it will have to be guaranteed that each operator will not get more than one block.

- Avoid creating artificial scarcity

  The option for the smallest usable block size has been identified as a manner of mitigating the risk of artificial scarcity, thus leaving to each player the decision about how many blocks he would needed.

As a general objective, some of the respondents also highlighted their aim to achieve a fair and non-discriminatory competition for spectrum. Furthermore, as mentioned by some, the options chosen have also taken into account the results from public consultations, namely information gathered regarding potential business cases including both existing and new players.

Having these considerations in mind, lot sizes reported are normally of 10 MHz and, although not as often, also of 5, 15 or 20 MHz. The basis for defining wider lots is normally linked with the requirements, namely to allow for higher bit rates. The RSPG report RSPG16-004 also addresses this matter and comes to similar conclusions about the lot sizes. One of the highlights from that exercise was the relevance of designing the procedure in order to counter the unnecessary fragmentation of the spectrum through an adequate award design. The answers received suggest that this is currently a common practice, i.e. that the design of the award takes into consideration that the spectrum assigned to each winning bidder is preferably contiguous.

5. License scope and characteristics

This section provides considerations on the following characteristics of awarded usage rights: their duration, scope and whether they are exclusive or not.

5.1. License duration

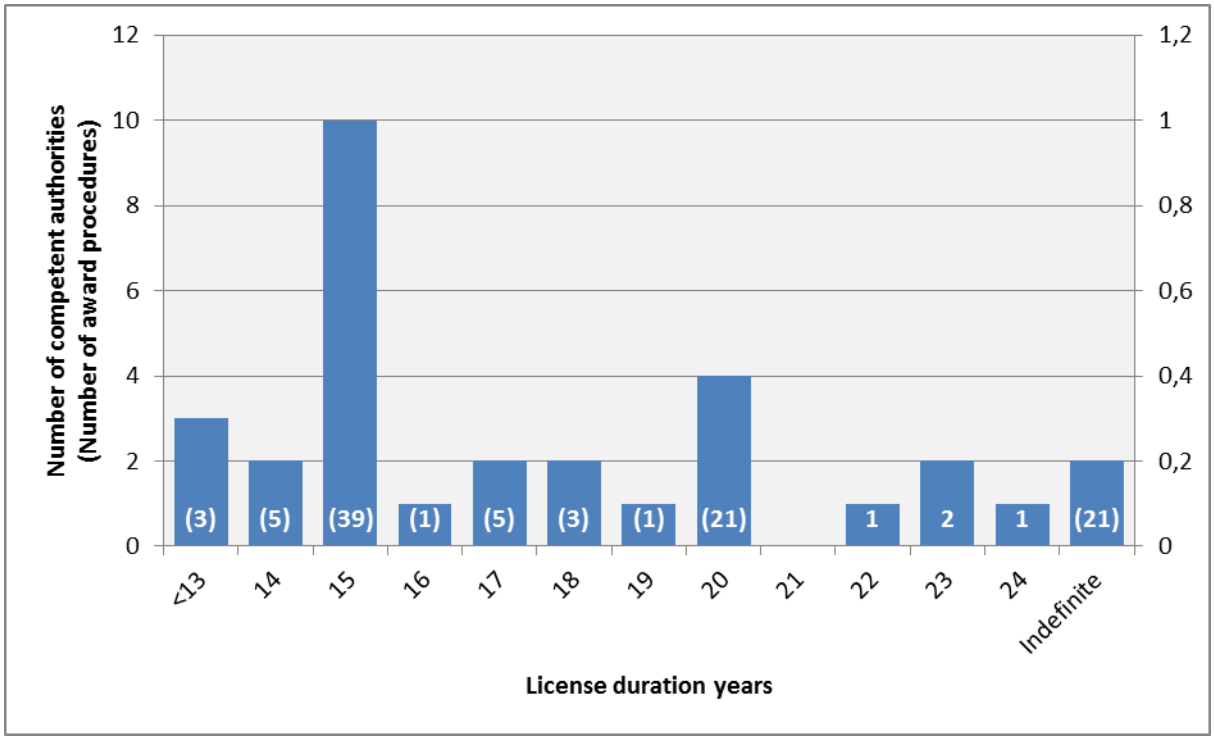

Figure 4: Distribution of license durations (out of 106 awards reported by 13 competent authorities)

The duration of a license defines the time an operator will be allowed to use the awarded spectrum and may thus give more or less predictability to the operator. As such, it is a key characteristic of spectrum licenses.

The most commonly reported license duration is 15 years with 10 competent authorities out of 13 that provided exploitable answers having awarded 15-year long licenses at least once. The second most reported durations are 20 years and indefinite with 21 awards each. However, these 21 awards of 20 year licences can be attributed to just 4 competent authorities while only 2 competent authorities award indefinite licenses. Indefinite licenses may include an initial period after which the license-holder's spectrum usage rights may be re-examined.

Contributors have also reported cases in which the license duration in a single band varies between operators. Sometimes, these licenses share a common end date but start at a different time.

Overall, contributors have reported issuing spectrum rights for durations in line with the new code i.e. at least 15 years, with only 3 cases out of a 100 reported of licenses shorter than 14 years awarded for fixed wireless services or to align licenses end dates in a band.

As for the considerations taken when setting the licence duration, the following arguments have been pointed out:

- investment security and predictability for both incumbents and new entrants (allow for planning reliability and amortisation of investments thus promoting investments and their sustainability);
- flexible market conditions;

- overall timetable for spectrum auctions in order to allow entering the market at regular basis (in some cases, a tentatively periodicity, e.g. every 5 years, is defined);
- synchronisation with other licences issued, e.g. in other parts of the band thus simplifying the next change-over in the band;
- reflect technology life cycles and therefore enable technological evolvements (encourage the deployment of new technologies);
- manage spectrum in an efficient manner (which is consequential to several of the above mentioned arguments);
- assessment of demand and national market circumstances;
- national and international benchmark information.

The 2016 RSPG Report on Efficient Awards and Efficient Use of Spectrum[7] also analyses this matter coming to similar conclusions about the impact of the licence duration and what should be taken into account when this duration is set.

In conclusion, the definition of an adequate duration of the rights is the result of considering and weighting the above mentioned arguments in order to successfully promote investment and, at the same time, continue to be able to adapt to technical innovation, to changes in consumer demand and to manage spectrum efficiently.

5.2. Geographical scope of licenses

When conducting an award, competent authorities may choose to assign spectrum on a national basis or on more limited scales to address different needs. The answers to the questionnaire show that the geographical scope of licenses is almost always national, except in the 1500 MHz and 3.4-3.8 GHz bands where some local or regional awards have been conducted, sometimes at the same time as national awards, and in some countries with overseas regions which decided to conduct specific awards in these regions.

With regard to the 3.4 - 3.8 GHz band, about half of the respondents indicates that regional licences have been awarded while others report having only national licences. In some cases, the regional licences are issued at the same time as the national ones.

With regard to the rationale behind the decision of having nation-wide rights, the reasons presented are normally:

- no demand from regional operators/result of public consultation;
- size of the country (in case of smaller countries);
- propagation characteristics of the bands, thus leading to a more efficient use of the spectrum (mentioned in the cases of the 700, 800, 900 and 1800 MHz bands);
- promotion of services at national level thus granting all citizens and consumers similar benefits;
- market interest.

[7] See item 6.1 and 6.2 of this Report.

As for opting for a regional scope, this was the preferred one in the case of one MS for the overseas regions, thus conducting specific awards in order to allow for more flexibility and better adapt to the different markets.

Furthermore, in the case of the 3.4-3.8 GHz band, from the responses that referred specifically to this band, a majority indicate having issued regional or, simultaneously, regional and national licences based. The arguments presented to support this option are the following:

- market demand and flexibility (potential different services and different market players according to the region);
- efficient use and effective management of spectrum (avoids the possibility of, afterwards, spectrum not being used in some parts of the country).

5.3. Type of rights of use (exclusive or shared)

The great majority of the answers provided indicate that the rights of use awarded for mobile services are exclusive. One of these respondents addresses specifically the possibility of sharing thus further clarifying that, subject to general competition law, sharing by the licence holders is possible.

However, some provide indication that the situation may evolve in the future and, namely, reveal that sharing with other services might be an option if deemed appropriate. Furthermore, four competent authorities indicate that individual rights are provided on a non-exclusive basis; nevertheless, some specify that the primary licence holder's use shall be prioritised and protected while secondary users may be permitted in the band on an interference free basis.

6. Coverage obligations

6.1. Review of existing coverage obligations

As referred to in section 1.2, for the purposes of this report, BEREC sent a second questionnaire asking specific questions to competent authorities on the type of mobile coverage obligations they currently attach to spectrum licenses (or Rights of Use - RoU), their characteristics and the rationality behind the obligations. While almost every competent authority has reported using coverage obligations, the answers display a wide variety in scope but a relative uniformity regarding the type of coverage obligations that have to be provided as shown by the distribution graph below.

A detailed analysis of the rationale for setting coverage obligations can be found in section 6.2 of the present report.

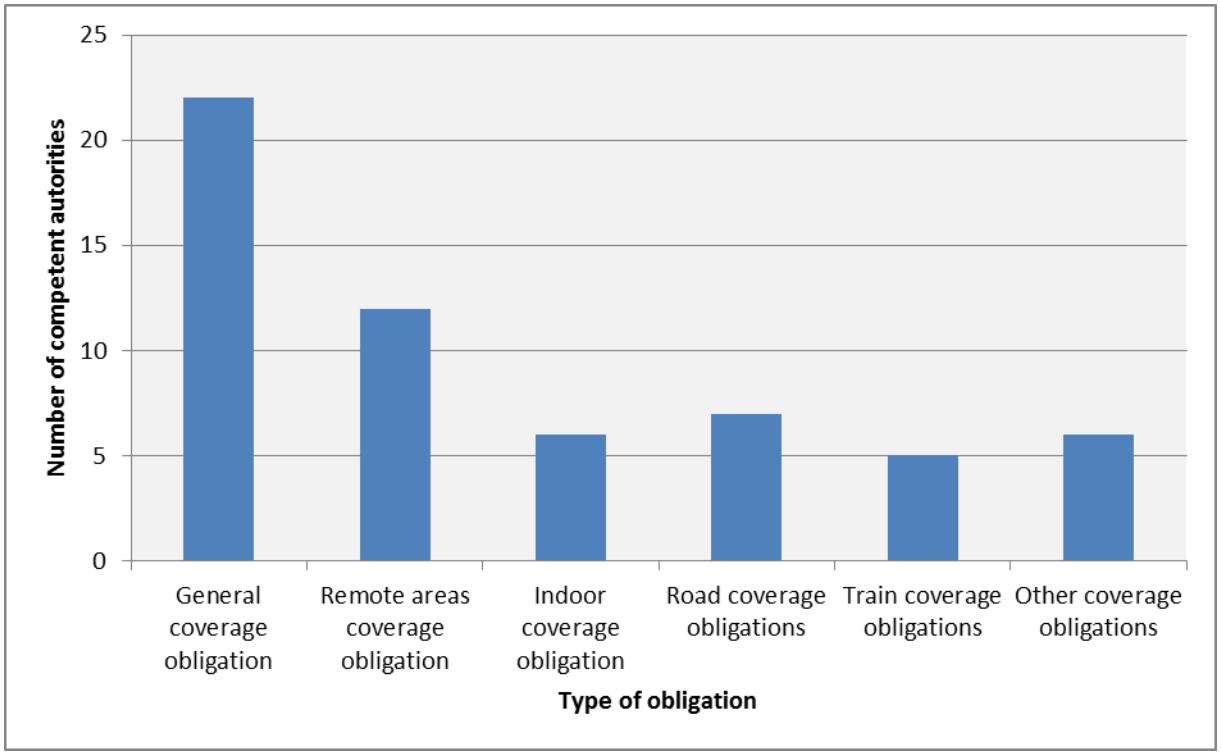

Figure 5: Usage of coverage obligation distribution

6.1.1. Services

According to the answers to the questionnaire, coverage obligations, regardless of their target, usually apply at least to data services and rarely only to voice services. Furthermore, to ensure that the adequate service is provided:

- most competent authorities define minimum quality of service operators have to respect; it is usually defined as a minimum throughput end-users should be able to experience or, for obligations that cover voice services, a maximum call drop rate and;
- about a third require a minimum availability of the service defined either as a maximum amount of time the service can be unavailable in a certain period or a minimum percentage of successful connection tests in any covered area.

However, concerning data services, from the answers received to the questionnaire, it was not possible to clarify if data rates, when imposed, are specified in which OSI layer (e.g. application, data network, physical) and what the data rate includes (payload, codification, signalling).

6.1.2. General coverage

A clear majority (22/26) of competent authorities impose general coverage obligations in at least one frequency band.

The target of these obligations is usually to bring mobile coverage to a certain level of population or households (16/26), less frequently a percentage of the territory (8/26) and rarely a specific number of base stations (3) or specified areas (5).

6.1.3. Challenge areas obligations

In 2017, BEREC and RSPG issued a joint report on facilitating mobile connectivity in "challenge areas", identifying specific areas where mobile connectivity is non-existent, namely remote areas, transportation routes and inside buildings. To address these connectivity challenges and to ensure an effective use of spectrum, most (16/26) competent authorities choose to impose specific obligations for at least one type of challenge areas (12 in remote areas, 6 indoor, 7 for roads and 5 on railways).

6.1.3.1. Remote areas

The competent authorities who have chosen to impose obligations to provide certain services to remote areas usually directly define the locations where the service has to be provided with a minimum throughput or a maximum call drop rate, depending on the service. These locations vary in size and go from individual end-users premises to regions. The service that has to be provided may be mobile broadband but also fixed wireless.

6.1.3.2. Indoor coverage

Competent authorities do not usually impose indoor coverage obligations as only 6 out of 26 respondents have indicated using them. When these are imposed, they are targeted at specific localities or premises with poor broadband coverage, sometimes they are defined in a similar fashion as general obligations, by population or territory.

While operators usually have to provide data service, in one case, they only have to provide voice services.

6.1.3.3. Transportation routes (road and train)

Most competent authorities do not currently impose road and train specific obligations in licenses/RoU: 5 do, one used to, one considered it but did not find them relevant to impose. An additional 2 competent authorities impose road-specific obligations but not train-specific obligations.

Road-specific obligations always target highways and most of the time other main roads. 2 competent authorities only target main railways or railways between large areas in their obligations and 2 others target smaller, regional or local railways.

In most cases operators have to provide data services with a minimum throughput and sometimes voice outside of the cars or trains. One competent authority imposes in-train obligations and is considering imposing in-car obligations.

6.2. Rationale for the mobile coverage conditions attached to the licences

Based on information gathered through the first questionnaire referred to in section 1.2, which took as a basis mostly awards that have already been conducted for the 800, 900, 1800, 2100, 2600 and 3400-3600 MHz bands and, not as often, more recent or under preparation awards

on the 700 MHz, the great majority of competent authorities indicates having mobile coverage conditions attached to the rights of use currently in force and/or which will be issued shortly (awards currently in progress). These coverage conditions are defined in terms of population and/or geographic area. Some common ground can also be observed with regard to the coverage obligations being applied gradually over a period, normally of 1 to 3 years, after the spectrum being assigned.

In addition, the answers show that, in many cases, coverage conditions reflect the inherent technical capabilities and intended use of each band, thus, in some cases, the focus is on extending coverage and, on others, the target is mostly to increase capacity or assure indoor coverage.

Furthermore, it can be noted that the obligations imposed are dependent on the characteristics of the country, namely in terms of population distribution and geography, as well as to the level of coverage already achieved at the time new obligations are imposed. Thus, the specific conditions attached at each point in time tend to mirror the countries' characteristics and needs at that period.

As referred to above, some lot sizes are defined to take into account those different coverage obligations (more demanding). In these cases, lots are normally wider.

With regard to the rationale that motivated defining coverage conditions, based on the responses, the following considerations/objectives have been mentioned:

- ensure that consumers are provided with a reasonable level of coverage/broadband coverage (e.g. depending on the bands, the target can be to foster broadband networks rollout in the main cities or the coverage of rural and sparsely populated areas, main transport routes, etc.);
- allow operators flexibility when defining the coverage obligations;
- avoid spectrum hoarding.

In pursuing these objectives, particularly when defining the coverage conditions for the 800, 900 and 1800 MHz bands, the following safeguards have been mentioned:

- safeguard against 'cherry picking' the most populated areas, achievable, e.g. by defining coverage obligations in terms of population percentage where the value for this percentage is above the sum of the population in the biggest cities (thus requiring a rollout beyond the population in those areas);
- at the same time, not to impose unnecessary burdens on operators and avoid inefficient infrastructure investment such as duplication of network infrastructure in low population density areas.

As noted in the RSPG Report on Efficient Awards and Efficient Use of Spectrum[8], it is important to ensure that spectrum managers have appropriate mechanisms to accurately measure coverage and identify if coverage obligations are being met. In this regard, attention should be drawn to the *BEREC Preliminary report in view of a common position on monitoring*

[8] See item 6.8 of this Report.

mobile coverage, from 6 October 2017. This work is currently being further developed with a view to reach a common position on this matter.

7. Future spectrum authorisation, award mechanisms and coverage obligations for 5G

7.1. Spectrum authorisation and award mechanisms for 5G

As previously noted, as 5G technologies develop, European countries are considering the granting, amendment or renewal of frequency licences which could accommodate these technologies. As regards the 5G pioneer bands (700 MHz, 3400-3800 MHz and 26 GHz bands), EU legislation has laid down a number of deadlines in order to facilitate the roll-out of 5G, subject to certain exceptions for justified reasons:

- Member States are required to allow the use of the 700 MHz band for terrestrial wireless broadband communications services by 30 June 2020[9].
- The European Electronic Communications Code requires Member States, by 31 December 2020, to reorganise and allow the use of sufficiently large blocks of the 3400-3800 GHz band and to allow the use of at least 1 GHz of the 26 GHz band, subject to demand and to any significant constraints on migration of existing users or band clearance[10].

The RSPG published, in early 2018, its 2nd Opinion on a Roadmap for 5G in Europe[11] in which it investigates sharing options and authorisation models. We note, and support, the message that “spectrum managers will need flexibility to choose the authorisation approaches most appropriate to address their particular circumstances and policy objectives”.

When looking at authorisation models, the findings from our questionnaire chime with the conclusions of the RSPG Opinion, namely that flexibility is required in order to employ a mix of authorisation approaches. These may include licenced and unlicensed use, on an individual or shared basis, and this sharing may be akin to the traditional ways of sharing we currently utilise, it might be on a geographical basis (national, regional, local and hyper-local) and indeed 5G may require more dynamic approaches to spectrum sharing that will require new and innovative tools to be developed.

[9] Article 1, Decision (EU) 2017/899 of the European Parliament and the Council of 17 May 2017 on the use of the 470-790 MHz frequency band in the Union, OJ 2017, L 138, p. 131.

[10] Article 54, Directive of the European Parliament and the Council of 11 December 2018 establishing the European Electronic Communications Code.

[11] RSPG 2nd Opinion - 5G Roadmap - January 2018

The bands currently identified as 'pioneer bands'[12] are a mix of low, mid and high frequencies which each have different characteristics and can be used to deliver different benefits. When looking at the different types of use foreseen by NRAs, all suggest a mix of usage. Low frequency spectrum (700 MHz) may be used to support improved coverage and end-user experience. Spectrum identified in the mid frequency range (3400-3800 MHz) may well be used to increase capacity for much in demand mobile services but might also be used for fixed wireless access (FWA) and backhaul services. And high frequency (mmWave) spectrum could be used to support new 5G applications, in particular those that require high capacity and very low latency. Most NRAs share the view that, while the 26 GHz band is likely to become important for 5G, at present it is too early to say exactly how the band will be used. Therefore, the question of authorisation and award remains theoretical as well, although it is widely assumed some innovative ways of authorising may be necessary. In the long term a variety of sectors may benefit from the use of the 26 GHz band, including the industry verticals (manufacturing, healthcare, transport, etc.).

The different bands identified may require different authorisation regimes, although again most NRAs note that it is too early to be definitive about this. Spectrum is already made available in a technology and service neutral way and this will continue with the 5G bands. However, spectrum managers will need to employ differing tools to make spectrum available in a variety of ways; for example, dedicated national licences, shared spectrum access and access on a licence exempt basis. And this may be at a national, regional or local level. Most, but not all, NRAs suggest that individual licencing is more likely in the 700 MHz and 3400-3800 MHz bands but are less sure about the 26 GHz band, noting it is too early to assess.

It should be noted that current assignments in the 3400-3800 MHz band have often been on a regional basis. However, some NRAs note that they consider re-assignment on a national basis. Almost all seem to favour a competitive award procedure for the 700 MHz and 3400-3800 MHz bands but some note that they may employ a 'first come first served' approach with the 26 GHz band. Again, there are many ways this can be divided geographically, which national licences being favoured for the low and mid frequency bands and potentially a more geographical approach taken in the 26 GHz band.

The relevance of sharing, and possible sharing models, still divides opinion. The majority of NRAs note that it is too early to comment but note that bands used to provide mobile broadband services can be difficult to share with other services; however this does not preclude investigating new sharing opportunities in order to promote the efficient use of spectrum. It seems likely that these new sharing opportunities are likely to manifest themselves more significantly in the 26 GHz band, and possibly the 3400-3800 MHz band.

There have been several '5G' auctions recently with more to come over the next 12 months. However, these have tended to be in the 700 MHz and 3400-3800 MHz band. Only one Member State so far awarded 1 GHz in the 26.5-27.5 GHz band within its recent 5G multi-

[12] RSPG 1st Opinion - 5G Roadmap - November 2016

band auction (including 700 MHz and 3600-3800 MHz band)[13]. The 26 GHz band is widely considered the most challenging band in terms of authorisation. Most NRAs which responded to the questionnaire remain open minded about what an award of spectrum in the 26 GHz band may look like.

7.2. Future coverage obligations for 5G

BEREC asked NRAs to provide information regarding the question whether the same kind of obligation as applied to older mobile networks generations for the bands currently in use (e.g. 4G) should be attached to licences in the 700 MHz, 3400-3800 MHz and 26 GHz bands, which can be used to promote 5G roll-out. A summary of the answers received are available in the following figures.

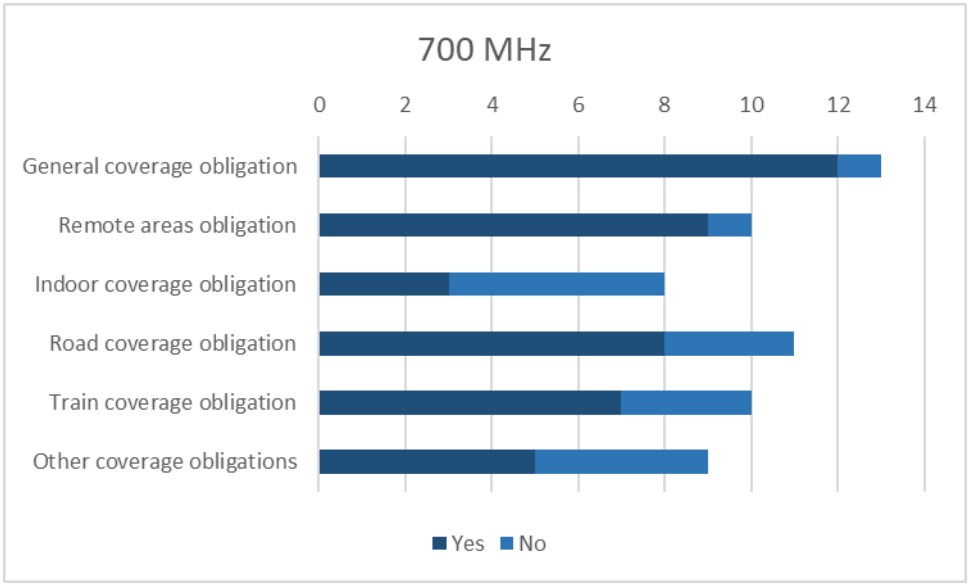

Figure 6: Coverage obligations 700 MHz

[13]In this case, the NRA set 5 nationwide rights of use of 200 MHz each, valid for 19 years, and set the so called "club use" model, according to which each licensee can dynamically use all the awarded spectrum (up to 1 GHz) in areas where frequencies are not used by other licensees. To this aim, licensees can stipulate commercial reasonable and non-discriminatory agreements, proportionally sharing the costs. Each licence holder has the pre-emptive right in favour on its assigned block of 200 MHz. Moreover, licensees can assign to a trusted third party the task of managing the uses to avoid harmful interference as well as the access scheduling.

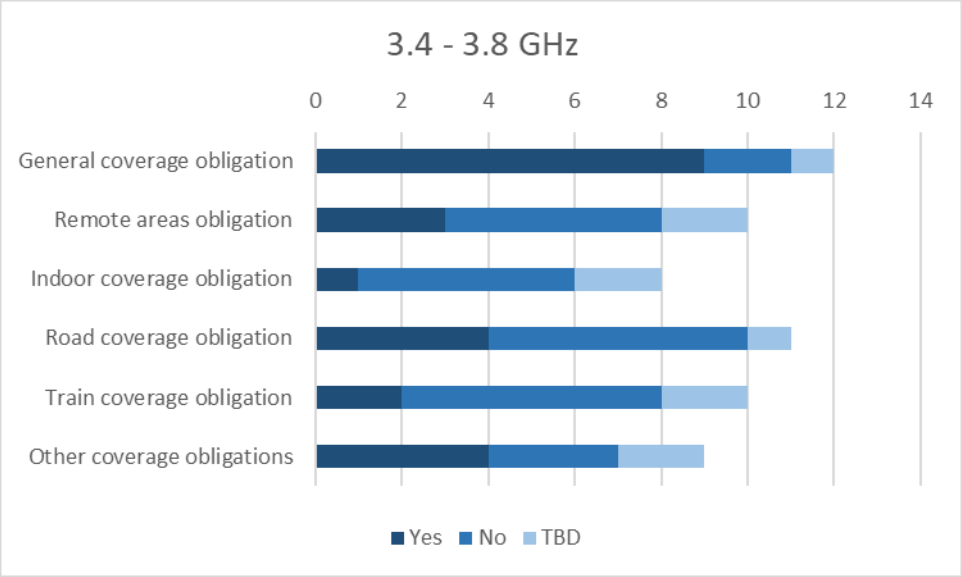

Figure 7: Coverage obligations 3400-3800 MHz

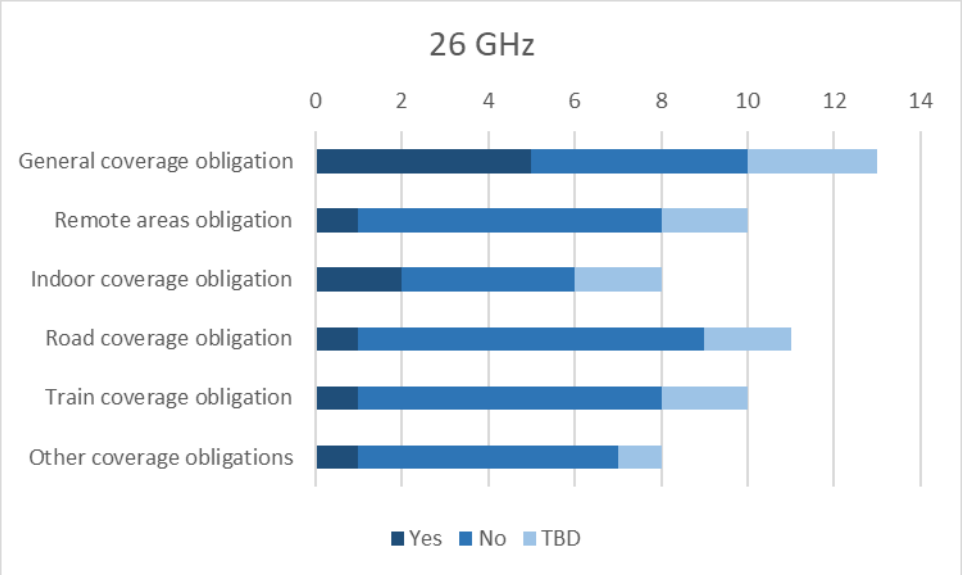

Figure 8: Coverage obligations 26 GHz

As shown in the figures above, NRAs still prefer general coverage obligations over specific coverage obligations, especially in higher bands (3400-3800 MHz band and 26 GHz band). However, compared to the existing obligations the importance of coverage obligations that focus on roads and railways seem to increase. This is in accordance with the European objectives on 5G coverage. To the contrary, indoor coverage obligations are not likely to play an important role. Not surprisingly, the figures also show that it is especially the 700 MHz band that is considered suitable to address “challenging areas” such as remote areas and traffic routes. In their answers NRAs expressed some doubts on the application of existing coverage obligations in the 26 GHz band.

The following list includes some of the coverage obligations and coverage targets for 5G that have been put forward by NRAs:

- General coverage obligations

- Major traffic ways (highways, major roads, railways etc.)
- Remote area obligation
- Specific locations obligations
- Area coverage (e.g. the area of each municipality)
- Enhanced mobile broadband in major cities
- Rural areas with inferior broadband coverage
- Households without any broadband connection
- Similar or same obligation as for legacy technologies
- Similar / the same obligations for 4G (different in different bands, but not different for different technologies)
- In the 3400-3800 MHz band it might be relevant to have coverage obligations similar to what is found for 2600 MHz and 2100 MHz bands, but with 5G-compatible quality requirements
- General and special PPDR obligations

Some NRAs consider capacity and quality of service obligations to be important for future awards (possibly defined on a case-by-case basis). That is something that might be different to the obligations for the bands currently in use. It is also mentioned that service availability at any moment, at any time and everywhere upon user's request with a certain quality of service becomes more and more crucial. However, defining obligations at this level is a challenge that should be carefully analysed.

Some NRAs regard it as important to take the needs of verticals into account when coverage obligations are designed. The current coverage obligations may not be suitable for the emerging divergent 5G use case. Those NRAs consider the obligations to reflect the needs of 5G use cases whilst still ensuring the efficient and effective use of spectrum. Depending on the kind of vertical, minimum quality of service or minimum availability of service could be included in the rights of use. One of the examples mentioned are capacity or quality of service obligations in the areas of big hospitals in order to enable remote surgery. Another example is an obligation alongside roads with specific capacity or quality of service obligations in order to support connected cars.

Other NRAs are rather sceptical on that issue. It is mentioned that verticals needs are difficult to foresee. There might be a lack of demand for certain use cases. Furthermore, in the 5G world of differentiated services it is unclear which quality of service will be required by the various use cases. This requires some flexibility to address their needs. The imposition of coverage obligations is not the only way to tackle the needs of verticals. It can also be addressed by assigning spectrum to a greater variety of players (e.g. by imposing sharing obligations that allow verticals to make use of spectrum that has been licenced to mobile network operators or other third parties) or by relying on co-investment models.

One NRA argues that market demand – coming at least in part from verticals – should dictate where 5G infrastructure is to be rolled out and to what specifications. It may be difficult defining coverage for 5G other than the traditional measures (e.g. field strength thresholds). One NRA states that it generally tries to avoid coverage obligations in "high" frequency bands.

Imposing coverage obligations in millimetre bands might be even more difficult. However, it could depend on the geographic scope of the licenses. If this spectrum is awarded nationally, coverage or service obligations seem inevitable to encourage the use of spectrum. If the awards are more local and if there is a greater variety of spectrum holders, coverage obligations become less important.

Many NRAs replied that it is too early to answer those questions and coverage obligations for 5G are currently discussed at an early stage.

Concerning the question about technology neutrality and the promotion of 5G, the most commonly reported opinion is that technology and service neutrality (including least restrictive conditions) shall be the dominant principle. It remains up to the market to roll out 5G, driven by demand and an accompanying business case. Given that the market will very likely use the bands in question for the introduction of 5G the corresponding coverage obligation will probably contribute indirectly to the rollout of 5G. At any rate, the conditions attached must not prevent 5G. It is important to enable the 5G rollout and coverage obligations should reflect the needs as required by the specific 5G use cases.

Some authorities suggest that although licenses are technology and service neutral, specific quality of service requirements can be used in order to ensure the deployment of 5G. Another way to foster 5G deployment is by referring to the 5G action plan that intends "*to meet the target of at least all urban areas and all major terrestrial transport paths, having uninterrupted 5G coverage by 2025*"[14].

[14]Communication COM(2016)588 from the commission to the European parliament, the council, the European economic and social committee and the committee of the regions (5G for Europe: An Action Plan), 14th September 2016: https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A52016DC0588

Appendix 1 – List of bands

Table 4: Bands considered in this report

Band name used in this report[15]	Corresponding frequencies
700 MHz	703-733 MHz and 758-788 MHz
800 MHz	791-821 MHz and 832-862 MHz
900 MHz	880-915 MHz and 925-960 MHz
1500 MHz	1427-1517 MHz
1800 MHz	1710-1785 MHz and 1805-1880 MHz
2100 MHz	1920-1980 MHz and 2110-2170 MHz
2300 MHz	2300-2400 MHz
2600 MHz FDD	2500-2570 MHz and 2620-2690 MHz
2600 MHz TDD	2570-2620 MHz
3400-3800 MHz	3400-3800 MHz
26 GHz	24,25-27,5 GHz

Appendix 2 – Reported award procedures

The following tables provide information on which award were taken into account in the making of this report:

- Table 5 provides the number of award procedures that have been reported by competent authorities in response to the first questionnaire mentioned in section 1.2 of the introduction. These procedures are the one used for statistical purposes in the report;
- Table 6 provides the number of award procedures that have been considered relevant for detailed considerations for this report by each competent authority. These procedures are refered in this report as “nominated award procedures”. Some competent authorities have provided detailed information on award procedures in general without targeting specific procedures.

[15] All bands benefits from both EU and CEPT harmonizations expect the 2300 MHz which is harmonised at CEPT level only and the 26 GHz whose EU harmonisation is under final process before adoption.

Table 5: Number of reported award procedures by competent authority and by band

	All bands	700 MHz	800 MHz	900 MHz	1500 MHz	1800 MHz	2100 MHz	2300 MHz	2600 MHz FDD	2600 MHz TDD	3400-3600 MHz	3600-3800 MHz
Total	283	15	31	38	18	41	33	7	28	26	32	22
Austria	10	1	1	1	1	1	1		1	1	1	1
Belgium	11	1	1	1	1	1	1		1	1	2	1
Bulgaria	16*	1**	1**	3	1**	3	1	-	1**	1**	3***	1**
Croatia	8		2	1		3	1				1	
Czechia	9	1	1	1		2			1	1	1	1
Denmark	12	1	1	2	1	2	1		1	1	1	1
Estonia	11		2	1		2	1	1	2	2		
France	19	1	2	3		3	5		2		3	
Germany	11	1	1	1	1	1	1		1	1	2	1
Greece	6			1	1	1	1		1	1		
Hungary	9		1	2[+]		1[+]	1[++]		1	1	1	1
Ireland	6		1	1		1	1				1	1
Italy	12	1	1	2	1	2	1		1	1	1	1
Latvia	10		1	1	1	1	1	1	1	1	1	1
Lithuania	11	1	1	1	1	1	1	1	1	1	1	1
Malta	11		1	1		1	1		1	1	1	
Montenegro	14	1	1	2	1	2	2	1	1	1	1	1
Netherlands	10	1	1	1	1	1	1		1	1	1	1
Norway	10	1	1	1	1	1	1		1	1	1	1
Poland	6		1	1					1	1	1	1
Portugal	12		1	3		2	2	****	1	1	1	1
Serbia	4		1	1		1	1					
Slovakia	11	1	1	1	1	2	1		1	1	1	1
Slovenia	12	1	1	1	1	1	1	1	1	1	2	1
Spain	9		1	2		1	1		1	1	2	
Sweden	8	1	1			1	1		1	1	1	1
Switzerland	7		1	1	1	1	1		1	1		
Turkey	6		1	1		1	1		1	1		
UK	10		1	1	1	1	1	1	1	1	1	1

* Includes both past and future plans to conduct award procedures
** Future plans to conduct award procedures
*** Includes both past (2 procedures) and future plan (1 procedure) to conduct award procedures
**** Spectrum used for SAP/SAB and radio amateur services granted on a first come, first served basis
[+] The award process concerned only part of the band
[++] The award process were more than 10 years ago

Table 6: Number of nominated award procedures by competent authority and by band

	All bands	450 MHz	700 MHz	800 MHz	900 MHz	1500 MHz	1800 MHz	1900 MHz	2100 MHz	2300 MHz	2600 MHz FDD	2600 MHz TDD	3400-3600 MHz	3600-3800 MHz	26 GHz
Total	131	1	9	17	15	6	22	1	10	3	12	10	12	10	3
Austria	5			1	1		1				1	1			
Belgium	7		1		1	1	1		1				1	1	
Bulgaria	0														
Croatia	2			2											
Czechia	9		1	1			2				2	2		1	
Denmark	4		1		1		1			1					
Estonia	3			1							1	1			
France	7		1	2	1		1		1		1				
Germany	11		1		1	1	2		2		1	1	1	1	
Greece	1						1								
Hungary	2												1	1	
Ireland	5			1	1		1						1	1	
Italy	5			1		1	1				1	1			
Latvia	1												1		
Lithuania	2				1		1								
Malta	0														
Montenegro	7			1	1		1		1		1	1	1		
Netherlands	6			1	1		1	1	1			1			
Norway	6		1		1		1						1	1	1
Poland	3			1							1	1			
Portugal	7	1		1	1		1		1		1	1			
Serbia	4			1	1		1		1						
Slovakia	3						1						1	1	
Slovenia	7		1			1			1	1			1	1	1
Spain	0														
Sweden	7	1	1			1	1						1	1	1
Switzerland	11		1	1	1	1	2		1		1	1	1	1	
Turkey	5			1	1		1		1		1				
UK	2									1			1		

Appendix 3 – Spectrum caps

Table 7: spectrum caps applied by NRAs to single bands below 1 GHz

Band	Number of countries	Cap (in MHz)	Cap in percentage of available spectrum(1)
700 MHz	1 2	20 MHz (2×10) 30 MHz (2×15)	33.3% 50%
800 MHz	10 1 1	20 MHz(3) (2×10) 30 MHz (2×15) 60 MHz	33.3% 50% 100%
900 MHz	1 1 1 1 1 1 3 2	9.6 MHz(3) (2×4.8) 10 MHz(5) (2×5) 12.5 MHz max (2×7.6, 2×1.4) 15 MHz 20 MHz (2×10) 23.2 MHz (2×11.6) 30 MHz (2×15) 40 MHz (2×20)	13.7% 50% 17.9% 75%(9) 28.6% 33.3% 43% 57.1%

(1) Percentage calculation: for each band it is the share of the spectrum cap and the total available/awarded amount of spectrum in each band; for combined bands it is the share of the spectrum cap and the sum of the total available/awarded amount of spectrum of the combined bands.

(3) Operators could acquire the maximum amount of spectrum in a given portfolio. Although the portfolio size limits the amount of spectrum, it should not be considered a spectrum cap. In another country reservation of in total 2x10 MHz in the 800 MHz band for new entrant (2 licences of each 2×5 MHz). In another country the caps are operator specific.

(5) To bidders that already are assigned spectrum in the same band.

(9) Reference is supply of 20MHz.

Table 8: spectrum caps applied by NRAs to single bands above 1 GHz

Band	Number of countries	Cap (in MHz)	Cap in Percentage of available spectrum[1]
1500 MHz	1 1	45 MHz not auctioned yet 20 MHz	 50%
1800 MHz	1 1 3 1 2 3 1	30 MHz 35 MHz[2] (2×10, 2×20, 2×29.8) 40 MHz[3] (2×20) 46 MHz (2×23); 60 MHz[7] 50 MHz (2×25) 60 MHz (2×30) 70 MHz (2×35)	20% 23.3% 26.7%; 35,01% 30.7%; 40% 33.3%; 35.7% 40%; 46.2%[8] 46.7%
2100 MHz	1 1 1	29.6 MHz[3] (2×14.8) 50 MHz (2×25) 60 MHz (2×30)	24.7% 41.6% 50%
2300 MHz	1	60 MHz (1×60)	60%
2600 MHz FDD+TDD, otherwise marked	1 1 1 1 2 4 1 1 1	5 MHz TDD 2×1×10 MHz TDD 15 MHz TDD 20 MHz (2×10) FDD 30 MHz (2×15) FDD 40 MHz[3] (2×20) FDD 50 MHz (2×25) FDD 55 MHz 60 MHz 2/3G; 80 MHz 3G FDD	14.3% 57% 43% 20% 21.4%; 30%[10] 28.6% 50% 37% 43%; 57%
3400-3600 MHz	1 1	60 MHz (6×2×5) 120 MHz	37.5% 75%
3600-3800 MHz	1 1 2	Up to 180 MHz (100 MHz[4]) 80 MHz incumbent; 160 MHz competitors (3600-3800 MHz band) 100 MHz TDD	45% (25%) 40%; 80% 50%

[1] Percentage calculation: for each band it is the share of the spectrum cap and the total available/awarded amount of spectrum in each band; for combined bands it is the share of the spectrum cap and the sum of the total available/awarded amount of spectrum of the combined bands.

[2] Each operator can submit a bid for only one packet and acquire 35 MHz max. taking into account already existing spectrum in this band.

[3] Operators could acquire the maximum amount of spectrum in a given portfolio. Although the portfolio size limits the amount of spectrum, it should not be considered a spectrum cap. In another country reservation of in total 2x10 MHz in the 800 MHz band for new entrant (2 licences of each 2×5 MHz). In another country the caps are operator specific.

[4] 100 MHz cap if more than three candidates; not auctioned yet.

[7] Second auction.

[8] In one country the reference is 130 MHz (2x65).

[10] Reference is supply of 100 MHz (2x50 FDD).

Table 9: spectrum caps applied by NRAs to a combination of bands

Band	**Number of countries**	**Cap (in MHz)**	**Cap in Percentage of available spectrum[(1)]**
700 / 900 MHz	1	50 MHz (2×25)	50%
800 / 900 MHz	1 2 3 1 1	30 MHz 40 MHz (2×20) 50 MHz (2×25) 60 MHz (2×30) 70 MHz	23.1% 30.8%; 50% 38.5% 46.2% 53.8%
700 / 800 / 900 MHz	1	60 MHz (2×30)	31.6%
800 / 900 / 1800 MHz	1 1	100 MHz (2×50) 140 MHz	35.7% 50%
800 / 900 / 1800 / 2100 / 2600 MHz	1 1 1	105 MHz FDD+TDD 210 MHz (2×105) FDD 270 MHz (2×135) FDD	17.8% 38.9% 50%
800 / 900 / 1500 / 1800 / 2100 / 2300 / 2600 / 3400-3800 MHz	1	340 MHz[(6)]	35.4%
800 / 900 / 1500 / 1800 / 2100 / 2300 / 2600 / 3600-3800 MHz	1	255 MHz	35%
1800 / 2100 / 2600 MHz	1	135 MHz	28.1%
3400-3800 MHz	2 1	100 MHz max. 150 MHz (regional)	28%; 31% 43%

(1) Percentage calculation: for each band it is the share of the spectrum cap and the total available/awarded amount of spectrum in each band; for combined bands it is the share of the spectrum cap and the sum of the total available/awarded amount of spectrum of the combined bands.

(6) Allocated spectrum of 150 MHz for 3400 MHz band.

Appendix 4 – Abbreviations

Table 10: list of abbreviations used in the report

Acronym	Definition
BEREC	Body of European Regulators for Electronic Communications
CCA	Combinatorial clock auction
CEPT	European Conference of Postal And Telecommunications Administrations
ECS	Electronic communication services
EU	European Union
FDD	Frequency-division duplexing
FWA	Fixed wireless access
ICT	Information and communications technology
IoT	Internet of things
MNO	Mobile network operator
MVNO	Mobile virtual network operator
NRA	National regulatory authority
PPDR	Public protection and disaster relief
RoU	Right of use
RSPG	Radio spectrum policy group
SMRA	Simultaneous Multiple Round Ascending Auction
TDD	Time-division duplexing