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Spectrum Award – 2.6 GHz band with possible inclusion of 700 MHz, 1.4, 2.3 and 3.6 GHz bands

First report

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DotEcon Ltd
17 Welbeck Street
London W1G 9XJ
www.dotecon.com

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Content

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London W1G 9XJ
www.dotecon.com

1 Introduction

1. Existing licences for radio spectrum in the 2.6GHz band expire in April 2016 and ComReg has commenced the process for awarding rights of use for frequencies in this band after this date. ComReg has engaged DotEcon to provide support in the design and implementation of the award process. In this report we discuss a number of key issues for the design of an award process for assigning rights of use for frequencies in the 2.6GHz band, and possibly of additional bands that could be offered in the same award.

2. As part of its advisory role, DotEcon has also been instructed to consider a number of other frequency blocks, available now or in the next few years, and assess whether it may be appropriate to offer rights of use for these blocks in a combined award with the 2.6GHz band or separately. These blocks include:

   - unpaired frequencies in the 1.4GHz band, the 2.3GHz band and the 3.6GHz band;
   - the 700MHz band;
   - two small blocks of paired sub-1GHz spectrum - 410 – 414MHz paired with 420 – 424MHz and 872 – 876MHz paired with 917 – 921MHz; and
   - frequencies in the 10.1GHz and 26GHz bands.

3. In our assessment we consider the extent to which demand for these blocks might be interrelated with the demand for 2.6GHz spectrum, taking account of:

   - the likely demand from potential users and the extent to which spectrum in different bands may be substitutable or complementary for bidders;
   - the extent to which demand from some bidders and the potential impact of the outcome of the award process on the downstream markets may be affected by current spectrum holdings in other bands;[1] and

[1] Most notably, in the 800MHz, 900MHz and 1800MHz bands, which were awarded on a liberalised basis in ComReg's 2012 Multi-Band Spectrum Award ("the MBSA") and in the 2 GHz band, which is currently licensed for 3G services, but could be liberalised in the near future (see ComReg document 14/65).

- ComReg's objectives and duties in relation to spectrum management.[2]

4. The bands above 1GHz, which make up the vast majority of the spectrum to be considered for release, may be of interest to provide relatively short-range services. Potential uses would include, for example, additional capacity for mobile networks to accommodate future growth in traffic (where this additional capacity would supplement a basic coverage layer provided by spectrum below 1GHz) or high-speed data services in specific areas. Moreover, given the large blocks of spectrum available, the upcoming award may also provide the possibility of accessing a relatively large amount of contiguous spectrum (at least by comparison with the MBSA), which may make this award an attractive opportunity for services that require one or more large blocks of contiguous frequencies.

5. Frequencies in the 700MHz band may also become available within a timescale that may allow integrating 700MHz spectrum in this award.[3] This would be an attractive option, as it would allow bidders to seek a combination of low and high frequency spectrum. In particular, this could provide greater opportunity for entry in the mobile communications market and increase the number of mobile network operators ("MNOs") in Ireland. However, the key considerations for an award of high-frequency spectrum only are different to those for a combined award of low and high frequency, such as the 2012 MBSA. Therefore, the potential inclusion of 700MHz spectrum has implications on the design of the award process.

6. There are a number of potential ways in which the spectrum might be used by different technologies. Therefore, it is difficult to judge how potential bidders might combine and substitute between different bands. For this reason, it is important that the award process provides flexibility for different potential users (and technologies) to acquire the amount and combination of spectrum that best suits their purposes. However, providing such flexibility also has implications for the design and corresponding complexity of the award process.

[2] A detailed summary of ComReg's statutory functions, objectives and relevant duties in relation to radio spectrum is provided in Annex 2 of ComReg document 14/101.

[3] DotEcon's views on the availability of the 700MHz band in this report are subject to ComReg's views on same as set out in paragraph 2.43 of the Consultation Paper.

7. This report is structured as follows:

- in Section 2 we consider the blocks available for potential inclusion in a combined award with the 2.6GHz band;
- in Section 3 we consider alternative mechanisms for the award and provide our recommendations for the design of an auction process;
- in Section 4 we provide a brief discussion of potential measures that could be used to safeguard competition in the downstream markets;
- in Section 5 we discuss potential licence conditions for the rights of use of spectrum in the bands included in the award; and
- in Section 6 we outline the potential approach and methodology for structuring licence fees and establishing minimum licence fees.

8. Annex A provides a summary of International Practice in setting coverage obligations.

2 Frequencies included in the award

2.1 General issues for a spectrum release plan

9. In DotEcon's view, facilitating an efficient assignment of spectrum in a manner consistent with ComReg's objectives (such as the promotion and safeguarding of competition and ensuring the efficient use of spectrum) entails:

- providing flexibility to bidders regarding the amount of spectrum they might acquire;
- where possible, allowing bidders to mix and/or substitute spectrum across different bands;
- safeguarding the competitive intensity of downstream markets and, where possible, promoting downstream competition (including providing appropriate incentives for entry) where this is efficient;
- providing a level playing field for competition for spectrum between bidders intending to adopt different technologies, and between current operators providing different end-user services, including any existing users of spectrum; and
- discouraging strategic behaviour by interested parties aimed at obtaining spectrum relatively cheaply as this would affect the efficiency of the outcome of the award process.

10. Spectrum use typically requires long-term, large-scale investment in networks. Therefore, encouraging the investment necessary for an efficient use of spectrum may require providing clarity about current and future spectrum availability, as this would avoid unexpected shocks to spectrum supply and to allow operators to plan over reasonably long periods of time. Accordingly, we believe that it is desirable to ensure that:

- interested parties have some visibility of future planned releases of spectrum, which would allow them to plan for their spectrum needs accordingly;
- operators have an opportunity to acquire in advance the spectrum they may need to meet future demand for their services (to promote investment);
- spectrum rights with value interdependencies (e.g. complementary/substitutable spectrum available within the same or similar timeframes) are made

available in the same award, thereby encouraging the efficient use of spectrum (see below);

- opportunities for speculative acquisition of spectrum are minimised; and
- unnecessarily fragmented assignments are avoided.

11. These benefits are unlikely to be achieved by offering different bands sequentially without providing clarity around future releases, as this could lead to many bidders acquiring small amounts of spectrum in each band. This would discourage bidders from focusing on obtaining larger contiguous blocks in some bands. An outcome where operators hold a small amount of spectrum in many bands is likely to be more costly for these operators than if they hold the same amount of spectrum but across fewer bands.[4] Therefore, subject to not creating undue delay, there are benefits from including close substitutes in the same award and providing clarity around the overall programme of spectrum release.

2.1.1 Offering bands in a simultaneous award

12. The demand for spectrum in different bands may be inter-dependent, i.e. the demand for spectrum in one band may depend on the price and availability of spectrum in other bands. This may give rise to strong economic efficiency reasons for combining bands into an integrated award process to reduce the risk for bidders and to provide maximum opportunity for different types of bidders (with potentially different intended uses and technologies).

[4] Adding frequency bands to an existing network may have cost implications in relation to the network's physical infrastructure (see http://www.commscope.com/Blog/How-to-Efficiently-Support-Multiple-Frequency-Bands/). For example, the operator may need to install additional antennae and supporting Radio Frequency path equipment to support different bands. In some cases, planning regulations or physical constraints related to antennae height and tower load may prevent the addition of antennae to existing sites, potentially leading to substantial costs if new sites have to be built. In addition to equipment costs, there may also be network performance issues when using multiple bands. In general, the likelihood of experiencing failure and of distortions to signal performance increases with the number of separate pieces of equipment used. Using multiple bands at a site also increase the likelihood of a type of performance distortion known as passive intermodulation (see http://mwrf.com/test-amp-measurement-analyzers/reigning-pim-cellular-systems). While some solutions may be available for operators to manage such risks (see http://online.wsj.com/article/PR-CO-20140212-911056.html), implementing these may be costly and may not fully eliminate all detriment to network performance.

However, any benefits from including additional bands in the 2.6GHz award need to be assessed against the risk that this might lead to a delay in the start date of usage rights for 2.6GHz spectrum.

Substitutability

13. If spectrum in different bands is substitutable, at least some interested parties will be prepared to accept spectrum in one band instead of another at certain prices. This means that their demand for rights of use of spectrum in each substitutable band will depend on its price relative to the prices of spectrum in other substitutable bands. Therefore, bidders would ideally want an indication of the prices that will apply to different bands in order to make and revise their offers for different combinations of the lots available. Sequential awards would expose bidders to greater uncertainty about the price at which substitutable spectrum may differ across awards.

14. Offering substitutable spectrum in a combined award also introduces some challenges when prices are determined as part of the award process:

- In the context of a sealed bid contest or a single round auction, an efficient assignment may only be guaranteed if the pricing mechanism elicits information about how bidders might be prepared to switch across bands in response to different relative prices. In a sealed bid process this could only be done on the basis of the sealed bids submitted by bidders. Therefore, it may only be possible if bidders are given an opportunity to express their demand for mutually exclusive alternatives. However, this involves a certain degree of sophistication in the award process in terms of evaluating bids and calculating winners and prices.
- In the context of a multi-round award process, bidders may wish to switch back and forth across bands in response to the evolution of prices, rather than simply select their preferred band at the start of the auction and stick with their initial choice. Accordingly, it is desirable to allow bidders to switch between different bands as the award process progresses. However, switching between bands of different value could also be used for strategic purposes. Therefore, it may be necessary to establish rules that impede or discourage such behaviour.

15. Substitutability issues are particularly relevant in the context of this award, as at least some of the bands under

consideration can be expected to be reasonably good substitutes in terms of providing capacity in the long-run despite any differences in timing and equipment availability. In addition, we can expect at least some demand to be driven by the need to ensure spare capacity to meet the predicted future demand growth of data services, in which case the immediate use of the spectrum may not be essential for some bidders. Therefore, some differences in timing and equipment availability across bands in the short- to medium-term may be entirely consistent with those bands being substitutes.

Complementarity

16. A further issue that bidders may face when the value of spectrum is interrelated is complementarity. In this situation, the value to a bidder of winning some spectrum will be contingent on winning other complementary spectrum or holding rights of use for complementary spectrum. There are a number of situations where such demand contingency can arise:

- When spectrum is packaged into relatively small blocks (e.g. 5MHz or 2x5MHz), lots within each band are likely to be complementary. This reflects the fact that bidders will typically have a valuation for a block of spectrum in a band that corresponds to multiple lots, which could exceed the sum of its valuation for each of these lots individually.[5] In this case, the value of a lot to a bidder is contingent on whether it wins other lots in the same band, and may also depend on whether all its spectrum holdings would form a single contiguous block (as for certain technologies this may allow for a more efficient use of the frequencies held by the bidder).
- Spectrum in different bands may also be complementary, as aside from any benefits arising from aggregating bandwidth there may also be benefits from combining spectrum in bands with different

[5] For example, some technical efficiency gains may require a minimum bandwidth of contiguous spectrum. This could lead to valuations jumping when the corresponding bandwidth thresholds are met, and to bidders placing a relatively low value on being allocated less spectrum than what they would require to benefit from such efficiency gains.

characteristics.[6] In this case, the value of spectrum in a band will depend on whether the bidder holds or may be able to acquire spectrum in complementary bands.

17. If all potential users of the spectrum were fairly similar in terms of how complementarity across lots affects their demand, then it might be possible to allow bidders to express at least some complementarity value by offering lots that assemble relevant combinations of spectrum (for example, blocks of different bandwidth). However, it may not be possible to address complementarity issues through spectrum packaging while providing a level playing field across bidders when complementarities may vary across users, which is a likely scenario in a technology-neutral framework.

Other issues

18. Demand for spectrum is further complicated by the interaction of substitutability and complementarity effects of spectrum in different bands, with the result that bidders may wish to switch between aggregations of lots in different bands (e.g. a bidder may wish to acquire 20MHz of contiguous spectrum in one of a few alternative bands).

19. The rules governing a simultaneous award that takes account of such dependencies may be substantially more complex than when bands are offered in separate awards. However, this is simply a reflection of the complexity of the

[6] The typical example of this is where an operator may wish to combine low frequencies for providing national coverage at a low cost (due to the greater propagation characteristics of low frequency spectrum) with higher frequency spectrum for providing additional capacity in high-traffic areas. In this context, the value of spectrum in a 'capacity band' would be contingent on holding or acquiring spectrum in a 'coverage band' and vice versa (though the strength of this contingency is likely not to be symmetric). There may also be benefits from combining bands with different usage restrictions or better suited for different technologies. For example, unpaired spectrum may complement paired spectrum for services in which uplink and downlink traffic is asymmetric. In this case, the value of paired spectrum used for providing symmetric traffic is dependent on whether the operator may also use unpaired spectrum to respond to asymmetric traffic increases, and vice versa. Equally, a mix of holdings across bands reduces exposure to risks from equipment availability and standardisation issues. However, there are also costs from fragmenting holdings across bands, as there are benefits from holding large contiguous blocks in terms of technical efficiency (throughput per MHz) and limitations on the maximum number of carriers that can be aggregated across different bands. Therefore, operators may prefer to hold large blocks of spectrum in a few bands rather than small blocks in many bands.

underlying demand and supply structure and the need to allow reasonable flexibility for bidders.

20. Opting for separate awards when there are demand interrelationships such as substitutability and complementarity does not reduce complexity; it simply shifts the complexity onto bidders when making their decisions. Offering bands for which demand is interrelated in separate awards would require bidders to make their bidding decisions in one award on the basis of their *expectations* on the availability of and demand for spectrum in bands that would be awarded at a later date. This increases the risk of inefficient outcomes, as bidders' expectations may be subject to a considerable degree of uncertainty and could be wrong. Conversely, awarding such bands in a simultaneous award would allow bidders to express their demand across bands taking account of any dependencies (provided that the award has been designed to this effect). This reduces the need for bidders to rely on their expectations on the demand for spectrum in other bands when determining what to bid.

21. In the award of rights of use for capacity spectrum, different spectrum blocks offered may not only be substitutable, but also complementary to the extent that users wish to aggregate multiple blocks (in the same band or across different bands) into a licence. In these circumstances, there would be a strong case for a combined award.

22. Another factor to be considered when determining whether to include different bands in the same award is the date from which the spectrum will be available. Awarding spectrum as early as possible and well ahead the start date of usage rights is desirable in terms of helping future users to plan roll-out of networks and usage of the frequencies they acquire. The award of spectrum rights should ideally be sufficiently ahead of their start date to avoid any unnecessary delay in the commercialisation of services, by providing enough time to allow:

- existing users to make the necessary transition arrangements (if any) in light of the outcome of the award process;
- winning bidders to deploy any necessary infrastructure for providing the services using the spectrum; and
- the adoption of any necessary interference mitigation measures to protect users of adjacent spectrum.

2.1.2 Timing issues

23. As discussed above, the likely substitutability and complementarity of spectrum in different bands for bidders are important issues in deciding whether spectrum should be included in the same auction, as they may affect the efficiency of the outcome. However, there are also other issues to consider that may also affect the efficient assignment of spectrum:

- the bands being considered for inclusion in the auction include the only low frequency band (the 700MHz band) that is expected to be made available internationally on a harmonised basis in the medium term; and
- the bands considered appear to represent the entirety of the spectrum that is due to become available in the medium term.

24. Given this, the issue of an efficient assignment of spectrum may need to take into account the use of spectrum over a longer time horizon. In particular:

- awarding spectrum now will generate value for consumers if there is use for it;
- on the other hand, awarding spectrum now will limit access to spectrum for services that might only become available at a later date.

25. This has a number of follow-on consequences for design of an award process for spectrum including the 2.6GHz band and for a spectrum release strategy more generally.

26. First, if awarding large amounts of spectrum now, we would want to be confident that reasonable measures are being taken to ensure that bidders are bidding for spectrum for appropriate reasons. On this issue:

- the possibility of spectrum hoarding and speculative spectrum acquisitions is discussed in Section 4;
- potential measures to prevent outcomes that could compromise competition in the downstream market are also discussed in Section 4; and
- market-based fees as a measure to discourage such behaviour are discussed in Section 6.

27. Second, the propagation characteristics of the 700MHz band make it attractive for providing cost-effective coverage. Therefore, its release represents a good opportunity for entry or expansion into the market and achievement of policy goals. In this context, we note that the MBSA assigned the right of use until 2030 for the spectrum

available in the other two sub-1GHz spectrum bands that are harmonised and can be used (amongst other things) for providing advanced mobile services, and that the 700MHz band is the remainder of the sub-1GHz spectrum currently scheduled to be harmonised for MFCN services and made available in the medium term.[7] However, the optimal timing for potential entry may conflict with the timing of demand for this spectrum by existing operators.[8]

28. Two further points to note about the possibility of awarding other capacity bands alongside the 2.6GHz band are that:

- if all capacity bands are suitable for award with 2.6GHz frequencies and 700MHz spectrum are not awarded alongside the 2.6GHz band, there may be some benefits from retaining some capacity spectrum for award alongside the 700MHz band; and
- if the spectrum offered in the award constitutes the entire medium-term supply of spectrum, then there may be a greater role for additional provisions that might be required to ensure that ComReg meets its objectives. For example, setting non-trivial upfront and on-going annual fees may help to ensure that users only acquire and retain spectrum if they have legitimate demand for it.

2.2 The 2.6GHz band

29. There is a total of 190MHz of spectrum in the 2.6GHz band. European Commission Decision 2008/477/EC harmonises the conditions for availability and use, and determines Block Edge Mask parameters for the 2.6GHz band. European Commission Decision 2008/477/EC sets a minimum recommended block assignment size of 5MHz, to be increased in multiples of 5MHz, and specifies a range of usage modes in the band including Frequency Division Duplex (FDD) and Time Division Duplex (TDD).

30. In Ireland, the 2.6GHz band is currently used by a Multipoint Microwave Distribution System ("MMDS") operator for the

[7] Harmonisation of the 700MHz band for mobile is due to take effect following WRC-15.

[8] Note that the benefits of release for use by existing users are constrained by current uses and progress on harmonization of this band.

distribution of pay-TV services, whose extended licences expire on 18 April 2016.[9] The band could therefore be made available on a liberalised use, technology-neutral basis with usage rights starting on 19 April 2016.

31. Uses of frequencies in the 2.6GHz band at European level include fixed networks, mobile networks and other uses (including passive earth exploration and space research and radio astronomy). Current applications are terrestrial Electronic Communication Services ("ECS"), including International Mobile Telecommunications ("IMT") and other Mobile/Fixed Communications Networks ("MFCN"), defence systems, radio astronomy and PMSE.[10] The EC decision on the 2.6GHz band provides for technology and service neutral use.

32. At an international level, the 2.6GHz band has been identified by the ITU as a capacity band for International Mobile Telecommunications (IMT).[11] It is therefore well suited for Next Generation Mobile Broadband ("NGMB"), which could be used to meet high and geographically-concentrated demand for capacity (potentially complementing basic coverage networks). At a European level, 2.6GHz spectrum licences for NGMB have been issued in many Member States in recent years. NGMB rollout in this band is progressing at a fast pace internationally, and the 2.6GHz band is a heavily used band for providing advanced mobile services using LTE at present. Therefore, the 2.6GHz band represents an opportunity to respond to the rapidly rising demand on a common basis internationally. As a result, NGMB is likely to be a primary contender for spectrum in this band.

33. Reflecting the transition towards NGMB, globally and in Europe, the number of countries where the 2.6GHz band is used for MMDS services has decreased materially.[12] Among those countries where MMDS services are being maintained,

[9] ComReg document 13/31, Decision No. D06/13

[10] See ERC Report 25 (October 2013) and RSPG13-521 rev1 (June 2013), Annex 1.

[11] ITU Radio Regulations 5.384A.

[12] As stated in paragraph 5.37 of ComReg 12/132, "*ComReg has had regard to the international experience in relation to the distribution of television services using MMDS and finds that there are far fewer countries maintaining MMDS services in the 2.6 GHz band than there were in 2008*". While information on the number of countries permitting use of MMDS in the 2.6 GHz band is unclear, Ireland may be the only EU member state with an actual MMDS operator currently using frequencies in the 2.6 GHz band.

some countries (e.g. Brazil,[13] Mexico[14]) have taken steps to release part of the 2.6GHz band for NGMB services while also using some of this spectrum for MMDS services.[15] In Ireland, UPC's position in its submission to ComReg's Draft Decision for Consultation on extending its licence until 2016 was for its 10 MMDS licences to be renewed up to 2017.[16] Having reviewed submissions of respondents in relation to the issue of coexistence of MMDS and other services in the 2.6GHz band, ComReg has stated that it 'remains of the view that the case for co-channel or adjacent channel sharing in the 2.6GHz band is so limited for technical reasons as to not be feasible'.[17] Therefore, we do not consider this issue further.

34. The band plan commonly adopted for this band across European countries that have awarded 2.6GHz spectrum for liberalised use includes fourteen blocks of 2x5MHz FDD spectrum and a 50MHz centre band of TDD spectrum. In many countries the centre band has been offered as nine blocks of 5MHz (corresponding to the lower 45MHz of the centre band) that can be acquired by different bidders, with a usage restriction on the lower frequency block assigned to each user to avoid interference to neighbouring users. The uppermost block in the centre band may then be left unassigned as a guard block or assigned to the licensee of the neighbouring TDD block subject to usage restrictions.

35. In the very short run, one factor that differentiates the 2.6GHz band from the other capacity bands is that 2.6GHz spectrum is already used for the provision of LTE services in a number of countries. As such, the 2.6GHz band is readily available for use, with large-scale availability of equipment already in the market. However, over longer time horizons, other capacity bands may be close substitutes.

[13] https://www.policytracker.com/headlines/brazil-builds-unique-conditions-into-450-mhz-and-2.6-ghz-auctions (January 2012)

[14] See https://www.policytracker.com/headlines/mexican-mmds-operators-give-up-130-mhz-of-spectrum-in-the-2.5-ghz-band/?searchterm=MMDS (October 2013)

[15] For example, in Brazil, the MMDS operators, Sky Brasil, is to launch wireless broadband services provided using 2.6 GHz spectrum. See: https://www.policytracker.com/headlines/sky-brasil-to-launch-wireless-broadband-in-tdd-portion-of-2.6-ghz-band/?searchterm=mmds

[16] This submission was published as part of ComReg Document 12/132s

[17] ComReg Document 13/31

2.3 Candidate bands for inclusion in the award of 2.6GHz spectrum

36. As discussed below, a number of additional capacity spectrum bands could potentially be offered alongside the 2.6GHz band in a combined award:

- The 1452-1492MHz band (the 1.4GHz band)
- The 2300-2400MHz band (the 2.3GHz band)
- The 3400-3800MHz band (the 3.6GHz band)

37. In addition, the 700MHz band may become available in the medium term. The 700MHz band would offer more than just capacity as, due to its propagation characteristics, it is very well suited to provide a wide coverage network and high indoor data rates.

38. As noted in the Radio Spectrum Policy Group (RSPG) opinion on Wireless Broadband,[18] all of these bands have been identified as candidates for the provision of wireless broadband in the near or medium term. Given this, there is likely to be scope for substitution across all of these bands, at least in the medium to long term. Hence, in the absence of any other considerations, including all of them in a combined award could be desirable.

39. To derive our recommendations on whether to include each of the candidate capacity bands, we consider each band in relation to the 2.6GHz band from the perspectives of:

- overall substitutability between the band and the 2.6GHz band, where the relevant information for this assessment may include a combination of
  - the amount of spectrum available in the band;
  - whether the band is harmonised on an international level;
  - current use in other countries (as a proxy for potential market); and
  - the technical conditions of the band.
- potential complementarity of the band with the 2.6GHz band where this is relevant;
- specific issues in Ireland that might affect demand interrelationships between the band and the 2.6GHz band; and

[18] RSPG13-521 rev1

- other issues (Ireland-specific or otherwise) that might affect the inclusion of the band in an award process alongside 2.6GHz.

40. Following this assessment, we consider the merits of including the 700MHz band in the same award process, examining the potential benefits and costs of such inclusion and any consequences for the overall spectrum release strategy.

2.3.1 Capacity bands

41. In general, the main consideration in recommending inclusion or otherwise of additional capacity bands in a 2.6GHz award is the potential for the demand for spectrum in these bands to be interdependent. Such interdependence is likely to be in the form of substitutability with part or all of demand for rights of use of spectrum in the 2.6GHz band from the perspective of at least some interested parties. However, it may also be in the form of complementarity between bands (see, for example, the discussion on the 1.4GHz band). In addition, the inclusion of additional spectrum rights of use in combination with an auction format that facilitates switching may also encourage potential entrants to participate given the greater supply and better chances of acquiring at least some spectrum.

42. The degree of interdependency between the 2.6GHz and other capacity bands (1.4GHz, 2.3GHz, 3.6GHz) is likely to be affected by:

- the outlook regarding equipment availability (as there is excellent availability of equipment for the 2.6GHz band, at least for MFCN);
- any differences in the propagation characteristics of the spectrum in the band, and the network design required for using the spectrum in each band.
- the harmonisation status of each band both now and in the near future, across Europe for terrestrial electronic communications services such as advanced mobile services;
- the amount of spectrum available in each band on a contiguous basis (as operators are becoming increasingly interested in large blocks of contiguous spectrum for use for advanced data services);
- the potential uses for each band (if there is no overlap of uses across bands, then there is little scope for substitution and less justification for including them in the same award); and

- other band-specific factors that might result in demand interrelationships.

2.3GHz band (2300-2400MHz)

Details

43. There is a total of 100MHz in the 2.3GHz band. Some frequencies at the bottom of the band are currently used for legacy services, namely Rurtel, the point to multipoint radio link service operated by eircom in a limited number of rural areas of Ireland. There is over 70MHz of contiguous spectrum between 2327-2400MHz currently unused nationally and could be made available on a national basis if appropriate.

44. ComReg consulted on the options for release of this band in 2009.[19] Following the consultation, ComReg's stated position at the time was to:

    - assign 70MHz at the top of the band (the frequency range 2330 – 2400MHz) as national licences; and
    - reserve 30MHz of spectrum (the frequency range 2300 – 2330MHz) for legacy services), and make the frequencies available for Local Area and Closed User Group licences in geographical areas where legacy services are not present.

45. Since 2009, Aervision has ceased frequencies in this band. In relation to use of frequencies for Rurtel by Eircom at present, we note that:

    - Eircom is using Rurtel to fulfil its universal service obligation;
    - at present, Eircom holds less than 50 licences;
    - the number of licences held by Eircom in this band has reduced since 2009 as Eircom migrates Rurtel customers to a fixed cellular solution; and
    - remaining licences each cover only a small geographic area and are in remote areas of the country.

46. Given the limited use of the spectrum, it is reasonable to assume that, if there was demand for it, the spectrum currently being used for Rurtel could be awarded either:

[19] ComReg consultation 09/49.

- as part of national licences, if ComReg was to cease its current local licensing of these frequencies; or
- as national licences with possibly a limited number of temporary exclusion zones corresponding to the areas covered by Eircom's licences for Rurtel customers.

47. It is expected that the spectrum in this band will be available for release under harmonised technical conditions following the completion of CEPT/EU level work, which is likely to (i) define the technical conditions for the use of this spectrum; and (ii) indicate whether such spectrum should be made available for the provision of ECS including wireless broadband services. Currently CEPT's harmonisation of the band for mobile/fixed communications services is at an advanced stage. A new ECC Decision harmonising implementation measures for MFCN (including wireless broadband access systems) in the 2.3GHz band including the least restrictive technical conditions (LRTC) was finalised in June 2014.[20] In addition, the European Commission has requested CEPT to develop harmonised technical conditions for the 2.3GHz band in the EU for the provision of ECS such as wireless broadband services. CEPT's response to this mandate is expected in November 2014.[21] Approximately half of CEPT countries have said that they would or might release all or part of the 2.3GHz band for private sector use.[22] In the UK, Ofcom is considering release of 40MHz of 2.3GHz spectrum in 2015.

48. This band has a reasonably well developed ecosystem for LTE (according to a GSA report from July this year there were then 361 LTE TDD devices compatible with the 2.3GHz band, and this number has been growing fast).[23] In the medium term it is expected that there will be widespread availability of devices with multi-band chipsets that include the 2.3GHz band and also bands used for 2G and 3G services provision in Europe, so availability of devices does not seem to pose a problem for awarding 2.3GHz spectrum.

[20] The final version of ECC Decision (14)02 was approved at the 37th ECC meeting, 24-27 June 2014. See: http://www.cept.org/ecc/37th-ecc-meeting,-aarhus,-denmark,-24-27-june-2014

[21] http://eccwp.cept.org/WI_Detail.aspx?wiid=458

[22] http://www.efis.dk/Questionnaire/doc?id=9

[23] GSA, Evolution to LTE Report (March 2014), available at http://www.gsacom.com/downloads/pdf/GSA_Evolution_to_LTE_report_310314.php4

49. There are potential coordination issues in the lower frequencies of the band due to Rurtel operating at some frequencies below 2330MHz. However, as stated above, the number and location of areas where this might be an issue is such that the requirement to coordinate in order to avoid services interfering with one another is unlikely to be a significant issue.

50. Therefore, if the 2.3GHz band is to be included in the award, we expect that the full 100MHz would be released on a national basis. However, it might be necessary to include technical conditions on the lower frequencies of this spectrum band to accommodate the incumbent Rurtel services.

Assessment

51. Overall, 2.3GHz spectrum is likely to be the closest substitute for unpaired 2.6GHz spectrum, both now and in the reasonably near future, given that:

- it has very similar propagation characteristics;
- the harmonised technical conditions for the use of the 2.3GHz band are likely to be the same as (and if not, very close to) those for the 2.6GHz band;
- technical studies at the European level (i.e. by CEPT) are advanced in regard to both conditions on adjacent users within the band and interference issues and related BEMs requirements at the edge of the band, with harmonisation expected to happen by the end of this year;
- spectrum in this band is already being used for providing (some of) the same types of services as might be provided using 2.6GHz;[24]
- while the interest in using this band for advanced mobile services in Europe is relatively recent, it has been on a strong upward trajectory in the last two years:
  (1) there are 15 networks in 10 countries already using this band to provide such services, and many more operators are engaged in trialling LTE in this band, and
  (2) the band is being used in both China and India for providing such services, ensuring the availability of cost-effective equipment for the band into the

[24] GSA, Evolution to LTE Report (March 2014), available at http://www.gsacom.com/downloads/pdf/GSA_Evolution_to_LTE_report_310314.php4

future. This reduces the impact of there being only partial interest in other EU countries in using this spectrum at present.

- manufacturers are already making chipsets capable of facilitating the provision of services (based technologies such as LTE) using frequencies in multiple bands, including the 2.3GHz band.[25] Similarly, there are already mainstream smartphones in the market with multi-band functionality that already includes the 2.3GHz band, including the latest iPhones.[26]

1.4GHz band (1452-1492MHz)

Details

52. There is a total of 40MHz available in the 1.4GHz band. These frequencies are currently unused in Ireland. Therefore, an imminent release would be relatively free of complications.

53. This band is relatively well developed from a regulatory perspective:

- in November 2013 ECC Decision (13)03 was approved on harmonised use of the band for MFCN Supplemental Downlink (SDL);
- ECC Report 202 studies the coexistence of MFCN SDL in the 1.4GHz band with other systems operating in adjacent bands, and the on-going work of project team SE 7 (Compatibility and sharing issues of mobile systems) will complement Report 202 by further exploring coexistence scenarios;
- a 3GPP work item was started in response to the harmonisation decision, to standardize the band and corresponding E-UTRA and UTRA requirements for SDL operation in Region 1 (i.e. Europe, Africa and the Middle East). The 3GPP published these requirements for use of 1.4GHz spectrum in combination with 700MHz frequencies in June 2014. Work to standardise these conditions for other paired bands is on-going.

[25] There are 129 devices that support the combination of the 2.3 GHz and 2.6 GHz bands. Source: http://www.gsacom.com/downloads/pdf/GSA_lte_ecosystem_report_190314.php4

[26] iPhone 5S Model A1530, as found here: http://www.apple.com/iphone-5s/specs/

iPhone 5c Model A1529, as found here: http://www.apple.com/iphone-5c/specs/

- The European Commission has issued a mandate to CEPT to develop harmonised technical conditions in the 1452-1492MHz band for wireless broadband electronic communications services in the EU.[27] The CEPT work in response to this mandate is in progress and it is expected that this work will be completed in November 2014.[28]

54. The global potential of the 1.4GHz band for mobile broadband using SDL has been widely recognised by industry, as well as by regulators. A successful trial of SDL in the 1.4GHz band has already been carried out in France. Equipment is expected to become available within the next two years[29]. The recent harmonisation of the band, the on-going harmonisation updates and the expected availability of equipment may indicate a potential for substantial market demand even in the short term.

55. In terms of use of this spectrum, while the relevant European decision allows for a wide range of uses other than MFCN, due to the relatively small size of the block available, a bidder may have to 'pair' this spectrum block with other spectrum rather than use it on a standalone basis, regardless of its intended use of the spectrum. This is in addition to alternative users of the spectrum, such as broadcasters, who may be able to use this spectrum on a standalone basis and whose use would be permitted under the ECC harmonisation decision.[30]

56. While the 'downlink only' nature of this spectrum may appear to be a usage constraint if this spectrum were to be used for MFCN, it is worthwhile to note that there is still significant flexibility of use for this spectrum. SDL use is possible under the UMTS/HSPA standards, and work is on-going by 3GPP to define standards for operation of this band

[27] https://circabc.europa.eu/sd/a/be312eb4-ed35-46a2-849f-4372f59cc0e8/RSCOM13-67rev3%20Mandate%20CEPT%201_5GHz.pdf

[28] http://eccwp.cept.org/WI_Detail.aspx?wiid=459

[29] https://www.policytracker.com/free-content/blogs/toby-youell/editorial-qualcomm-to-develop-sdl-chip-for-l-band and http://www.huawei.eu/files/publications/pdf/the_full_spectrum_of_possibilities_-_meeting_future_demand_for_commercial_mobile_broadband_services_in_europe_2.pdf

[30] ECC Decision (13)03 provides that "the designation of the frequency band 1452-1492MHz to MFCN SDL does not prevent administrations from using part of the band for terrestrial broadcasting, aeronautical telemetry, MFCN other than SDL or other terrestrial applications to adapt to national circumstances".

in combination with paired channels from several other bands.[31]

Assessment

57. On initial examination, spectrum in the 1.4GHz band may be somewhat substitutable with unpaired 2.6GHz spectrum as:

- within CEPT this spectrum has recently been harmonised for advanced mobile services;
- technical studies at the EU level to determine harmonised technical conditions are advanced;
- the amount of spectrum available in the 1.4GHz band is comparable to that available as unpaired 2.6GHz spectrum.

58. However, there are reasons to consider that it is not as close a substitute to 2.6GHz as 2.3GHz:

- The frequencies are not as close to 2.6GHz, so there might be greater propagation differences between 1.4GHz and 2.6GHz spectrum than there are between 2.6GHz and 2.3GHz spectrum. Notwithstanding this, the better propagation characteristics of 1.4GHz spectrum may make it a valuable substitute for 2.6GHz.
- The spectrum in the 1.4GHz band is likely to be harmonised and released as supplemental downlink only, and therefore it is unlikely that it would offer any uplink possibilities (as opposed to most spectrum awarded as unpaired, including unpaired 2.6GHz and 2.3GHz, which offer uplink possibilities via TDD).
- Therefore, the potential market for 1.4GHz spectrum is likely to be limited to operators who have or who acquire holdings with which this SDL can be combined, while, unlike the 1.4GHz band, the market for 2.6GHz frequencies also extends to interested parties able to provide services using 2.6GHz spectrum on a standalone basis.

Therefore, this is only a partial substitute in the sense that (a) only some users may be able to shift their demand to this spectrum; and (b) such users might only be able to switch part of their demand to this spectrum.

[31] These include the 800MHz, 900MHz, 1800MHz, 2.1GHz and 2.6GHz band. 3GPP has already set out standards for use of the 1.4 GHz band in combination with the 700MHz band, which will be incorporated into LTE Release 12.

59. A further issue with this band is that, while already fairly well developed, incorporating this band into devices may not be a priority for equipment makers in the near term due to the relatively small size of the band.

60. However, some of the differences between 1.4GHz and 2.6GHz spectrum are not as pronounced as they might appear because:

- The band has the potential to be made available for wireless broadband in multiple regions, being largely unused across the world and being a strong contender for identification for IMT at WRC-15. Further, there may be a possible enlargement of this band at WRC-15 in line with Agenda Item 1.1 of the conference to consider additional bands for allocation to mobile services. This, in combination with the fact that it could act as a SDL for multiple alternative bands, makes it a relatively flexible spectrum resource.
- In terms of interest in this band from existing operators (or new entrants that may have the option of acquiring this spectrum alongside other frequencies included in the award process), it is reasonable to assume that if operators have access to complementary spectrum to meet any uplink traffic needs they may have, then they might be indifferent between acquiring downlink-only or other unpaired spectrum to address traffic asymmetry issues.[32]

61. In short:

- 1.4GHz spectrum is a reasonably good substitute for unpaired 2.6GHz spectrum by providing additional capacity for those that hold or acquire paired spectrum; and
- Paired 2.6GHz frequencies (as well as any other paired spectrum bands offered or already licensed) are potential complements to 1.4GHz spectrum. Therefore, the value of acquiring usage rights for 1.4GHz spectrum for interested parties with no existing paired spectrum holdings is likely to be dependent on whether they may

[32] For example, suppose that a mobile operator holding paired mobile spectrum estimates that it requires 10MHz of effective uplink capacity and 50MHz of downlink capacity on top of its current holdings in the medium term. This could be met by using 60MHz of unpaired spectrum with a 5:1 downlink to uplink ratio; or, alternatively, by using 20MHz of spectrum in the 1.4GHz band for downlink and 40MHz of unpaired spectrum in another band based on a 3:1 downlink to uplink ratio.

also acquire usage rights for paired 2.6GHz spectrum (or other paired spectrum that may be included in this award).[33]

Therefore, we expect that there might be benefits in offering this band along with 2.6GHz and other capacity bands.

3.6GHz band (3400-3800MHz)

Details

62. There is a total of 400MHz of spectrum in this band, split into two sub-bands of 200MHz each. This constitutes a very large amount of spectrum available for release. The band is currently in use in Ireland for the following services:[34]

    - an FWA Local Area licensing scheme, FWALA, which will operate in this band until 31 July 2017;[35]
    - state services in the 3435-3475MHz range, which are expected to continue to be protected by ComReg for the foreseeable future.

63. Therefore, the licensing of most of the spectrum in this band (360MHz) is possible from August 2017 onwards.

64. In terms of developments on the regulatory front concerning this band:

    - This band has been globally identified for IMT:
        - 3GPP has set out an IMT band plan for the entire 3.6GHz band.
        - The 3400-3600MHz sub-band is identified for IMT in the Radio Regulations (F/N 5.430A) for various countries in Region 1 including Ireland.

[33] Note that this complementarity is only one-directional – the value of paired 2.6GHz or other paired frequencies is not contingent on acquiring 1.4GHz spectrum in particular.

[34] The 2008 EC Decision on spectrum in this band (2008/411/EC) required that national regulatory authorities also make this spectrum available for Broadband Wireless Access (BWA); however, no such licences exist in Ireland at present.

[35] These users have licensed spectrum in this band on a 'local area' basis. One substantial user, Imagine, is using this spectrum to provide wireless access effectively nationwide. There are also two significant users, Airspeed and PermaNet, one providing wireless broadband services in select locations nationwide and the other providing services in two large regions of the country. There are a further 10 operators, offering broadband services in a small number of (often very rural) areas.

    - The 3600-3800MHz sub-band is a potential candidate band for consideration for IMT at WRC-15.[36]
- Harmonised technical conditions and frequency arrangements for the 3.6GHz band have been defined in EC Decision 2014/276/EU[37] and ECC Decision (11)06 (amended March 2014). However, while the harmonised band plan specifies a TDD arrangement as the preferred option for the 3400-3600MHz range, it also allows Member States to implement an FDD arrangement as an alternative. Therefore, while harmonisation will facilitate the large scale use of this band for advanced data services, some uncertainty remains about the balance of countries that may adopt the different band plans (although this will hopefully be resolved in the short run).
- Awards of 3.6GHz spectrum in the next two years are planned in countries such as the UK, Czech Republic and Slovakia. In many countries, existing services in the band will be a factor in the feasibility and timing of an award. For example, a large number of 3.6GHz licences have been assigned on a regional or local basis across European countries, including Ireland.

65. There are a large number of local fixed wireless networks in Ireland. Therefore, there is potential demand for spectrum in this band for these services.

66. In terms of mobile use, LTE in the 3.6GHz band is still in early stages of evolution globally and has limited market take-up so far. Equipment for LTE also continues to be limited in comparison to more established LTE bands (including 2.6GHz).[38] However, there are some early adopters of this band for mobile data services:

    - In the UK, in 2012, UK Broadband deployed the first TD-LTE services in the band.
    - Since then, commercial launches of LTE services using this band have taken place in Spain, Bahrain, Canada,

[36] https://www.itu.int/md/dologin_md.asp?lang=en&id=R12-WRC15.PREPWORK-C-0012!!PDF-E

[37] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014D0276&from=EN

[38] As of July 2014 the GSA identify 24 LTE devices in this band. Source: http://www.gsacom.com/downloads/pdf/GSA_Evolution_to_LTE_report_280714.php4

Belgium and the Philippines, and a launch is planned in France.[39]

67. Further, the bandwidth available in this band is unprecedented compared with that in other bands previously awarded for advanced mobile services and the recent advances in European harmonisation makes it potentially very attractive for wireless broadband in the medium term:

- the band has recently had the technical parameters updated to include this use,[40] a prerequisite for equipment makers to begin large-scale manufacture of equipment for the band for this purpose;
- the potential market size for such equipment is large, creating greater certainty that this equipment will become cost-effective relatively quickly; and
- timescales for requiring large amounts of additional capacity for mobile networks are in keeping with availability of this band i.e. not before 2017.

68. The band is of particular interest, both to mobile operators and to equipment manufacturers, as it consists of a large quantity of contiguous spectrum. This increases the likely interest in the band further, as:

- multiple operators would be able to acquire large amounts of contiguous frequencies, and
- this further increases the potential market for devices to include this band, as there may be multiple operators in a given country holding spectrum in this band.

69. Overall, this band is likely to become a mainstream band for mobile capacity in the medium term.

Assessment

70. Including this band in the award would result in a substantial increase in the supply of spectrum relative to a situation where only 2.6GHz spectrum and any other bands are awarded.

71. From a general capacity perspective, 3.6GHz spectrum seems to be a reasonably good substitute for 2.6GHz spectrum. For example, both bands could provide incremental capacity for mobile networks as part of a multi-band spectrum strategy.

[39] Ibid.

[40] ECC/DEC/(11)06, updated March 2014

72. However, the 3.6GHz band is relatively far away within the radio spectrum from the 2.6GHz band, and has less favourable propagation characteristics and poorer building penetration. Therefore, the costs of rolling out a capacity network using each of these bands could differ significantly. On the other hand, 3.6GHz spectrum might be more suitable for high-capacity hotspots and femtocell use.

73. The key issue in determining substitutability is the extent to which some bidders will be willing to switch between these bands in response to price differences (which would offset any additional costs of using this spectrum). For example, a bidder might be indifferent between a package of 2.6GHz blocks at a price of 6 units per block and a package of 3.6GHz blocks of the same size at a price of 4 units per block. Furthermore, we would expect the degree of substitutability between 2.6GHz and 3.6GHz spectrum to increase in the long run.

74. If the 3.6GHz band is to be included in the award, it may attract considerable interest from existing FWALA operators, who may not necessarily be interested in any of the other bands. However, there could also be some interest from MNOs, in recognition of the band's longer-term potential. If at least some bidders are willing to substitute between this and other bands, then it is beneficial to offer this band in the same award. Therefore, it seems appropriate to award at least some of the spectrum in this band alongside the 2.6GHz and potentially other capacity bands.

75. However, in addition to the issue of whether this band should be included in an award process on the grounds of substitutability with 2.6GHz, therefore, we must also consider the effect the alternative timing options for making capacity available over the next few years may have on competition and end users.

National versus sub-national licensing

76. Given the likely interest by different types of user of this spectrum from 2017, it may be appropriate to award at least some of this spectrum on a sub-national basis. For example, many of the existing 3.6GHz local area users may not require national coverage. While a national licence would include the rights to use the spectrum in the areas where they need it, acquiring a national licence for local area use might be undesirable:

- this could lead to frequencies being unused in the remaining areas, where other users might have been willing to operate;

- any nation-wide licence conditions (if applied) could depress the value of a national licence for regional users, as these might require a larger network; .
- the willingness to pay of a local area user might be small compared to that of a national user simply due to the relative size of their business, but this might not be reflective of value of each user for using the frequencies in the geographic area where the local area user would operate.

77. It might be possible for some of these operators who wish to acquire a local area licence for non-overlapping regions to bid under a consortium, subject to compliance with competition law. However, this might require a degree of coordination amongst parties that may be difficult in practice. For example, there may be impediments to forming a consortium (e.g. difficulties in agreeing a common bid strategy) or which could inhibit expression of a full valuation.

78. In this context, offering some licences on a sub-national basis would provide an opportunity for local area users to express their demand individually in the award process. In addition, the desired footprint of some local area users may be compatible with that of a national operator that already has nationwide coverage and only wishes to acquire capacity spectrum for specific high-traffic spots in some urban areas. Rather than establishing a specific frequency range for sub-national licences and offering those in a separate process, one would ideally offer sub-national licences alongside national licences in the same process. This would allow for:

- a national operator to acquire a combination of sub-national licences (potentially covering the whole country, or only those regions it values most) if there is excess demand for national licences; or
- a sub-national bidder to bid for national licences if the price premium to be paid over some combination of sub-national licences is sufficiently small.

79. Allowing bidders to switch between national and sub-national licences increases the scope for competition. It would also allow for the establishment of geographical footprints on the basis of demand.

Additional considerations for the inclusion of the available capacity bands

Meeting demand for unpaired spectrum

80. Given current developments, there is potentially a large amount of spectrum available that might be a good substitute for 2.6GHz spectrum in the medium and long term.

81. If only 2.6GHz spectrum were to be awarded, the total amount of spectrum available might be insufficient to meet demand for unpaired spectrum:

- There has been huge growth in mobile data traffic in recent years, as the range of high-bandwidth mobile devices capable of providing content-based data services on the move has increased significantly. This has meant that mobile operators are carrying increasingly asymmetric traffic, with customers downloading to their mobile devices increasingly more data than they upload, and forecasts suggest that this trend will continue. Therefore, unpaired capacity spectrum constitutes a strong complement for mobile operators to their existing paired spectrum holdings. Conversely, the consequence of mobile operators with increasingly asymmetric capacity pressures on their network using only paired spectrum is that frequencies earmarked for uplink traffic could be underused.
- LTE is the most rapidly developing and the fastest technology for advanced mobile services, and both LTE and its next generation variant, LTE Advanced (LTE+), achieve the greatest speeds in large blocks of contiguous frequencies. Therefore, in order to be able to achieve the efficiency of spectrum use that comes from operating large blocks of contiguous spectrum, the 50MHz of unpaired 2.6GHz spectrum can effectively be shared by a maximum of two mobile operators.[41] Given this, the 2.6GHz band on its own is unlikely to satisfy demand even from existing MNOs alone, as the amount of TDD spectrum available in this band is insufficient to accommodate all MNOs with the bandwidth they might require to meet their increasingly asymmetric traffic.[42]

82. The potential scarcity of unpaired spectrum if the 2.6GHz band were awarded on its own could create unnecessary demand for FDD spectrum for downlink-only use, as

[41] In fact, some countries have packaged the 2.6GHz centre band as a single 50MHz block for award to a single operator.

[42] MNOs already have access to some TDD spectrum, these constitute only small blocks that are unlikely to be sufficient to meet the increasingly asymmetric data traffic forecasts.

releasing the 2.6GHz band alone would likely mean releasing predominantly paired spectrum. As a result, the demand for frequencies for downlink-only traffic could displace users who require a balanced up and downlink traffic from FDD spectrum, leading to uplink frequencies being underused when it could have been more efficient to accommodate unidirectional, or asymmetric, traffic using unpaired spectrum. This would result in an inefficient pattern of usage, simply as a result of operators not being able to acquire an efficient mix of paired and unpaired spectrum.

Aggregation across bands

83. A related issue is that there are limits to the capabilities of technology when aggregating across bands. Therefore, it may be appropriate to facilitate the acquisition of large blocks of contiguous spectrum to not unduly constrain the capability of operators to provide advanced mobile services in the context of rapidly growing data traffic.[43]

84. For example, mobile operators have increasingly been pursuing carrier aggregation in LTE advanced networks. It is expected that LTE will allow users to combine up to five carriers of potentially different sizes (i.e. 1.4, 3, 5, 10, 15 or 20MHz), allowing for a maximum aggregated carrier size of 100MHz.[44] The potential benefits include higher peak data rates and more consistent quality of service.[45] Where carrier aggregation across bands is feasible, these benefits might counterbalance the costs associated with operating with several frequency bands. Aggregation of non-contiguous spectrum within the same band could also mitigate the

[43] For example, equipment manufacturer Ericsson predicts a ten-fold increase in data traffic between 2013 and 2019 (source:, "Spectrum Harmonization", a presentation by Stephanie Huf, Ericsson, at the CommunicAsia 2014, Singapore, 17-20 June 2014)

[44] http://www.3gpp.org/technologies/keywords-acronyms/101-carrier-aggregation-explained

[45] http://www.4gamericas.org/documents/HSPA+LTE%20Carrier%20Aggregation%206.26.12.pdf

disadvantage often associated with receiving a split assignment within a band.[46]

85. Carrier aggregation technology counterbalances the costs of using spectrum in many bands. However, there are some limitations to this at present – while carrier aggregation across two bands is emerging as a viable option for many bands in the short to medium term, aggregation across three bands could be a more distant prospect. Aggregation of a greater number of bands and carriers may be technically feasible[47] but is a longer-term possibility. Against this backdrop, carrier aggregation may not be a complete solution for operators such as the existing MNOs in Ireland, who already hold spectrum in four different bands, excluding any additional spectrum they might acquire in the award. A separate, inherent limitation of inter-band carrier aggregation is that its feasibility and its achievable performance inevitably depend on the characteristics of the bands that are being combined. In particular, the possibility of achieving improved performance in a particular geographic area by aggregating carriers is completely dependent on the coverage offered by each band in that particular area.

86. The possibility of carrier aggregation may increase complementarities between frequency bands. However, the limitations of carrier aggregation technology and the

[46] 3GPP Release 11 version 11.9.0 (available from http://www.3gpp.org/DynaReport/36101.htm) specifies several combinations that include frequency bands used in Ireland. Of relevance to this award are the inter-band configurations that combine the 2.6GHz band with the 800MHz band and with the 1800MHz band. Release 12 version 12.4.0 (available from http://www.3gpp.org/DynaReport/36101.htm), still being developed, will substantially broaden the scope for carrier aggregation technology by expanding the list of possible combinations. Based on the July 2014 update (see http://www.3gpp.org/DynaReport/FeatureOrStudyItemFile-551000.htm), Release 12 will include (i) new intra-band non-contiguous configurations for the 2.6GHz band and the 3.4-3.6GHz band; (ii) new two-band configurations (combining the 2.6GHz band and the 700MHz band; the 2.3GHz band and the 900MHz band; and the 1.4GHz band and the 800MHz band); and (iii) the introduction of the first three-band combinations (under development at the time of writing). At present, two-band carrier aggregation has been implemented or trialled by operators in at least nine European countries, as well as elsewhere (Based on GSA Evolution to LTE Report of July 2014, available at http://www.gsacom.com/downloads/pdf/GSA_Evolution_to_LTE_report_280714.php4). Aggregation across three bands has not yet progressed to this stage, though the first commercial trial took place in South Korea in June 2014 (see http://pr.huawei.com/en/news/hw-343675-lg.htm#.U_S479yppZh).

[47] See e.g. http://nsn.com/news-events/press-room/press-releases/lte-throughput-leader-nokia-sets-world-record-with-sk-telecom-of-close-to-4-gbps-using-tdd

possible costs associated with operating many bands mean that operators with existing spectrum holdings may prefer acquiring additional spectrum in a minimum number of bands, subject to acquiring sufficient spectrum to meet their requirements. This might therefore also increase substitutability between large blocks of spectrum in different bands.

87. Including several bands in the same award would allow bidders to express this substitutability. However, this would suggest that it would be beneficial to design the award mechanism in a way that it allows bidders to manage the risk of winning spectrum that is fragmented across bands.

Managing a large supply of spectrum

88. Including all the available spectrum in the award would result in an unprecedented supply of spectrum. This has clear advantages in terms of promoting spectrum use and related services, and in turn intensify competition in the downstream markets. In particular, it may provide a good opportunity to acquire significant bandwidth of contiguous spectrum and therefore promote entry and the development of novel services. However, the large supply of spectrum increases the scope for excess supply and hoarding if demand is low relative to availability, and consequently ComReg cannot simply rely on excess demand and competition ensuring that all the available spectrum will be assigned efficiently. Accordingly, the issues associated with low demand scenarios should be considered carefully.

89. First, present demand for spectrum is likely to be affected by expectations on future supply of spectrum, especially demand for additional capacity to meet future needs. For example, some potential users may wish to defer the acquisition of spectrum if they do not have an immediate need for these, as this would allow them to observe developments in the market and defer any costs. However, uncertainty about future availability and the timing of future awards might prompt such users to acquire spectrum early to insure against scenarios in which they cannot acquire the spectrum when they need it. Therefore, the treatment of unsold spectrum may have an influence on bidders decisions. Accordingly, it would be desirable to provide clear indication about when and how any unsold spectrum may be offered in the future. This is particularly relevant when there is a large supply of spectrum, as this increases the likelihood that rights of use in respect of some spectrum might remain unsold.

90. Second, low participation scenarios may provide an opportunity for existing operators to acquire a substantial

amount of spectrum to have readily available to meet potential demand in the future. Spare capacity should promote competition for customers and traffic in the downstream markets, the development of new services and mobile applications. However, offering operators the spectrum at a low price could lead to bidders acquiring excessive amounts of spectrum in for hoarding purposes, and might reduce the availability of spectrum for future users and applications. Therefore, it may be desirable to set minimum prices that take into account expectations on the future market value of spectrum, with a view to promoting an efficient assignment in the long run.

91. Making a large amount of spectrum available may also increase the scope for strategic demand reduction, especially in low participation scenarios. Even if there might be excess demand overall or in some specific categories, bidders may reduce demand or switch to substitutable bands early to reduce the competitive pressure on prices and win spectrum close to reserve prices. Such strategies are more attractive when there is sufficient spectrum to allow operators to obtain reasonable bandwidth without having to compete strongly. The benefits for bidders engaging in such strategies are also greater if reserve prices are below expected clearing prices, as this determines the cost saving when buying lots close to reserve rather than at competitive prices. Strategic demand reduction might lead to inefficiencies in the assignment of spectrum and could weaken competition in the downstream market, as we will explain below. However, the award process can be designed with the aim of making strategic demand reduction unattractive (for example by setting prices close to expected clearing prices, thus reducing the benefits from strategically reducing demand).

92. Overall, increasing the supply of spectrum will accentuate the importance of setting minimum prices at an appropriate level. Minimum prices should be set at a level that is not too high and chokes off efficient demand. On the other hand, they should be reflective of market value and opportunity cost to reduce incentives for strategic demand reduction and to ensure that the spectrum is not sold simply because it can be acquired cheaply.

93. Spectrum usage fees and licence conditions may also need to be set taking into account that capacity spectrum may be used in combination with existing spectrum holdings. For example, capacity spectrum may only be required in certain high-traffic areas, rather than widely across the whole network, and therefore the network to support this spectrum

may be rolled out in stages driven by demand for capacity rather than to provide wide area coverage.

2.3.2 The 700MHz band (694-790MHz)

Details

94. At present in Ireland, the 700MHz band is used on a primary basis by Digital Terrestrial Television (DTT). RTE holds two DTT Multiplex licences, both of which are due to expire on 13 March 2019. Programme Making and Special Events (PMSE) also operate in the band on a non-interference, non-protected basis. The release of the 700MHz band for the provision of mobile services would require moving RTE's spectrum assignment to frequencies below the 700MHz band.

95. At a European level, the 700MHz band is predominantly used for delivery of Digital Terrestrial Television (DTT) services and other applications such as PMSE. However, following the WRC-15, the 700MHz band is expected to be allocated on a co-primary basis for mobile (excluding aeronautical) services. On-going work for harmonising the 700MHz band is being conducted by CEPT (and expected to be completed by the second half of 2016).[48] This should define the harmonised technical conditions for the provision of wireless broadband services and other uses in this band.

96. The frequency arrangement likely to be adopted for this spectrum, the Asia-Pacific Telecommunity ("APT") 700MHz FDD band plan, comprises 2x30MHz, with the possibility of utilising the lower guard band and the duplex gap to provide 2x5MHz for Public Protection Disaster Recovery if required. In terms of the availability of LTE devices supporting this band plan,[49] a GSA report from March this year indicates that the first commercial user devices have now been

[48] Realwireless, October 2013, 'Terminal capabilities in the 700MHz band', available at: http://stakeholders.ofcom.org.uk/binaries/consultations/700MHz/annexes/30_Terminal_capabilities_in_the_700MHz_band.pdf

[49] Realwireless, October 2013, 'Terminal capabilities in the 700MHz band', available at: http://stakeholders.ofcom.org.uk/binaries/consultations/700MHz/annexes/30_Terminal_capabilities_in_the_700MHz_band.pdf

launched in the market.[50] The number of devices is likely to rise once the harmonisation process of this band in Europe is completed. A recent report from Realwireless for Ofcom,[51] which includes a section about device manufacturers and their support for the different possible band plans to be adopted in Europe, states that it is expected that "by 2020 [...] a majority of handsets available in the EU [should] support APT700".

97. The most recent developments in Ireland relating to this band are ComReg's consultation on the UHF radio frequency band in Ireland (ComReg 14/13) published in February 2014 and its response to consultation setting out next steps (ComReg 14/85) published in August 2014. In its initial consultation document, ComReg considered the use of the 700MHz band for various services including DTT and mobile broadband services in light of the ITU/EU-level developments and future forecasted demand. In its recent response document, ComReg stated its inclination to allow for accommodation of DTT services in the UHF band below the 700MHz band so that the 700MHz band itself can be released for other services. It also stated its view that co-existence issues with other services can be dealt with smoothly.

98. However, before taking any action, ComReg will conduct a detailed cost benefit analysis of migrating current users of the band into the lower frequencies of the UHF band. This should be conducted in the forthcoming months.

99. DotEcon's views on the availability of the 700MHz band are without prejudice of the UHF consultation process and may be reconsidered in light of the information obtained in the consultation.

Assessment

100. In contrast to the other spectrum considered for inclusion in an award alongside 2.6GHz frequencies, spectrum in the 700MHz band has propagation characteristics that make it suitable for providing cost-effective wide-area and indoor

[50] GSA, Evolution to LTE Report (March 2014), available at http://www.gsacom.com/downloads/pdf/GSA_Evolution_to_LTE_report_310314.php4

[51] Realwireless, October 2013, 'Terminal capabilities in the 700MHz band', available at: http://stakeholders.ofcom.org.uk/binaries/consultations/700MHz/annexes/30_Terminal_capabilities_in_the_700MHz_band.pdf

coverage in addition to the capacity boost that additional frequencies would provide. As such, it is likely to be considerably more valuable than 2.6GHz and other spectrum above 1GHz that might be made available in this award, which may eventually be used in a limited number of areas only. More importantly for this award, 700MHz spectrum may be highly complementary to the 2.6GHz band and other capacity bands that may be included in the award, at least for some bidders.

101. On these grounds, should the 700MHz band become available it would be desirable to offer it alongside at least some capacity spectrum. This would provide a good opportunity for any potential entrants to acquire a spectrum portfolio that allows them to deploy a cost-effective network providing wide-area coverage and capacity boosts in high-traffic areas.

102. However, there is some degree of uncertainty in relation to when and if this band may become available. This is because no decision has been taken regarding the availability of this band or as to where the existing user might be migrated. Therefore, the benefits from including this band in the same award as the higher frequency capacity bands must be considered taking into account the risk that a delay in freeing these frequencies might delay the release of capacity spectrum in other bands that are readily available.

103. In this context, some delay in the award of 700MHz might provide greater scope for new demand to develop, as an opportunity to acquire a combination of low and high frequency spectrum was brought to the market relatively recently (end of 2012) with the MBSA. This could be desirable if there was a concern that awarding this band too soon might inhibit competition on the grounds that, at present, there is no other low frequency spectrum forecast to become available in the next 10 years. However, holding back spectrum is undesirable if there is potential demand for it, as this might delay benefits from using the spectrum.

104. In addition, it is important to note that a significant development with respect to the structure of the market has occurred: the acquisition of O2 by 3 in Ireland has recently been approved by the EC. This means that the number of mobile network operators in the market will be reduced from four to three, but there are commitments in place linked to the clearing of this merger that are aimed at mitigating the

effects of the merger.[52] In this context, the release of 700MHz spectrum may provide a good opportunity for entry into the market for advanced data services, or for a niche player to develop its business. Therefore, the timing of release of this band should be assessed in this context also and ComReg's objective to promote competition more generally.

105. Other considerations when assessing whether to include the 700MHz band in the upcoming award might be the negative consequences of a potential delay in the award of capacity spectrum, and the urgency of releasing rights of use in the 700MHz band into the market. If the 700MHz band is not included in the award, one possibility would be to retain some higher frequency spectrum so that it can be offered along 700MHz in a subsequent award. However, this may be unnecessary given that at least some licences in the 2GHz band (which could also be a good complement for 700MHz spectrum) may expire and become available in the near future.

2.3.3 Other available spectrum

106. Other frequencies to be considered for potential release jointly with the 2.6GHz band in the forthcoming award are:

- 410-414/420-424MHz;
- 872-876/917-921MHz;
- 26GHz; and
- 10.1GHz.

We look at each one of the frequency blocks available separately and provide an assessment of whether it seems appropriate to include them in the award.

410-414/420-424MHz and 872-876/917-921MHz

107. These spectrum ranges are currently licensed for Wideband Digital Mobile Data Services ('WDMDS') in Ireland. The licences are held by Wirefree Communications and Digiweb respectively. No services are being offered that make use of the spectrum covered by these licences. Both licences are due to expire in December 2015, meaning that 2x8MHz of

[52] http://europa.eu/rapid/press-release_IP-14-607_en.htm

spectrum, formed of two contiguous blocks of 2x4MHz, will then be available for re-licensing.

108. At the European level, ECC Decision 04(06) addresses the availability of spectrum for Wide Band Digital Land Mobile Professional Mobile Radio/Public Access Mobile Radio (PMR/PAMR) in the 400MHz and 800/900MHz bands.[53] The Decision specifies that the spectrum requirements for Wide Band Digital Land Mobile PMR/PAMR systems must be met within the following bands:

- 410-430MHz and/or 450-470MHz, and
- 870-876MHz paired with 915-921MHz.

109. The Decision requires that sufficient spectrum in these bands is made available in order to meet demand from those systems.[54] These bands have also been identified by CEPT for use by various short-range devices.[55]

110. While the frequencies concerned can be used for wireless internet services and PMR/PAMR services, they are not expected to be harmonised for a greater range of uses in the foreseeable future,[56] which means that there is likely to be very limited substitutability or complementarity between these frequency ranges and the 2.6GHz band, or indeed the other bands considered for this award.

111. In addition, the spectrum blocks available, even if combined, still represent a quantity of spectrum that is less than 5MHz contiguous blocks, paired or unpaired, which would be the minimum lot size for 2.6GHz spectrum. We also note that these amounts of spectrum are not consistent with any of the carrier sizes for LTE. Therefore, the total bandwidth available might be insufficient and incompatible with demand from potential users, as these are likely to require a larger blocks of contiguous spectrum.

[53] ECC Decision (04)06, "The availability of frequency bands for the introduction of Wide Band Digital Land Mobile PMR/PAMR in the 400MHz and 800/900MHz bands", available at: http://www.erodocdb.dk/docs/doc98/official/pdf/ECCDEC0406.pdf

[54] The Decision applies to the bands 410-430MHz, 450-470MHz, and 870-876MHz paired with 915-921MHz.

[55] See ERC/REC 70-03

[56] See RSPG13-521, available at: https://circabc.europa.eu/d/a/workspace/SpacesStore/c7597ba6-f00b-44e8-b54d-f6f5d069b097/RSPG13-521_RSPG%20Opinion_on_WBB.pdf

112. There is also a lack of equipment availability for the use of this spectrum for purposes such as the deployment of mobile broadband services, TV services or services provided via broadband wireless access for this same reason. While this may change over time, this is not foreseeable, and trends of spectrum access for such services are going the other way, with minimum requirements for contiguous spectrum on the rise.

113. In summary, these frequencies are unlikely to offer the benefit of choice for bidders interested in 2.6GHz spectrum, or indeed any of the other frequency blocks considered for award alongside the 2.6GHz band. Therefore, there is no obvious benefit to including this spectrum in the current award.

26GHz

114. Part of this band is licensed for Point to Point and Point to Multipoint services on a national basis, currently used for backhaul. Licences are held by BT Ireland, Irish Broadband, Telefónica Ireland and Vodafone, and are due to expire in July 2018. There are also blocks in this band that are unassigned at present.[57]

115. At the European level, the preferred channel arrangements have been set out in Annex B of ECR Recommendation 13-02 and later supported in ECC/REC/(11)01.[58] None of these arrangements supports channels of 5MHz. In line with the recommended arrangements, there is a potential 2x896MHz of spectrum available in the range 24.5-26.5GHz for fixed service systems.[59] There are currently no further requirements for harmonised use of this band.

[57] ComReg 07/93R, The Award of National Block Point to Point and Point to Multipoint Assignments in the 26GHz band, Information Memorandum, 24 January 2008.

[58] ERC Recommendation T/R 13-02, "Preferred channel arrangements for fixed service systems in the frequency range 22.0 - 29.5GHz", available at http://www.erodocdb.dk/docs/doc98/official/pdf/TR1302.pdf and ECC/REC/911)01, available at: http://www.erodocdb.dk/docs/doc98/official/pdf/Rec1101.pdf

[59] These arrangements include a 49MHz guard band at the lower end of the band, a 47MHz guard band at the upper end of the band and a 112MHz centre gap.

116. Aside from the fact that the 26GHz band is not expected to be harmonised for other uses in the foreseeable future,[60] the scope of potential uses for this band is strictly limited by its propagation characteristics.

117. Some of the current licensees in the 26GHz band may take part in the 2.6GHz award. Therefore, it might seem to be useful for bidders for 26GHz spectrum to be included in the same award as 2.6GHz frequencies. However, it is not clear that there are genuine potential benefits from doing so. Specifically, while point-to-point and point-to-multipoint are technically mobile solutions, the substitutes for 26GHz spectrum for providing backhaul services are unlikely to be based on using alternative radio frequencies such as 2.6GHz; they may possibly use different technical solutions altogether (e.g. fibre). For the same reason, complementarities between these two bands are likely to be negligible.

118. As the range of services that could be provided using this spectrum is limited and likely to be different to those that could use 2.6GHz spectrum we do not believe that including this band in the award of 2.6GHz spectrum would have any material benefits. Therefore, overall we consider that it may be more appropriate to exclude this band from this award.

10.1GHz band (10.0 – 10.154GHz)

119. The 154MHz in this range are currently unused in Ireland. These frequencies has several applications across Europe, including amateur and PMSE services, but there is no harmonised approach to this band at the European level.

120. The possible release of this spectrum was consulted on by ComReg in 2009 together with proposals for release of the 10.5GHz band under the FWALA scheme.[61] The consultation included several aspects of a potential release, including band plans and whether such spectrum should be used on a TDD or FDD basis. However, only the latter proposals of releasing 10.5GHz spectrum were implemented.

[60] See RSPG13-521, available at: https://circabc.europa.eu/d/a/workspace/SpacesStore/c7597ba6-f00b-44e8-b54d-f6f5d069b097/RSPG13-521_RSPG%20Opinion_on_WBB.pdf

[61] See ComReg documents 09/03 and 09/36.

121. At the time of the consultation on the potential uses of this spectrum, ComReg considered that there was little reason to release the frequencies 10-10.154GHz at that time, finding "very little interest" in licensing the underlying spectrum and noting that the issue would be kept under review.[62]

122. This spectrum has substantially lower propagation characteristics than the 2.6GHz band and therefore might be a poor substitute for spectrum offered in this award.

123. Owing to the lack of harmonisation at the European level, it appears unlikely that considerable interest in these frequencies will have developed. Moreover, harmonisation for a range of uses similar to that for 2.6GHz or other bands being considered for award alongside 2.6GHz is not expected in the foreseeable future for this band.[63] Therefore, we do not see any benefit in including 10.1GHz band in the 2.6GHz award. Therefore, we would recommend also excluding this block of spectrum from the award.

2.3.4 Summary

124. The most commonly used 2.6GHz band plan designates most of the band for FDD use, with only 50MHz being designated for TDD use (which may also need to include guard bands or restricted blocks to protect neighbouring use from interference). Due to the minimum bandwidth requirements and the need for guard bands between different (uncoordinated) users, this is unlikely to allow for more than one or two users of TDD spectrum in this band. As such, there is limited availability of spectrum for TDD use in the 2.6GHz band, as the available TDD spectrum in 2.6GHz might be insufficient to accommodate the demand from either the existing MNOs or new entrants, even in the absence of any other competitors for these frequencies. This means that if only the 2.6GHz band is included in the award, it is likely that excess demand would be very high and that a number of bidders would leave the auction empty-handed. Bidders would not be able to explore the possibility of using substitutable bands as part of the process, so any decisions to drop out from this band in the hope of acquiring spectrum

[62] See ComReg document 09/36.

[63] See RSPG13-521, available at: https://circabc.europa.eu/d/a/workspace/SpacesStore/c7597ba6-f00b-44e8-b54d-f6f5d069b097/RSPG13-521_RSPG%20Opinion_on_WBB.pdf

in other bands would need to be based on expectations about when any other bands may be awarded and the potential demand for those bands. In addition, a small supply of TDD spectrum could lead to excessive fragmentation if too many bidders win TDD lots.

125. Scarcity of TDD spectrum might lead to some users switching to FDD spectrum as a substitute for unpaired spectrum. This would increase competition for FDD spectrum, but may lead to an inefficient use of the spectrum overall given that other TDD spectrum could have been made available. For example, any bidder buying FDD spectrum as a substitute for TDD spectrum may not make full use of both uplink and downlink, but might displace users who require FDD spectrum for both uplink and downlink. Such outcomes would be undesirable from an efficient and effective spectrum management point of view.

126. If only the 2.6GHz band was available, then one possible option to address the scarcity of unpaired spectrum would be to allow for a flexible band plan, i.e. allow TDD use in a greater number of 2.6GHz blocks. This might support outcomes where uplink and downlink blocks are assigned to different users. This could help to minimise the risk of inefficient outcomes where:

- the uplink frequencies of a paired spectrum licence are underused; or
- spectrum assignments are unnecessarily fragmented as a result of some users combining spectrum in the centre band with additional paired blocks for TDD use.

However this seems unnecessary given the availability of substitutable unpaired spectrum, in particular in the 1.4GHz and 2.3GHz bands. Moreover, this could lead to unnecessary scarcity of FDD spectrum if FDD use was required to compete with TDD use, and overall this would increase the requirement of users of this band to coordinate with adjacent countries, where both the UK and France have adopted a fixed 2.6GHz band plan.

127. Overall, the likely scarcity of unpaired spectrum in the 2.6GHz band suggests that there is a strong case for including some additional capacity bands in the same award. In addition to the artificial scarcity issue where there exists substitutable spectrum, this issue also relates to spectrum efficiency. There may be significant costs associated with

using spectrum in many capacity bands.[64] Therefore, it would be preferable to provide an opportunity for parties interested in capacity spectrum to acquire large blocks of spectrum in a small number of bands (instead of a small amount of spectrum in many different bands), as this could contribute to a more efficient use of the spectrum. The immediate candidates for inclusion are the 1.4GHz and the 2.3GHz bands, and we would recommend their inclusion in the forthcoming award.

128. There are also benefits from including the 3.6GHz band in the same award. While the supply of spectrum without this band may already be sufficient to meet demand at the time of the award, there is still scope for demand substitution between the 3.6GHz band and the other bands discussed above (accepting that 3.6GHz may be an imperfect substitute for 2.6GHz spectrum given the lower propagation of signals using these higher frequencies). The inclusion of this band would also provide a better framework for existing users in the 3.6GHz band to compete for these frequencies or attempt to find alternative frequencies before their current licences expire.

129. Given the large amount of spectrum available in the 3.6GHz band (i.e. from 3.4GHz to 3.8GHz), there is a potential concern that offering this band early on could possibly lead to excessive take-up from existing users if there is limited competition for this band and spectrum sells at a low price. While this might allow for early use of the band, it could also preclude future users from accessing the spectrum once technology and services using this band develop further.

130. One option to protect future users would be to include only part of these frequencies in the current award (e.g. 3.4GHz to 3.6GHz), leaving the rest to be awarded at a future date to provide a staged release of spectrum over time. However, this solution may introduce artificial differentiation between spectrum frequencies within the 3.6GHz band, which might otherwise be very close substitutes. An alternative option would be to offer all of the available spectrum in the band, but subject to minimum fees that reflect the value of retaining spectrum for potential future use. This approach is more flexible, as it allows for the full band to be utilised if there is strong demand for spectrum in the present award, while at the same time it would ensure that the spectrum is only assigned if its value to potential licensees is sufficiently

[64] See footnote 4.

high relative to the value of retaining spectrum for future assignment. However, this approach would require estimating the potential value of future use of the spectrum that provides the basis for the corresponding minimum fees.

131. Spectrum in the 700MHz band may not only be a substitute for high-frequency capacity spectrum, but also be a key complement that could create opportunities for market entry by operators seeking a combination of low and high frequency spectrum. Given the scope for strong complementarities between this band and other capacity bands, including this band may introduce some additional complexity in designing the process. However, providing an opportunity for market entry seems desirable, both in the context of ComReg's objective of promoting competition generally and in light of recent changes to the structure of the mobile market. Further, awarding this band in a separate award would create even greater complexity for any potential bidders seeking a combination of 700MHz spectrum and capacity spectrum.

3 Type of award process

132. ComReg's 2011 Strategy Statement covering spectrum management,[65] which sets out ComReg's views on a number of matters in relation to the management of radio spectrum, is a key input in considering the type of award process for the 2.6GHz spectrum and any other spectrum bands. In this Strategy Statement, ComReg outlined its position on the advantages of certain award mechanisms, including the use of auctions, and notes that it does not necessarily favour any specific approach for awarding spectrum rights, preferring to consider each award on its merits.[66] It goes on to note that "[i]n recent years ComReg has found it beneficial to use auctions as an award mechanism for certain bands where the number of licences to be awarded was limited and it seemed to it that demand could exceed supply. Auctions have proved to be a quick, fair and transparent method for assigning spectrum rights. ComReg considers that a suitably designed auction is equally appropriate in both 'greenfield' and 'brownfield' settings, as appropriate design can address matters germane to the circumstance."

133. In this section, we consider a number of options for the design of an award process for assigning spectrum in the 2.6GHz band and any other bands that may be included in the same award.

3.1 Alternative mechanisms for assigning spectrum

134. Awarding spectrum licences using an administrative award might be appropriate in the case that there is no excess demand for spectrum in any of the bands. However, given the rapid and massive growth of demand for mobile broadband data in recent years this seems an unlikely scenario at least for the 2.6GHz band.[67] As an additional

[65] "Strategy Statement – Strategy for Managing the Radio Spectrum 2011-2013", ComReg document 11/89, 22 November 2011

[66] Section 4 of "Strategy Statement – Strategy for Managing the Radio Spectrum 2011-2013", ComReg document 11/89, 22 November 2011

[67] See ComReg D06/13.

reference, demand for 2.6GHz spectrum across Europe has been strong, both from MNOs and wireless broadband operators, and there is no reason to believe that this might not be the case in Ireland.

135. Given this expectation, it is necessary to establish a mechanism for determining which applicants will obtain rights of use for spectrum in excess demand. In this context, an administrative award may fail to ensure an efficient assignment. For example, assigning spectrum on a first-come, first-served basis cannot ensure that the spectrum is assigned to those applicants who can generate greater value to society from using the spectrum. Similarly, using a beauty contest type of award would involve some challenges for ComReg in assessing the likely value of alternative uses of the spectrum when making a decision on alternative candidate licensees.

136. Auction mechanisms promote outcomes where licences are awarded to the bidders with the highest willingness to pay. We have not identified any reason why we should be concerned about market failure, and thus we expect that the willingness to pay of different operators should reflect the bidders' ability to generate value using the spectrum and therefore provide a good instrument to maximise the value of spectrum use.

137. As an aside, we note that any auction mechanism would sit within a wider framework for awarding spectrum, where:

- an auction would be run in the event that there was competing demand for at least some of the spectrum available; or
- the spectrum could be directly assigned to interested parties if it were possible to satisfy the demand expressed on all applications with the available spectrum (subject to any additional conditions as necessary being satisfied).

138. In light of the considerations above, an auction mechanism would appear to be well-placed to achieve the objective of using an award mechanism that is objective, transparent and non-discriminatory[68] if there is excess demand, as it is likely to be the case in this award. In addition, if a multi-round auction is used, then this could also help bidders in addressing common value uncertainty, as discussed below.

[68] ComReg Radio Spectrum Strategy Statement, ComReg document 11/89.

We also note that an auction mechanism would be desirable even if, owing to the inclusion of additional capacity bands in the award, there were no excess demand for spectrum overall but there was excess demand for a particular band. In this context, an auction mechanism would allow to determine the assignment of specific frequencies, and thus which users would get access to which bands, on the basis of the preferences for specific bands expressed by bidders.

139. However, ComReg should be equally prepared for potential low participation scenarios where there may be no excess demand, or where applicants may be willing to switch to other bands so that all users may accommodated. Therefore, it is important to establish licence conditions and minimum fees, discussed in sections 4 and 6 that are adequate to address such situations.

3.2 Design of an award process including an auction for assigning spectrum

140. In designing an auction for a 2.6GHz award, potentially in combination with a number of other bands, we consider the main options as set out below:

- We first consider combinatorial formats, describing the format used for ComReg's MBSA in 2012, the combinatorial clock auction (CCA), the format used for the 26GHz auction in 2008, the sealed bid combinatorial auction (SBCA) as well as a simple clock format;
- We then consider the possibility of a simultaneous multi-round ascending (" SMRA") auction for this award, discussing the format at a high level and some of the features that can be added to tailor the auction format to a particular award;
- We then consider factors that may be an issue in this award, evaluating the level of potential of these factors to affect bidders or the auction and ultimately the award outcome; and
- We assess the different auction formats, rating their ability to deal with the issues identified as important for this award.

3.2.1 Combinatorial auction formats

141. The feature common to all combinatorial formats is that a bid submitted by a bidder is for a *package* of lots. Bidders must be awarded one of the packages of lots that they have

bid for during the auction or nothing at all; a bidder cannot be awarded any combination of lots for which it did not explicitly submit a bid.

142. This feature is important in auctions where there are aggregation risks, such as where the demand for spectrum by one or more bidders is for multiple lots, in particular if bidders have minimum spectrum requirements that consist of more than one lot.

Mechanics of combinatorial auctions

143. In this sub-section:

- We first discuss the mechanics of a simple clock auction;
- We then discuss the SBCA; and
- Finally, we describe the CCA, highlighting differences between this and the other formats.

Simple clock auction

Mechanics of the auction

144. A simple clock auction progresses over a number of rounds, where similar lots are combined into the same lot category:

- In advance of the first round, the auctioneer declares prices that will apply during the first round,[69] and price increments that will apply on a category-by-category basis if there is excess demand in one or more lot categories;
- During the first round, bidders state their demand for lots in all categories based on the pre-set prices for each category;
- After the round, the auctioneer will assess demand:
    - If there is no excess demand, the auction will close and each bidder will be assigned the package of lots they bid on in the first round at the sum of round 1 prices for lots in their winning package; and
    - If there is excess demand for at least one lot or lot category, then another round will be announced and the auctioneer will declare prices

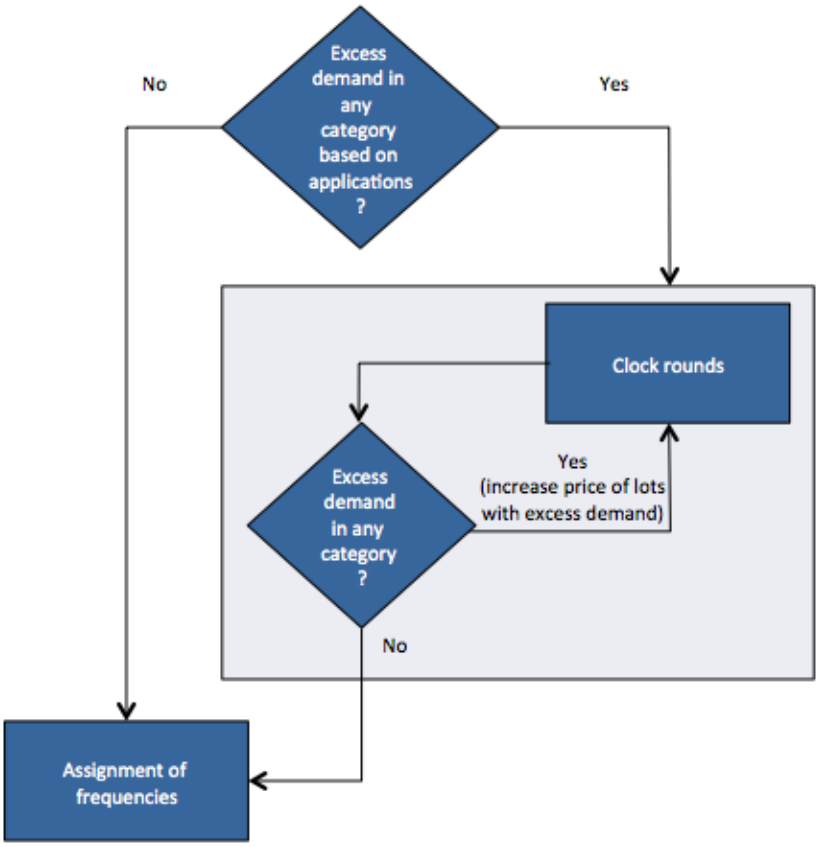
[69] This will either be (i) the reserve price or (ii) the reserve price plus one price increment in the event that bidder applications are treated as bids.

that will apply during the next round. Prices will be unchanged relative to the previous round for categories of lots not in excess demand, and prices will increase by one increment for categories of lots in excess demand.

- Where further rounds are required in multi-round auctions, activity rules govern the bidding behaviour that is feasible. Activity rules are aimed at ensuring that bidders do not withhold their true demand until near the end of the open phase, so that the information disclosed during the open phase is meaningful. In essence, activity rules intend to prevent bidders from expanding their demand when prices increase. The simplest activity rule that might be imposed is that package size cannot increase from round to round as prices increase – they can only be reduced or maintained.
- The auctioneer will continue the process of declaring prices, accepting bids at these prices during rounds and assessing demand until there is a round in which there is no excess demand.
- Following the close of a round during which there was no excess demand:
    - Bidders in that round will be declared winners;
    - The packages they bid for in that round will be declared winning packages; and
    - Their winning prices will be the sum of the prices in that round for all of the lots in their respective winning packages.[70]
- If lots have been auctioned in lot categories and based on the auction outcome there is more than one alternative possible assignment of frequencies in one or more category, the assignment of specific frequencies to winners in such categories will be conducted in a follow-up process.

145. This process is illustrated below:

[70] While this is a 'pay as bid' auction format, bidders are only required to bid up to the amount that is necessary to force competitors to contract their demand. Therefore, the price achieved to is marginally above the opportunity cost, reflecting the value that competitors are willing to pay. Note that this assessment of what represents opportunity cost only holds if values are linear (e.g. the value of two lots is twice the value of one lot), all lots are the same and there are no unsold lots. Without these assumptions, the opportunity cost becomes more complex to compute.



146. There are two problems with this simple clock auction format:

- *No bids are binding until the last round, which may facilitate strategic bidding.* This would be a problem if prices were to be driven up by non-serious bids and the auction were to end unexpectedly, leaving lots in the hands of those that do not value them the most. This is a serious problem in the case of awarding public resources such as radio spectrum, as efficiency is a key objective of such awards.
- *There is a risk of unsold lots, and this may affect the efficiency of the outcome.* This is not an issue where bidders have (i) decreasing returns on additional lots (i.e. the incremental value of adding a lot to a package is smaller the more lots are in the package to start with), and (ii) demand that can be satisfied with one lot; under these circumstances bidders can begin the auction bidding on all the lots they have value for and reduce demand gradually as prices rise. So long as price increments are small towards the end of the auction, in this case, the issue of unsold lots is not relevant. However, if bidders have a minimum requirement of multiple lots, or at least some bidders have increasing returns for additional lots then there is a significant risk that multiple lots will go unsold; if bidders' preferences

have such a structure then demand may reduce in discrete jumps involving many lots, even if prices increase only slowly. Preferences with such a structure may occur quite naturally in spectrum auctions where spectrum is offered flexibly as small blocks that are combined.

147. In practice, a number of additional rules have been imposed in many of the auctions using this format in order to mitigate this first issue. For example, the 3G and BWA auctions in India in 2010 consisted of a simple clock auction format augmented with a system of standing high bids. This meant that as long as a lot was bid on at the reserve price in the first round, it was always associated with a bidder, and the bidder with the standing high bid at the end of the auction for the lot became its winner.

148. However, the second issue cannot be adequately addressed within this format. In particular, if some lots go unsold, it may be possible to improve on the auction outcome:

(1) In some cases it may be possible to assign lots unsold at the final clock price at a lower price to achieve a more efficient outcome; and
(2) Further, it is also possible that a different combination of winning packages, which together assigns more of the lots available, might generate higher value, which would be a more efficient outcome.

149. There is the possibility within the simple clock auction to look to earlier bids from bidders with winning packages and see if additional lots might be awarded to these bidders at lower prices (option 1 above). Leaving to one side the effect on bidding behaviour that such a modification may have, the remaining issue is that alternative outcomes are not fully considered. The magnitude of the effect this may have depends on, among other things, the scope for unsold lots. The larger the minimum requirement of lots by bidders, and the existence of increasing returns to additional lots, the greater the potential for unsold lots and the larger the number of unsold lots that might result in a simple clock auction. If this number of lots unsold at the final clock price is large, the range of options for awarding these lots might

be rather limited if we only consider outcomes where existing winners are awarded more lots.[71]

150. One possibility to address this issue is to allow for bidders to express their value for a range of different packages and to award lots based on the highest value option for doing so (given certain rules), having evaluated all different combinations of these bids and the collective value they generate. This process of accepting a range of different bids from each bidder and evaluating all options for awarding the lots available based on these bids is used in both the CCA and the SBCA formats; it is known as *winner determination*.

Sealed bid combinatorial auction

151. This auction format has the benefit of allowing bidders to express, in a single round, a range of demand and their relative value for different packages of lots, and selecting a winning combination of bids from the pool of all feasible combinations.

Mechanics of the auction

152. During the single round of the sealed bid combinatorial auction, bidders are permitted to express multiple bids for different packages of lots. These bids are subject to 'floors' on the value of their bids, which amount to the sum of the reserve prices for the lots included in a package. They may also be subject to caps on the number of lots that they contain (spectrum caps, which would be set out prior to the bidding round). Following the end of the round, all combinations of bids submitted in the round are generated, and all feasible combinations of bids are evaluated. A combination of bids is feasible to become the winning outcome if:

- It contains exactly one bid from each bidder, where this might be a default zero bid (a bid for zero lots for a bid amount of zero representing that bidder winning nothing) for one or more bidders;
- The number of lots in each category awarded in the combination of bids is no greater than the number of lots available in the auction in any category; and

[71] Note that this 're-activation' of previous bids has its own drawbacks – it exacerbates incentives for strategic demand reduction and it has a number of follow-on consequences for bidding because of the effect of such re-activation on budget-constrained bidders.

- The bid amounts associated with all bids in the given combination of bids adhere to applicable floors.

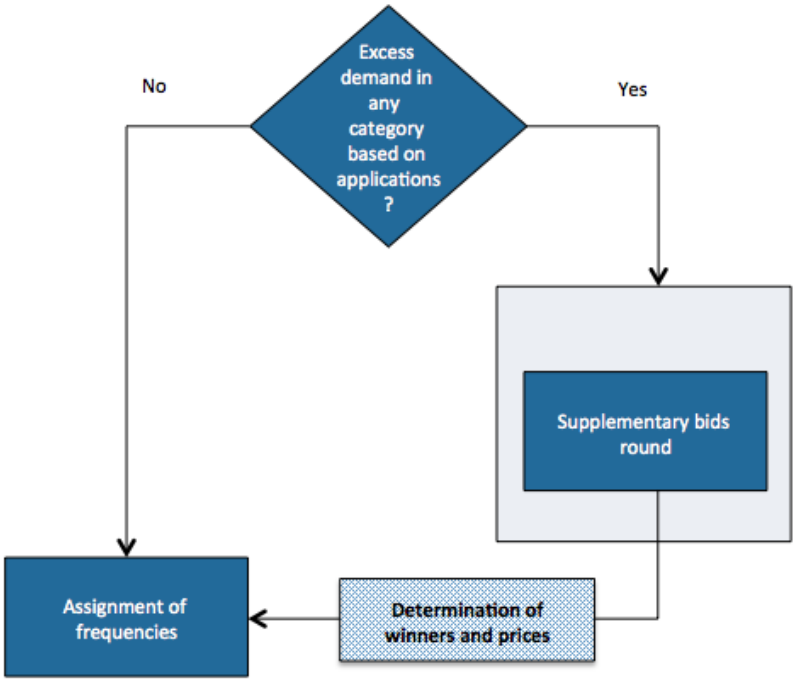
The highest value combination of feasible bids is declared the winning outcome.

153. Prices to be paid for winning packages are determined through the use of opportunity cost pricing, with:

- each winning bidder paying enough for its package to still win this package, given the value of feasible bids of other bidders; and
- winning bidders collectively paying enough for the combination of winning packages to still win, given the value of all other combinations of feasible bids.

154. If lots have been auctioned in lot categories and based on the auction outcome there is more than one alternative possible assignment of frequencies in one or more categories, the assignment of specific frequencies to winners in such categories will be conducted in a follow-up process.

155. This process is illustrated below:



Combinatorial clock auction

156. The CCA is essentially a two-phase bidding process consisting of an 'open' or multi-round phase, which is akin to a simple clock auction, followed by a further combinatorial bidding round. The combinatorial bidding round is similar in nature to the SBCA, as bidders can submit multiple bids,

covering the range of its demand. There are, however, a number of key differences between the CCA and the simple clock auction and SBCA as described above:

- Bids made throughout the 'clock' phase of the CCA are binding, as they will be considered like all other bids when evaluating which combination of bids has the highest value and becomes the winning outcome.
- In order to be feasible, bids made in the second phase of bidding must adhere to spectrum caps and floors on bid amounts as in the SBCA, but they are also subject to caps on bid amounts generated based on bids in the first round of bidding. These caps on bid amounts are imposed to ensure that bidders can only express preferences for some packages over others in the second phase that are consistent with their bidding behaviour in the clock phase.

157. This auction format combines the benefits of both the simple clock auction and the SBCA:

- The first phase allows for price discovery, as bidders get to observe the level of market demand at different prices before setting out their final schedule of prices for different packages of lots.
- In complex auctions with many possible packages and outcomes, the first phase provides information to bidders about the types of packages they might potentially win, which allows them to focus on valuing the differences between realistic alternatives. This may also assist bidders with budget constraints to understand what they might be able to win.
- This format also has the benefit of allowing bidders to express a range of demand and their relative value for many different packages of lots that are substitutes for the bidder, and selecting a winning combination of bids from the pool of all feasible combinations.

Mechanics of the auction

158. As with the simple clock auction, the first phase of bidding progresses over a number of rounds, where similar lots are combined into the same lot category:

- In advance of the first round, the auctioneer declares prices that will apply during the first round, and price increments that will apply on a category-by-category basis if there is excess demand;
- During the first round, bidders state their demand for lots in all categories based on the pre-set prices for each category;
- After the round, the auctioneer will assess demand. If there is excess demand in any category, then another

round will be announced and the auctioneer will declare prices that will apply during the next round. Package size (as defined by eligibility points associated with each lot)[72] can only be reduced or maintained as prices increase.

- The auctioneer will continue the process of declaring prices, accepting bids at these prices during rounds and assessing demand until there is a round in which there is no excess demand.

159. Following the close of a round during which there was no excess demand, the auction moves from the first to the second phase of bidding, the supplementary bids round.

160. During the supplementary bids round, bidders are permitted to express multiple bids for different packages of lots:

- They may increase or leave unchanged bids for packages bid for during the first phase; and
- They may place bids for packages not yet bid on.

161. During the first phase, rules are imposed on bidding activity in order to limit the scope for bidders to bid strategically, with activity rules ensuring that bidders could not withhold their true demand until near the end of the open phase. In the supplementary bids round, analogous rules are imposed on bidders through caps on supplementary bids, ensuring that preferences for packages of different sizes are consistent with those preferences expressed through bids submitted during the first phase.

162. Following the end of the supplementary bids round, all combinations of bids submitted in the auction to that point are considered and all feasible combinations of bids are evaluated. A combination of bids is feasible to become the winning outcome if:

- It contains exactly one bid from each bidder, where this might be a default zero bid (a bid for zero lots for a bid

[72] Under eligibility-based activity rules, each lot is attributed a number of eligibility points (reflecting their perceived relative values). The activity of a bidder in a given round is then defined as the sum of eligibility points across all lots for which the bidder has an 'active' bid (either a bid placed in the round or, in the case of an SMRA, a standing high bid at the start of the round). Bidders are then attributed an eligibility level that is adjusted round on round, and are subject to the restriction that their activity in a round cannot exceed their eligibility level. In subsequent rounds, the eligibility level of a bidder is then set to its activity in the preceding round. The effect of this is to ensure that bidders cannot increase their demand, measured in eligibility points.

amount of zero representing that bidder winning nothing at all) for one or more bidders;

- The number of lots in each category awarded in the combination of bids is no greater than the number of lots available in the auction in any category; and
- The bid amounts associated with all bids in the given combination of bids adhere to applicable caps and floors (generally, the sum of the reserve prices of lots included in each package).

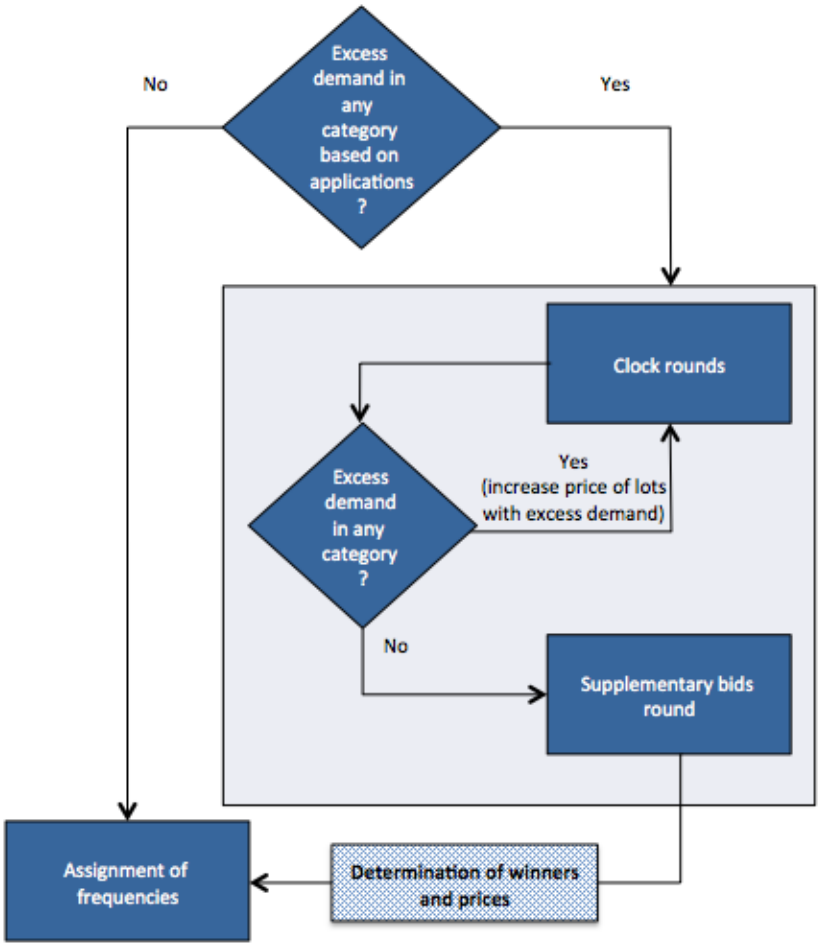
The highest value combination of feasible bids is declared the winning outcome.

163. As in the SBCA, prices to be paid for winning packages are determined through the use of opportunity cost pricing, with:

- each winning bidder paying enough for its package to still win this package, given the value of feasible bids of other bidders; and
- winning bidders collectively paying enough for the combination of winning packages to still win, given the value of all other combinations of feasible bids.

164. If lots have been auctioned in lot categories and based on the auction outcome there is more than one alternative possible assignment of frequencies in one or more categories, the assignment of specific frequencies to winners in such categories will be conducted in a follow-up process.

165. This process is illustrated below:



166. The MBSA adopted the relaxed activity rules, which facilitates switching across categories when relative prices change, if doing so is consistent with the preferences revealed in earlier rounds where the bidder has contracted demand. The relaxed activity rule has the effect of:

(i) facilitating bidders bidding on their most preferred package of lots in every round; and

(ii) solidifying the outcome of the clock rounds.

3.2.2 SMRA

In an SMRA auction, each bid for a specific lot is treated independently – competition for a lot takes no account of competition that might be taking place for other lots in the auction. Broadly speaking, this means that:

- On the one hand, the format is susceptible to an aggregation problem, where bidders for multiple lots face a risk of bidding according to valuations but only winning some of the lots desired.

- On the other hand, this 'series of independent competitions' aspect of the format has certain advantages, including a general perception of simplicity relative to combinatorial formats such as the CCA that rely on a winner determination and pricing algorithm being applied at the end of the auction (discussed above).

167. The 'traditional' or most common implementation of the SMRA allows bidders to place bids for frequency-specific lots, in a process described below.

Mechanics of the auction

168. With this format, an auction for all lots available proceeds simultaneously as follows:

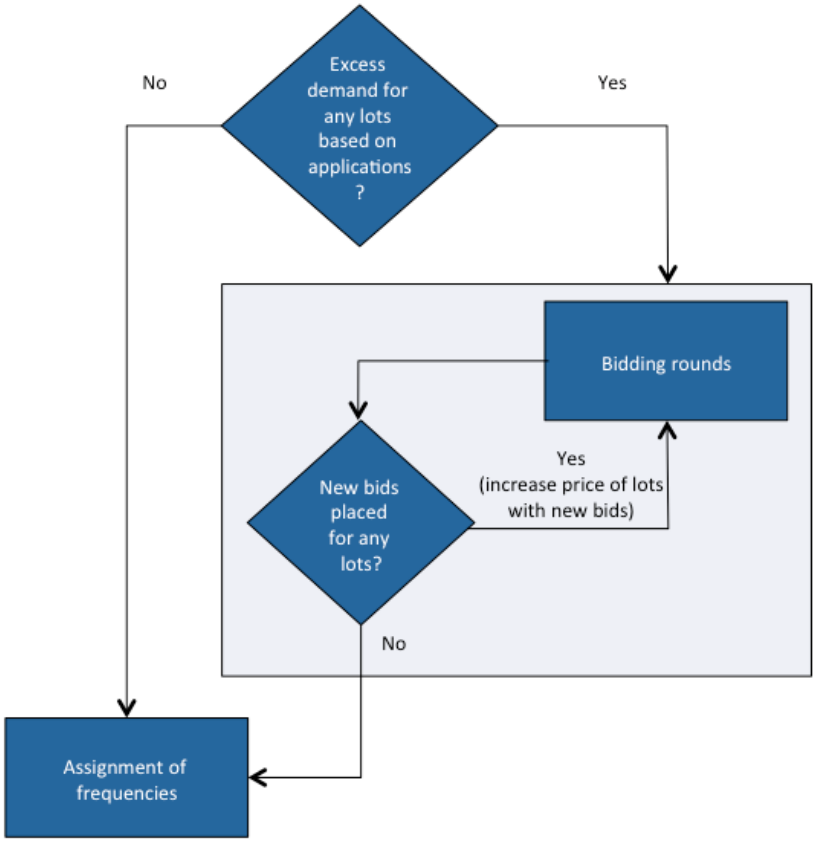
- In advance of the first round, the auctioneer declares prices that will apply during the first round.
- During the first round, each bidder may place a bid for one or more of the lots available, subject to any spectrum caps or other restrictions.
- After the round, the auctioneer assesses demand. For each lot, the highest bid received on the lot becomes the standing high bid on that lot, and the associated bidder is notified that it is the standing high bidder on that lot. If there are multiple bids for a specific lot at the round price, a tie-breaking rule is used to select a standing high bidder.

- In all following rounds:
  - A new, higher price is set for those lots that received at least one bid at the previous round price.[73] Price remains the same for all lots that have not received any bids at the most recently set price.
  - During the round, bidders are able to place bids at the prevailing prices. A bidder's activity in a round is set by (i) the lots on which it has the standing high bid, as determined in some previous round, *plus* (ii) the lots on which it places a new bid in the current round. A bidder's activity can only be maintained or decreased in subsequent rounds; it can never increase.

[73] This is called non-discretionary bidding, where the auctioneer sets the level of new bids. However, there are a number of variants of this, where bidders set their own, higher prices within certain constraints.

- The auctioneer continues this process of declaring prices and selecting standing high bids until there is a round in which no new bids are made. At this point, the auction closes and standing high bids become winning bids, with those bid prices becoming final prices.

169. The process is illustrated below:



170. Note that while this auction format is a 'pay as bid' auction, winners are still only required to pay the opportunity cost of their winnings, as the price of each lot is set at the level at which competition for the lot ceases, the approximate value of the lot to the competition.[74]

171. Building upon the 'traditional' SMRA format, some implementations have included more sophisticated features, for example:

[74] The actual value of a lot to a 'loser' will be somewhere in between the last price at which it bid for the lot and the next round price, at which it did not place a bid. The concept of opportunity cost becomes more complex with non-linear prices, multiple types of lot and/or unsold lots in the final round.

- Frequency-generic lots may be used instead of frequency-specific lots, where lots of a similar nature (often, lots of the same size and in the same band) are aggregated into a single generic lot category. In this instance, bidders would be able to bid for a number of lots in a category, rather than explicitly for specific frequency blocks. In such cases, an additional assignment stage is necessary in order for winning bidders to bid for their desired frequency assignments. This removes the risk of winning non-contiguous frequency assignments within a lot category.
- Allowing a bidder to withdraw its standing high bid on one or more lots under certain conditions. This may help bidders seeking multiple lots to be able to switch between alternative combinations of lots in a single action.
- A staged activity requirement to allow bidders some flexibility during the early rounds, so that they may get a sense of relative prices before expanding their demand to all of the lots they wish to win. In the situation where bidders are interested in a number of alternative packages across different categories, this facility would allow them to hold back from committing themselves to certain categories until after some price information has been revealed. Nevertheless, the auction may not close until the activity requirement has been raised to 100% – that is, until bidders are required to express their full demand.

172. The precise context of a particular award is important in determining whether or not any additional SMRA features can be expected to have a beneficial net effect. These additional features may also bring the complexity of the SMRA to a level comparable to that of the CCA format.

3.2.3 Considerations for ComReg for this award

173. In assessing which variant of existing auction formats might be the best fit for this award process, we consider some of the issues surrounding spectrum auctions, assess how important they are for this award process and recommend a format that best facilitates an efficient outcome in the context of this specific award.

Common value uncertainty

174. The value of spectrum to a bidder will be determined in part by factors related only to that bidder – for example, the value

of the service enabled by the spectrum and the level of take-up of the service – and factors that affect all bidders for the spectrum in a similar way – for example, timing of low-cost equipment for a particular band. Whether there is significant uncertainty that affects the values of all bidders in the same way will depend on the specifics of the market environment and the potential bidders for the spectrum. Where there is uncertainty surrounding these latter 'common' factors, there may be benefit to bidders pooling information about their outlook surrounding these factors. This may increase the efficiency of the outcome.[75]

175. In the event that there are common factors that are uncertain, it is preferable to use a multi-round auction format. With an open auction format, if a bidder has expectations about common factors that are out of line with those of other bidders, and has adjusted its valuation accordingly, it will observe during the open rounds a level of demand at given prices that is out of line with its expectations. In this situation, the bidder would have the opportunity to adjust its valuation and its bidding behaviour based on what it has observed. In contrast, in a one-shot process such as a SBCA, such a bidder would only discover this mismatch of expectation between it and other bidders following the round, without a chance to re-bid.

176. We consider that there is significant uncertainty surrounding this award that is common to at least some bidders, even if it were only to include 2.6GHz frequencies:

- While the economics surrounding the use of 2.6GHz spectrum are relatively clear – the band is allocated in many countries for mobile use, there is a good level of equipment and devices available for this band already – the costs associated with the use of this band for providing TV services in the medium term are not clear, with few countries using this spectrum for this purpose. However, given that this is the existing use of the spectrum in Ireland, this is a candidate use for this spectrum going forward; therefore, this uncertainty cannot be ignored.
- Values of spectrum licences awarded in this band have varied dramatically across countries. Some of this

[75] Under these conditions, it is necessary to be careful what is meant by 'efficiency', as the optimality of an outcome needs to be judged given the information available. The concept of efficiency we are using here is what is usually called 'ex-post efficiency', that is the efficiency of the outcome once information is pooled.

variance can be explained by country-specific factors, and some by differences in the level of competition for spectrum in this band within competitive processes (with the presence of 3 or 4 mobile operators in the downstream market having at least some influence, for example). However, there has also been a significant impact on recent awards of this spectrum from the amount of high frequency spectrum likely to become available in the near to medium term that could also be used for providing advanced data services, in particular mobile data. For example:

- At the time of the relatively early releases of the 2.6GHz band for advanced mobile data services (2008 to 2010), this spectrum was the only high-frequency spectrum that was perceived to become available in the medium term for these services;
- In the following years (2010 to 2013), a significant amount of spectrum liberalisation took place, and 1800MHz spectrum quickly became an important band (also harmonised in the EU and a number of other regions) for provision of advanced mobile services, and a potential substitute for 2.6GHz spectrum; and
- Over the course of 2013, the technical conditions for a number of other capacity bands have fast been developed at the EU level and beyond for use on a liberalised basis. This technical work has largely been completed, and interest in these bands (2.3GHz, 1.4GHz and 3.6GHz, as described in section 2.3) is developing rapidly. While there is undoubtedly differences between these bands, (i) the past 5 years has shown that differences in the level of development between bands can diminish rapidly, if interest exists from potential users, and (ii) these bands do not need to be exact substitutes in order for there to be substitutability, with substitution occurring on some set of terms. This has generated the circumstance that 2.6GHz spectrum releases in the near term will be in the context of a relatively large amount of spectrum becoming available within capacity bands capable of providing the same types of services.

- The large amount of spectrum that will become available in the relatively short term raises the issue of attractiveness of this band relative to other capacity spectrum. While ComReg will be able to provide clarity, one way or another, about the availability of these other

bands, this assessment requires expectations to be formed about attractiveness of these other bands, which will take into account timing of award or liberalisation of these bands, potential market for equipment that these bands will represent and the timing of cost-effective equipment coming to market.

A multi-round auction format may be beneficial in mitigating this uncertainty.

177. An obvious extension of this is that if other capacity bands were to be included in this auction, this would strengthen the case for a multi-round auction.

Strategic demand reduction

178. Strategic demand reduction is a phenomenon that can arise in auctions where bidders are choosing the quantity of lots they are bidding for. In some auction formats, the quantity of lots sought by a bidder can be anticipated to affect the price it needs to pay. Such a bidder may identify that the price for its winning package may be lower on a per lot basis if it seeks to win fewer lots from early in the process (instead of competing for many lots and then dropping back to fewer lots if its larger package gets too expensive). Faced with this situation, a bidder may choose to bid for fewer lots than it would have bid for had it not anticipated having any effect on price. This can lead to inefficiency (as bidders are not seeking lots they have value for) and reduced competition.

179. Consider an example with one lot category with 9 lots and two bidders (A and B). Suppose that the bidders each have value for 6 lots and 3 lots and that the value they attribute to each package respectively is 41 and 25 for bidder A and 37 and 25 for bidder B. Now consider the following scenario for Bidder A assuming that Bidder B bids in a straightforward manner:

Round	Price per lot	Bidder A's bid (truthful bidding, i.e. price bid by A)	Bidder B's bid (truthful bidding, i.e. price bid by B)	Bidder A surplus for bidding on 6 lots	Bidder A surplus for bidding on 3 lots	Bidder B surplus for bidding on 6 lots	Bidder B surplus for bidding on 3 lots	Excess demand (total demand minus available lots)
1	1	6	6	35	22	31	22	3 (12-9)
2	2	6	6	29	19	25	19	3
3	3	6	6	23	16	19	16	3

4	4	6	6	17	13	13	13	3
5	5	6	3	11	10	7	10	0

180. In this example, we can see that the efficient outcome assigns a package of 6 lots for bidder A and a package of 3 lots for bidder B, given their valuations, if both bidders bid according to these valuations, and this is the outcome that would result if Bidder A also bid according to its valuations. However, if A anticipates that it will end up winning the smaller package anyway, it may have a higher surplus if it does not compete for the package of 6 lots and by doing so manages to secure the package of 3 lots at a low price.

181. This example illustrates that this strategy may be a profitable one for bidders in practice - if bidder A were to drop down to 3 lots in any of rounds 1 to 4, closing the auction, it would have had a greater surplus than if it has won 6 lots at round 5 prices. This example also highlights the detriment to efficiency that can occur in the case where expectations of bidders about others' valuations are wrong – in this case, based on values, the efficient outcome would have been to award Bidder A 6 lots, whereas in maximising its surplus based on expectations of others' values Bidder A stopped bidding on 6 lots early and was only awarded 3 lots.

182. Two further points to highlight about strategic demand reduction are that:

- In order to execute such a strategy effectively, a bidder would need to have reasonable certainty that its actions will have an effect on prices, in this case that the bidder can close the auction and ensure that it pays the price per lot in any of rounds 1 to 4.
- The incentive for strategic demand reduction is greater in the situation where only linear prices apply, as a bidder wishing to maintain its bid for lots additional to a smaller package will need to increase its bid for all of the lots within the package in order to do so.

183. The first point has implications for setting an optimal transparency policy during the award process. The second point should be taken into account in assessing auction designs and whether they allow for non-linear pricing.

184. Generally, it is clear from this example that strategic demand reduction can have a serious impact on the efficiency of an award, as seen by the different packages awarded to Bidder A resulting from its deviation from straightforward bidding in the example above. The issue for auction design is how relevant this issue is likely to be for this award.

185. We consider that strategic demand reduction is an important factor to consider in the choice of format for this auction:

- Regardless of whether additional bands are included, there will be a large amount of spectrum made available in the auction. This raises the issue of whether there may be an accommodated outcome where one or more bidders act strategically to 'fit in' amongst other demand instead of competing for its preferred amount of spectrum given alternative business cases.
- There is likely to be at least some asymmetry amongst bidders, which may mean that strategic demand reduction is more likely than otherwise, where one or more bidders identify themselves as relatively weak and opt to reduce demand early instead of competing.

186. Strategic demand reduction is particularly concerning in the context of a capacity auction for two reasons:

- First, bidders seeking capacity spectrum are likely to be more flexible in relation to the total bandwidth they acquire, which means that they may have greater scope for reducing demand with the prospect of a cost saving;
- Second, strategic demand reduction could lead to less competitive downstream markets, as having less capacity may increase marginal costs and reduce incentives to compete for customers and offer new services that boost traffic.

Substitution risks

187. Substitution risks can arise when one or more bidders view at least some alternative packages of lots as substitutes but cannot reflect this amenity to switch its bidding from one package to another based on prices because of some sort of impediment to switching.

188. This is an important issue to consider for this award, with there being multiple bands that may be substitutes for some bidders. Impediments to switching are likely to affect bidders differently, and as such we are of the view that it is appropriate for ComReg to be confident before the award that its outcome will not be influenced by such differences and so fail to be competitively neutral.

189. In the context of substitutable bands, it would be desirable to facilitate:

- switching across bands (and generally across lot categories) in response to changes in relative prices (i.e. a bidder may prefer A to B when the price difference

between A and B is at least X, but may prefer B to A if the price difference is less than X); and

- switching between packages that include different amounts of spectrum in different bands or categories (i.e. a bidder may be willing to switch between X lots in band A and Y lots in band B, especially if the availability of lots of characteristics of spectrum differ across bands).

190. Some important implications of this are that:

- Regardless of format, a series of activity rules will have to permit the types of switching that are deemed desirable. Traditional activity rules based on eligibility points and strict restrictions that do not allow bidders to bid above their eligibility level may prevent legitimate package options when relative prices change.
- Switching is not straightforward in SMRA-style auctions. As touched on in section 3.2.2, the standard SMRA has various modifications available to it to facilitate switching. Such modifications mainly focus on how standing high bidders are determined and defined, and on the possibility for allowing withdrawal of standing high bids (either in limited quantities or in limited circumstances).[76] However, there is a fundamental trade-off with these modifications, where the increase in flexibility to switch results in an increase in scope for strategic behaviour and gaming.

Aggregation risks

191. This refers to the risk that bidders win only enough spectrum to meet part of their demand. This is a serious issue for bidders in auctions as they may have increasing returns for spectrum, at least to some extent. For example, a bidder may have a minimum requirement of, say, 4 lots, and have little value for being awarded less than 4. If the expression of this type of valuation is not easily facilitated and relatively riskless within the bidding process, bidders may deviate from straightforward bidding behaviour to insure themselves against the risk of ending up with only some of what they want at a price at which their winnings have negative value

[76] For instance, the SMRA with 'augmented switching' format allows withdrawals only in the event that a bidder places a new bid (as opposed to increasing a bid on a lot it is already bidding on) for each withdrawal that it makes.

to them. We explain below why this issue is particularly relevant for spectrum auctions.

192. Until relatively recently, spectrum awards assigned spectrum for specific uses and, as such, the relevant frequencies could be easily packaged into licence-sized blocks for award amongst interested parties. In such an environment, the issues of aggregation of lots and its associated risks were not relevant. However, with the move towards spectrum liberalisation, allowing users in the same spectrum band to operate different services using different technologies, and a shift towards awarding spectrum in multiple bands together, often where these are considered to be substitutes or complements for one another, the concept of licence-sized blocks (where spectrum is packaged in lots that can be used by licensees on a standalone basis) has reduced in significance. In many recent awards across Europe, spectrum has been awarded in lots of 5MHz or 2x5MHz, which is viewed as an acceptable building block size for bidders to aggregate into licences, the optimal size of which may depend on individual bidders, their existing services and customer bases and forecasts for business growth. This concept of "no-one-size-fits-all" spectrum licensing is becoming greater in importance as spectrum liberalisation begins to result in significant band sharing by different user types, and will be a particular issue for the ComReg award:

- If 2.6GHz spectrum only is included in the award, there may be demand from at least two different classes of use;
- If other capacity bands are included, the potential user pool may extend to those currently providing broadband wireless access; and
- In any case, it would be desirable to facilitate bidding by bidders not already in the wireless market.

193. This is a substantial issue for this award because:

- With the move to LTE-Advanced, operators may well require blocks of 20MHz, or multiples of these in the medium term to meet network demand;
- Existing FWA providers are currently using spectrum block sizes larger than 5MHz,[77] with some utilising substantially bigger blocks. In the 2.6GHz band UPC is licensed to use 144MHz of spectrum from 2524 to 2668MHz, based on the 10 licences that it holds.

[77] FWALA operators currently provide broadband access to 58,984 customers with 37,342 of those customers attributed to the 3.6 GHz band.

- Were one or more to exist, we would want to facilitate parties with new business propositions making use of spectrum being able to acquire rights to use it, and this may well extend to propositions requiring a significant amount of spectrum.[78]

194. In short, without the benefit of an obvious licence size in which ComReg can package spectrum, safeguards to mitigate or remove the risk of bidders ending up with amounts of spectrum that are unusable for their purposes are imperative to ensure that spectrum does not go unused inefficiently.

195. Aggregation risks would also be accentuated if some spectrum is offered on a sub-national basis, as some bidders may wish to acquire a combination of lots to obtain a specific footprint (or even nation-wide licences). However, such bidders may place less value on winning licences in only some of the regions they bid for.

196. The issue of aggregation does not exist in combinatorial auctions, as bidders can only possibly win packages of lots that they have bid on. Aggregation risk is substantial in the SMRA, and the 'standing high bidder' element of the SMRA exacerbates the issue by creating impediments to switching. As aforementioned, a number of modifications have been developed to address the issue, such as minimum bids and withdrawal allowances, but these modifications mitigate this issue at the expense of introducing other potential problems.

Complexity

197. There are two distinct types of complexity that feature in the assessment of auction designs and their ability to meet auction objectives given market circumstances and parties interested in participating in the auction:

- complexity of rules and the auction mechanism;
- complexity of decisions faced by bidders.

[78] See BT's response to a call for inputs by Ofcom on use of 2.3GHz and 3.4GHz spectrum in the UK in which it notes the possibility of a 'neutral host operator' providing wholesale access to capacity, for which it estimated it or another operator would require 120MHz of this spectrum.

http://stakeholders.ofcom.org.uk/binaries/consultations/2.3-3.4-ghz/responses/BT.pdf

198. Complexity within an auction can be tolerated to a degree if the value of what is being auctioned is high as the importance of achieving the auction's objectives (in particular, efficient assignment) is great and likely participants should have a keen interest in becoming familiar with the detail of how the auction will work.

199. Complexity of auctions becomes more of an issue in the event that:

- the costs to bidders in time and money of preparing for an auction become a material proportion of the value of the spectrum for award, as this risks deterring potential bidders; or
- there is the possibility that small bidders or potential new entrants may lack auction experience and the resources to invest in substantial auction preparation and development of bid strategy.

Complexity in the CCA

200. The CCA is often considered to have a relatively complicated structure (in the main due to the use of algorithms for winner determination and pricing). Design of an effective bid strategy does require an understanding of key concepts such as:

- the concept of opportunity cost underpinning the pricing rule; and
- the supplementary bids round and the caps on bids that result from primary bids.

201. However, once the model itself is understood and bidders have generated their valuations for different packages of lots, the process of bidding to reflect these valuations (and importantly, relative preferences between different packages) bidding can be relatively straightforward. Therefore, there is no need to adopt a complex bid strategy to bid successfully in a CCA.

202. As an aside, we note that a considerable amount can be done by the regulator to aid bidders in developing an understanding of the auction rules through, for example, setting out examples to illustrate concepts that are somewhat abstract and providing tools necessary for bidders to simulate auction conditions. For example, in the MBSA process, software was made available to interested parties to allow calculation of winning bids and prices. This educative process could be extended to providing bidders with access to a series of mock auctions as ComReg has done previously and, in the case of the CCA or SBCA, a standalone tool for working out winners and prices given a specified set of bids. Therefore, we do not consider that the complexity of the

mechanisms of combinatorial auctions are a significant impediment to their adoption, as much can be done to help bidders.

Complexity in the SMRA

203. In contrast, the early versions of the SMRA, which were implemented including licence-sized licences, were regarded as relatively easy to understand. Bid strategy within an SMRA was also considered relatively straightforward. However, with the demand-led shift towards building block-size licences, the complexity of rules has increased. In particular, designing an effective bidding strategy for an SMRA with many lots organised into categories is complex and will depend on assumptions about the behaviour of others. This is because the standing high bid concept inherent in the SMRA means that bids for multiple lots can be 'sticky', where a bidder may be out-bid on some but not all of its lots in a round. In addition, eligibility reductions have non-reversible consequences that will prevent a bidder from increasing its demand later in the auction if prices change. As a consequence bidders may need to second-guess what others might do and how much others value different combinations of lots, in order to form expectations on likely end prices, and about which alternative packages they might win. This task gets increasingly more complex when there is a large number of lots, lots in different bands and many bidders. In particular, as discussed above:

    - Aggregation risks have become an important issue with using this format for spectrum auctions, and a number of additional rules have been added to the format to mitigate these risks, e.g. staged activity requirements, minimum bandwidth requirements (which ensure that bidders will not be assigned spectrum if the number of lots won were not to provide at least its minimum bandwidth requirement), limited withdrawals. However, both minimum bids and withdrawals also have knock-on consequences that require additional rules to address.
    - Substitution risks have also prompted more sophisticated rules around the concept of standing high bids in order to allow a degree of flexibility to switch between packages, e.g. 'augmented switching', which permits the withdrawal of a bid on a lot on condition that a bid is placed on another lot that the bidder is not already bidding on.

204. These types of rules not only increase the complexity of the auction itself, but also make the bidding process much more complex. For example, introducing minimum bids and withdrawals to mitigate aggregation and substitution risks mean that the bidder holding the standing high bid on each

lot subject to a withdrawal at the previous lot price will be re-activated on that lot at this previous price. This creates a bid management task, which can be substantial. For instance, where a bidder is re-activated on a lot, it may be at a later point in the auction by which time (i) the bidder may have insufficient eligibility to bid back on the full package to which this lot relates, or (ii) the bidder may have re-committed the budget from the lot after it was out-bid on it, leaving it financially over-committed. While the bidder may be able to withdraw such a bid, withdrawals are necessarily limited as without a relatively tight limit (i) bids are no longer committing in practice, making strategic price-driving behaviour riskless, (ii) bid and budget management would be unwieldy, and (iii) the price discovery benefit of an open auction format would be eroded.

205. In summary, it cannot be assumed that an SMRA with features intended to address aggregation and substitution risks with multiple bands would be simple. Also bid strategies may need to be complex.

Concerns about collusion

206. A potential issue with open auctions is that it may allow bidders to engage in tacit collusion, where a number of bidders jointly reduce their demand to moderate the prices they have to pay. The open rounds may facilitate such outcomes by providing bidders with an opportunity to signal their intentions, observe the behaviour of their competitors and (progressively) adjust their own bids.

207. In contrast, such bidder interaction is not possible when using sealed bid auctions, which exposes bidders to much greater uncertainty about whether their competitors may be willing to withhold competition to avoid high prices, or conversely compete aggressively (which could lead to a more undesirable outcome for bidders that withhold demand).

208. Collusion incentives, which may be strong in SMRAs, are usually weaker in the CCA, where prices are mostly determined by the bids submitted by competitors, and where bidders may deviate from expected behaviour in the supplementary bids round.

Price-driving strategies

209. Price-driving bids are bids that do not reflect a bidder's true valuations for the underlying lots but a bidder places with the aim of increasing the price paid by other bidders. Such

behaviour is not necessarily a concern on efficiency grounds, unless there is a genuine probability of bidders bidding strategically in excess of valuations and ultimately winning those lots at a price above valuation. It may also be a problem if the auction format or rules are seen to favour or disadvantage particular bidders through the impact of price-driving strategies (e.g. if 'weaker' bidders appear to be less able to engage in such strategies due to budget constraints or due to inexperience), which could lead to complaints from disadvantaged bidders.

210. In general, the likelihood of such behaviour depends on the extent to which bidders can judge the probability of any particular bid becoming a winning bid. This may depend on the degree of transparency but also on other detailed auction features, e.g. any provisions that can make bids non-committing. For example, in a CCA, in some cases bidders may be able to calculate supplementary bids that have zero probability (or a low probability) of winning, while having the effect of raising prices paid by others. In an SMRA, price-driving may be encouraged by design features such as withdrawals or minimum spectrum requirements.

211. Broadly speaking, the incentive for price-driving should be weaker when lot categories are highly substitutable for many bidders:

- In such a scenario, bidders will respond to price-driving behaviour in one category by switching to other categories and therefore applying upward pressure on prices in those other categories; and
- Therefore, if a bidder attempts to drive prices up in a category that it is not interested in, it will risk causing a knock-on effect that subsequently also drives up prices in those categories containing lots that it is actually interested in winning.

212. In this award, if additional bands are included, lots in at least some different categories are likely to be good substitutes, which suggests price driving in one category could easily result in higher prices for all categories. However, there are likely to be at least some bidders that are expected to have strong preferences for certain spectrum who might then be more vulnerable to price-driving if they are unwilling to switch to other bands. Further, with either a CCA or SMRA format, any price-driving behaviour during open rounds of an auction can erode price discovery. Therefore, having selected an auction format, reasonable steps would need to be taken to try to prevent price-driving strategies (for example, adopting an information policy that prevents bidders from easily identifying opportunities to engage in price driving, or ensuring that bidding in the auction is

committing, so that bidders cannot submit price-driving bids with impunity).

3.3 Packaging of available spectrum

213. EC Decision 2008/477/EC requires that spectrum blocks in the 2.6GHz band be assigned in multiples of 5MHz. Most countries have responded to this by defining the smallest possible lots (2x5MHz for paired 2.6GHz spectrum and 5MHz for unpaired spectrum), allowing bidders the flexibility to 'assemble' their own licences. However, there have also been exceptions where larger lot sizes have been used.[79]

214. For other candidate bands, the relevant European harmonisation measures for mobile broadband use of 2.3GHz, 1.4GHz and 3.6GHz spectrum[80] also specify frequency arrangements formed of 5MHz blocks.

215. As discussed above, offering spectrum in small blocks that can be aggregated into licences of variable size, instead of packaging it into licences of predetermined size, provides greater flexibility to bidders:

- They can choose the exact amount of spectrum that they wish to acquire; and
- They can reduce this amount in relatively small increments if necessary as market prices become apparent.

216. However, we note that ComReg's previous work and Decisions relating to all of the above bands do not constrain the set of packaging options available for any prospective award. As an alternative to offering the spectrum in 2x5MHz or 5MHz lots, one could consider packaging them into larger blocks. This might reduce the scope for aggregation and substitution risks, and thus mitigate the problems inherent in non-combinatorial auction formats (such as the SMRA). Therefore, prior to our assessment of the suitability of

[79] For instance, in the Spanish Multiband auction in 2011 some paired spectrum was offered as 2x10 lots (with one of the frequency blocks offered on a regional basis) and unpaired spectrum in five 10MHz lots. Another example is the Belgian 4G auction, which had provisions to package some paired spectrum into 2x15 or 2x20MHz lots depending on the number of applicants, and in which the unpaired spectrum was offered as a single 45MHz lot.

[80] Respectively, ECC Decision 14(BB) (draft), ECC Decision 13(03) and ECC Decision (11)06

alternative auction formats for this award, we consider whether it may be possible to use larger building blocks without unduly restricting the range of potential outcomes and disadvantaging some potential users.

217. The range of potential bidders that may be interested in the spectrum offered in this award could have different requirements. Even if only 2.6GHz spectrum were offered in the award, it would be necessary to provide a level playing field for, at least, mobile communications, fixed broadband and TV services, as likely potential uses. On the basis of these three alternative uses alone, it may already be difficult to established a larger technology and service neutral block size:

- Observations from other 2.6GHz auctions in Europe are inconclusive as to what constitutes the optimal licence size within this band (or even as to whether licences require a mix of paired and unpaired spectrum in this band or not);
- TV services have access to 144MHz of this spectrum at present, although it is estimated that a shift to MPEG4 technology would half this requirement. However, this means that these users might still require a larger bandwidth than that which has been assigned to any mobile users in this band in other countries. In addition, such users would also need to acquire additional bandwidth to provide any necessary guard blocks to ensure that technical requirements on interference are met. Therefore, there is uncertainty about what the total spectrum requirement would be for such a bidder.

218. If the 3.6GHz band were included, there is no clear indication of what might be the optimal lot size for existing users:

- The spectrum is currently licensed for different technologies (FDD and TDD) and in blocks of different sizes, ranging from 10MHz (in channels J and L) to 35MHz (channel B);
- Some bidders are currently aggregating these in the same area (e.g. Imagine Wireless Ltd has licences in the adjacent channels B and K* in the centre of Dublin, which provides a contiguous bandwidth of 51MHz); and
- The band is currently being licensed on a local area basis, making it difficult to forecast spectrum demand of bidders if all or part of the band were to be licensed from 2017 on a national basis.

219. If the 2.3GHz band were included, it is similarly difficult to set an optimal block size, despite the fact that this is the next most developed of the capacity bands available following 2.6GHz:

- LTE-Advanced users are likely to wish to acquire relatively large block sizes and minimise fragmentation across bands to minimise network management costs;
- On the other hand, some bidders may be prepared to accept a relatively small amount of this spectrum each (i.e. less than 20MHz) in combination with spectrum in other bands, in order to benefit from the relatively high degree of certainty about this band while at the same time maintaining a lower overall cost for their licence.

220. In the 1.4GHz band, if it were also included, the bandwidth requirement from different bidders might also depend on what complementary spectrum each bidder may have access to.

221. In light of our brief assessment, there is no obvious larger block size that can be expected to be equally preferable and suitable to all technologies and bidders. On the other hand, while we might be able to remove aggregation risks for some bidders by increasing the lot size to, say, 20MHz, this could create asymmetries amongst bidders to the extent that this might only be a suitable building block for some but not all bidders. This would not be aligned with the objective of technology neutrality. On the other hand, using a variety of lot sizes could introduce some restrictions on switching between lots of different sizes, creating further challenges for auction design and for bidders. Therefore, there is no clear reason for deviating from standard building blocks of 5MHz or 2x5MHz. This is our working assumption when evaluating alternative auction formats.

3.4 Summary

222. A scenario where there is excess demand for at least the 2.6GHz band is likely. Therefore, we recommend using an auction mechanism for the award of usage rights, as this should promote the assignment of licences to those users who value them most, which in turn can be expected to lead to an efficient use of the spectrum.

223. A natural candidate auction format for this award is the CCA, which was used in the 2012 MBSA. The CCA was designed with the specific purpose of mitigating bidders risks and of providing good incentives for bidders to bid truthfully. However, the CCA can be a complex auction design, and may be challenging for bidders who bid under a tight budget.

224. We have also considered the SMRA auction format, which has been widely used for the award of spectrum licences. An SMRA auction can be run on the basis of relatively simple

rules. The simple rules of the SMRA give bidders a sense of control over their financial exposure and likely winning bids round by round. However, the SMRA may perform poorly when spectrum is offered in small lots and bidders may bid for multiple lots. First, the SMRA exposes bidders to aggregation and substitution risks, and provides ample scope for gaming strategies. Second, the SMRA provides strong incentives for strategic demand reduction, which may undermine the value of the process in determining the best assignment of lots amongst bidders. In addition, bidding in an SMRA is strategically complex in that a bidder's optimal bid strategy is typically reliant on its expectations of competitors' behaviour and end prices.

225. In this award, bidders may be interested in different bandwidths, with different users potentially having distinct requirements. For this reason, pre-packaging spectrum in licences of specific bandwidths may be overly prescriptive both in terms of licence sizes and on the number of operators that may have access to spectrum. Using small lots will provide flexibility for bidders to express demand for packages of spectrum that will meet their requirements. However, using a small lot size creates scope for bidder risks that should ideally be addressed by auction design. In particular, bidders are likely to require a combination of lots within a band, and to be willing to substitute between bands. Therefore, using a combinatorial auction format is desirable on the grounds of reducing aggregation and substitution risk.

226. Strategic demand reduction is also a key concern in relation to capacity spectrum, as bidders are likely to be more flexible to reduce demand relative to when bidding for spectrum required to deploy a basic network, and due to the potential impact that this could have for competition in the relevant downstream markets. Incentives for bidders to strategically reduce demand can be mitigated by setting minimum prices close to expected end prices, and by using auction rules that allow bidders to compete for large packages without necessarily pushing up the price they may have to pay when falling back to a smaller package.

227. These concerns are better addressed in a combinatorial auction than in an SMRA. Our conclusion is that it would be appropriate to use a CCA with similar rules as those used for the MBSA, including the relaxed activity rules, which contribute to reducing the uncertainty about the final outcome.

4 Measures to safeguard competition

228. The distribution of radio spectrum has the potential to affect competition in downstream markets that rely on spectrum as an input (such as, but not limited to, mobile telephony). It could be detrimental to consumers if bidders were able to acquire spectrum in an auction in the anticipation of gaining downstream market power by denying spectrum to their competitors. Therefore, spectrum auctions typically feature measures to ensure that resulting outcomes are sufficiently competitive. Caps on the amount of spectrum that may be acquired by a bidder are commonly used. Other measures used have included reservations of spectrum for entrants and collective caps on incumbents.

229. In ComReg's previous MBSA, the approach taken to protecting and promoting competition was to:

- ensure that auction outcomes could not result in strongly asymmetric outcomes amongst MNOs that might diminish the existing intensity of competition; and
- ensure that the possibility of entry was not precluded, primarily through making choices of auction format and detailed rules that promoted neutral competition between existing and potential new users of spectrum.

230. The first of these objectives was achieved through the use of caps on the spectrum that could be acquired at auction. These caps allowed the possibility of asymmetric outcomes in which the existing MNOs might end up with differing amounts of spectrum. However, strongly asymmetric outcomes that would have adversely affected competition amongst MNOs were precluded.

231. Since the MBSA, the competitive landscape for mobile telephony in Ireland has changed due to the merger between Telefónica and H3GI, reducing the number of infrastructure-based mobile competitors from four to three, though subject to undertakings to make wholesale capacity available to MVNOs. Despite this development, broadly the same considerations apply now as for the MBSA, in that:

- in the event of no entry occurring, competition amongst the existing MNOs should not be diminished as a result of the auction; and
- the possibility of entry should not be precluded through any auction design or packaging choices.

232. In assessing the impact on competition amongst existing MNOs, we must consider how access to additional spectrum will affect MNOs' costs. In the absence of additional

spectrum, MNOs need to add network infrastructure (e.g. more cell-sites) to expand capacity. However, additional spectrum from this award may provide other options to provide extra capacity, reducing the need for additional infrastructure. Therefore, we can expect that access to additional spectrum should tend to reduce the long-run marginal costs to MNOs of expanding network capacity.

233. Typically, we would expect lower marginal costs of capacity to feed through into stronger incentives for MNOs to compete for customers and to provide additional services, which in turn should be pro-competitive with these benefits being passed through to customers. However, this relies on maintaining effective competition amongst MNOs. For instance, if only one MNO enjoyed such benefit from additional spectrum, there would be no competitive pressure to pass benefits through to consumers.

234. In the current three-player environment for mobile telephony, competition is already somewhat limited, as evidenced by the requirements set by the European Commission for merger clearance. Therefore, there is good reason to be especially cautious about adverse competition impacts in the upcoming award. Given this, a reasonable approach may be to limit outcomes in which one or two MNOs could gain a material competitive advantage over a third MNO by denying it access to sufficient additional spectrum. This does not require symmetric outcomes (and indeed such outcomes might even be inefficient if they lead to excessive fragmentation of bands, rather than MNOs holding larger blocks of contiguous spectrum).

235. In this award, it is possible to implement such an approach using spectrum caps to preclude outcomes in which, in the absence of entry, would lead to one of the three MNOs being significantly disadvantaged. However, the details are highly specific to which bands are included and there are a large number of possible scenarios in this regard. Therefore, it is too early to formulate specific proposals for caps, other than to note that caps can be set at levels that preclude significantly asymmetric outcomes, yet not impose entirely symmetric ones and thereby inhibit competition for spectrum within the auction.

236. In considering caps, an important issue is the degree to which different bands included in this award are substitutes. If two bands are close substitutes then it may be better to set a cap on total winnings across both bands. However, if bands are not substitutes, and especially if they are complements, then separate caps on each band may be more appropriate.

237. In this regard, the 2.6GHz band is already in use for mobile services widely across Europe and not subject to technological and regulatory uncertainties to the same extent as the other possible high-frequency bands that might be included in this award. Therefore, there could be a concern that the distribution of the 2.6GHz band could have an impact on competition. However, this is only a short-term consideration. Over the longer term, other capacity bands (such as 2.3GHz, 1.4GHz and even 3.6GHz) should be reasonable substitutes in terms of providing capacity in high traffic hot spots.

238. If 700MHz spectrum were included in this award, then there is a strong case for this band to be subject to a separate cap. There is already a clear precedent from the MBSA, where a sub-1GHz cap was applied because of the competitive importance of lower frequency spectrum in providing cost-effective coverage and in-building penetration. Given that the various sub-1GHz bands (700MHz, 800MHz and 900MHz) are all substitutes over the long-run for providing coverage and in-building penetration, there is likely to be merit in applying a sub-1GHz cap taking account of both existing spectrum holdings and spectrum won in this award in the 700MHz band.

239. For spectrum above 1GHz, even though there is now a significant asymmetry in holdings of the 1800MHz band due to the recent merger, these differences are small in comparison with the amount of spectrum potentially available in the upcoming award (depending of course on the bands included). Therefore, the question of whether an overall spectrum cap should include or exclude existing holdings alongside spectrum bid for is largely irrelevant.

240. In summary, a workable approach reflecting these considerations may be to use an overall spectrum cap, and, if 700MHz were included, a sub-1GHz cap. In the case of the 700MHz cap, this should take into account existing holdings of sub-1GHz spectrum. Consistent with the approach taken in the MBSA, any caps would apply to the spectrum won in the auction and would not necessarily inhibit subsequent spectrum transactions or re-arrangements, whose competition impacts would need to be considered by ComReg on the merits at the time they occurred.

241. In terms of encouraging entry, this award creates opportunities for various types of operator other than MNOs. In some cases, it might be possible for such parties to offer services that compete to some degree with MNOs (e.g. high bandwidth data services in hot-spot areas). Therefore, it is important that such entry is not precluded. This depends on:

- ensuring that any caps are sufficiently permissive to allow business cases for services by non-traditional players;
- adopting an auction format to resolve competing demand that makes predatory bidding against entrants difficult (e.g. by limiting transparency); and
- possibly using regional licensing for at least some 3.5GHz spectrum to the extent that this opens up greater possibilities for entrants.

242. Given the uncertainties about the viability of efficient entry, we do not believe that it would be appropriate to use a reservation, as this could simply encourage rent-seeking entry that does not contribute to sustainable long-run competition.

5 Licence conditions

243. When considering potential licence conditions, we are minded that some users may wish to acquire capacity spectrum only to provide additional capacity in high-traffic areas or as demand for additional capacity develops in line with growth in traffic. Therefore, the business cases underpinning demand for capacity spectrum could possibly be built on the basis of limited coverage and usage to meet specific traffic needs, or on the basis of having some spectrum readily available to be able to increment capacity rapidly when needed. As such, the conditions that apply to the rights of use of other spectrum currently licensed, including those for licences assigned in the MBSA, might be too onerous when licencing capacity spectrum.

244. However, there may still be a risk that some bidders may wish to acquire spectrum strategically. Therefore, it may be appropriate to set licence conditions that encourage an efficient use of the spectrum.

245. In this section we discuss the incentives for spectrum hoarding and speculative acquisition specific to the present award, and then consider licence conditions that could be used to prevent strategic acquisition of spectrum. We specifically focus on coverage obligations, roll-out obligations and "use it or lose it" conditions.

5.1 Spectrum hoarding and speculative acquisitions

246. Hoarding in this case relates to the strategic acquisition of spectrum rights by existing operators, not for the purposes of using the spectrum for providing services in a downstream market but to ensure that no one else may use it to provide such services. A particular case that is of concern is the hoarding of spectrum to ensure that there cannot be entry into downstream markets.

247. Speculative acquisitions by new entrants may also be the result of strategic rather than competitive motives. In particular, in an environment where spectrum trading exists, there is the potential for a bidder not intending to use the underlying spectrum to acquire rights of use in respect of spectrum in this award, keep it and sell these to an interested party at some later point.

248. On the other hand, there may also be legitimate reasons to purchase rights of use in respect of capacity spectrum in this auction without the need to use it immediately. Specifically, capacity bands may have option value for existing operators, for example the mobile operators, given the growth in mobile traffic and the infrequent nature of spectrum awards. This is pro-competitive for downstream markets if it results in lower marginal costs of serving more customers and rolling out new services.

249. We note that a wireless broadband provider might need a large amount of contiguous spectrum for services to be economically feasible, so one needs to be cautious about addressing issues of spectrum hoarding or speculative acquisition through stringent spectrum caps. Similarly, as the 2.6GHz band and much of the other spectrum available is capacity spectrum, it may not be practical to use coverage obligations as a method to reduce the scope for this type of behaviour. Capacity spectrum may only be needed in high-traffic areas, and it may not be necessary to extend its usage beyond these areas at least in the short run. It is therefore very difficult to anticipate how demand for additional traffic may evolve, and how an efficient operator may best roll-out its use, in order to establish appropriate coverage obligations.

250. There are a number of factors that may mitigate the risk of spectrum hoarding in the current award:

- Given the current expectations on the amount of spectrum that can be released in the short to medium term, there is less concern relative to previous awards that hoarding capacity spectrum could be used to prevent entry. However, spectrum hoarding might still be an issue in relation to the 700MHz band.
- Any notion of efficient use clearly must have an implicit time scale and should not be judged over too short a period. As mentioned above, maintaining access to spectrum may act as an insurance against unpredictable growth rates in downstream services; this could be beneficial to competition, as the long-run marginal cost of expanding capacity to provide services to additional customers or to provide new services may be lower as a result.
- We also consider the risk that bidders may acquire more spectrum (e.g. for hoarding or for speculative reasons) than it would be appropriate for an efficient use of the spectrum, especially in the event that the spectrum is cheap. Some measures might make such behaviour undesirable:

    - On-going spectrum usage fees can be used to encourage licensees to transfer or return unused spectrum, and may discourage long-term spectrum hoarding.
    - Usage obligations may also be used to prevent bidders from retaining large amounts of unused spectrum for hoarding or speculative purposes.
- Any benefits from spectrum hoarding capacity spectrum might dissipate as soon as additional spectrum is offered. In this context, we note that at least some spectrum in the 2GHz band could become available in the medium term, which would reduce the time period over which spectrum hoarding could be profitable.

5.2 Licence conditions to prevent strategic acquisition of spectrum

5.2.1 Coverage obligations

251. Coverage obligations are typically applied to rights of use for spectrum that can be used to provide a coverage layer, as for instance in 900MHz GSM licences and 2.1GHz 3G licences. In contrast, coverage obligations may be less appropriate for spectrum explicitly earmarked for providing capacity, as for example the 1800MHz GSM licences for boosting quality of GSM services in urban areas.

252. Establishing an appropriate level of coverage for a technology or service has become more difficult in the face of:

    - Technology neutrality, with bands no longer licensed for specific technology (e.g. in the past the 900MHz and 1800MHz bands were licensed for the deployment of the GSM technology); and
    - Service neutrality, where licensees have the discretion to use the spectrum for providing whatever services they wish, subject to interference constraints.

253. However it is possible to establish conditions that require the deployment of a radio signal (without specifying the exact technology that would be deployed) or service conditions that are conditional on the use of the spectrum to provide a particular service (as was done in the MBSA). However defining licence conditions becomes increasingly difficult for spectrum bands with a relatively uncertain future in terms of use, where a range of different novel technologies and services could develop. As a consequence, the licensing of

spectrum increasingly needs to take into account a particular band's propagation characteristics and corresponding feasibility of providing different types of services using the relevant spectrum..

254. A further trend is that services can now be provided by many frequency bands, and spectrum licensing is increasingly defining licence obligations that allow licensees the discretion to use whatever frequencies (as was done in the MBSA) or alternative means (such as the provision of broadband provided via fixed networks) that they wish to provide services that fulfil these obligations.

International experience

255. It is useful to review the level of coverage obligations set with respect to licences in the 2.6GHz band in other countries. We have analysed the coverage obligations imposed in this band in European auctions since 2010, and provide the full table of coverage obligations in Annex B. The decision on whether to impose a coverage obligation with respect to this band varies widely. Overall, we note that:

- Only half of the fourteen countries in our sample imposed coverage obligations on licences in the 2.6GHz band.
- Among the countries that imposed coverage obligations in this band, there is considerable variation in the specific coverage and roll-out targets imposed. For example, Romania required 80% population coverage for incumbents (although that might be achieved with other frequency bands other than that of 2.6GHz). Conversely, the Czech Republic only required 30% population coverage within 7 years.[81]

Experience in Ireland

256. In the MBSA, the following coverage obligations were imposed on the liberalised licences awarded:

[81] In this comparison, we do not take into account the Dutch award coverage obligations, as these are not directly comparable with the ones imposed in the other awards.

- Existing GSM or 3G licensees shall cover 70% of the Irish population within 3 years of the start date of the licence;
- Bidders that win spectrum in the auction but that do not possess a GSM or 3G licences shall ensure coverage of 35% of the population within 3 years and 70% within 7 years.[82]

257. We note that these coverage obligations are considerably lower than claimed actual coverage of all mobile operators in Ireland, both at the time of the MBSA[83] and at present,[84] and lower than the coverage obligations in the 3G licences.[85]

258. In the MBSA, coverage and roll-out obligation targets distinguished between winners that had existing mobile networks and those that did not. It is also a clear trend in international practice to distinguish coverage obligation targets between incumbents and entrants.

5.2.2 "Use it or lose it" conditions

259. A "use it or lose it" condition specifies that a licensee who does not use spectrum covered by the licence may lose the rights of use for that spectrum. The "use" of spectrum in this condition might be defined by reference to a "reasonable use". Therefore, these conditions provide a relatively flexible option in ensuring that spectrum is not acquired for strategic purposes only. .

260. "Use it or lose it" conditions have been imposed in several spectrum awards in European member states.[86] One such recent award was in Slovakia, where spectrum was awarded in multiple bands simultaneously in 2013. Resulting licences required winners of 2.6GHz spectrum to start using the assigned frequencies within six months from the day the licence commenced.

[82] ComReg document 12/52

[83] See section 5.5.2.6 of ComReg 12/25 and paragraphs 5.155 and 5.156 in particular

[84] The websites of Meteor, O2, 3 and Vodafone all claim 99% population coverage

[85] http://www.comreg.ie/radio_spectrum/search.541.874.10003.0.rslicensing.html

[86] See ERG (09) 22, available at: http://rspg-spectrum.eu/_documents/documents/meeting/rspg19/rspg09_278_erg_rspg_report_on_radio_spectrum_competition_issues_090604.pdf

5.3 Suggestions for this award

261. There are a number of issues for setting coverage obligations for this award, specifically:

- Should 2.6GHz spectrum have coverage and rollout requirements, or is a 'use it or lose it' condition sufficient?
- If other capacity bands are to be included in the award, should these be licenced under the same conditions?
- Should the conditions be different for the 700MHz band and possibly the 1.4GHz band if it is included in the award (and in particular should a material coverage obligation apply to the rights of use of 700MHz spectrum)?

262. The uncertainty about the eventual use of the bands under consideration makes defining a coverage obligation difficult, as an efficient use of high-frequency spectrum might only involve using it for high-traffic spots rather than nationally, which might not be possible if a stringent coverage obligation is imposed on licences.

263. In addition, if we consider a wider range of services than those available at present, defining a coverage obligation becomes further complicated by the difficulty in defining coverage itself. For example, the parameters typically used for defining a coverage obligation might not be relevant for a user using the spectrum to provide a wireless local loop. The issue becomes more abstract when trying to consider services that are not yet available.

264. On the other hand, if the coverage requirements necessary to meet public policy objectives are already met by existing licences, it might not be necessary to impose coverage obligations on any new licences issued. In this case, 'use it or lose it' conditions requiring licensees to make *reasonable use* of the frequencies assigned to them might be sufficient for licences issued in this award.

265. Licence conditions for spectrum in coverage bands (e.g. the 700MHz band) might be considered as a special case. On the one hand, it might be appropriate to licence this spectrum under similar conditions than those used for licencing 800MHz and 900MHz spectrum. On the other hand, one might expect that if this band is highly valuable for coverage purposes due to its greater propagation characteristics, then users are already likely to use it for providing extensive coverage absent an explicit licence condition.

266. Nevertheless, specifying a coverage obligation could impede the use of this band for the provision of novel services that could benefit from the propagation characteristics of this band without necessarily seeking nationwide coverage. This needs to be balanced against the risk that this valuable spectrum is simply acquired to prevent competition in existing services, and in particular in the mobile communications market.

6 Spectrum fees and minimum prices

267. In this Section we outline a general approach and key considerations for setting the fees for spectrum licences assigned as part of this award.

6.1 Fee structure

6.1.1 Fee structure in the MBSA

268. Licences awarded in the MBSA were subject to a Spectrum Access Fee (SAF), an upfront payment determined in the auction, and annual Spectrum Usage Fees (SUFs). The fees were calculated as follows:[87]

- ComReg determined a "minimum price" for each lot offered in the auction, which was set by reference to a conservative lower bound estimate of the actualised value of the lot using international benchmarks;
- the annual SUFs corresponding to each lot accounted for half of its minimum price, divided into annual payments over the lifetime of the licence, and the total SUF applicable to a licence was the sum of SUFs of all lots included in the licence (to be adjusted every year in line with CPI);
- the reserve price of each lot was set to the remaining half of the minimum price; and
- the SAF corresponding to each licence was calculated in the auction on the basis of the bids received, and therefore was at least the sum of reserve prices of all lots included in the licence.

269. Our working assumption is that a similar fee structure would be used for this award, although the actual split of the minimum fee between reserve price and SUFs and the level of the minimum fee may differ.

[87] For further details, see Chapter 4 of ComReg document 12/25 and Annex 10 of ComReg document 12/25A.

6.1.2 Upfront versus on-going fees

270. On-going fees depress the upfront value of a licence, as bidders will take such payments into account when determining how much they will want to pay upfront for the licence. In addition, loosely specified, variable on-going fees may cause or accentuate uncertainty about the overall value of lots, which could further depress the amount that bidders are willing to pay for spectrum.

271. However, on-going fees could also boost demand by reducing the need for an upfront payment, especially if they are well specified in advance of the auction. For example:

- being able to defer part of the payment for licences may be valuable to bidders with a limited upfront budget, as reducing upfront payment needs may strengthen their position relative to competitors with a higher upfront budget (but who could possibly place a lower overall value on some of the lots offered);
- in addition, on-going fees may lower the financial exposure for bidders who are uncertain about the value of lots, as such bidders could avoid the burden of any remaining on-going payments by returning the spectrum they acquired at a later date if it fails to achieve the value they expected.

272. Using low on-going fees is quite common,[88] as this reduces the administrative burden of determining appropriate discount rates and any actualisation mechanisms in subsequent years, and the risk of any inefficiencies that could arise in the event that these are inappropriately specified. However, there may also be good reasons to deviate from this approach, as we discuss below.

6.1.3 Promoting efficient use and value-enhancing transfers

273. One of the motivations for setting relatively high annual SUFs in the MBSA was to provide incentives for licensees to return part or all of any spectrum holdings which they no

[88] As an example, in the recent Slovenian multiband auction, paired 2.6GHz spectrum was offered at a reserve price of €80,000/MHz, while the annual fee associated with that spectrum was €1,308. (Source: http://www.akos-rs.si/files/APEK_eng/Radio/draft-information-memorandum.pdf and http://www.akos-rs.si/files/APEK_eng/Radio/tender-documentation.pdf)

longer had any use for (or for which the value of use would fall below the SUFs).[89] Returned spectrum could then be reassigned to a user who values it above the level determined by the SUFs thus ensuring the optimal use of spectrum.

274. The introduction of spectrum transfer reduces the importance of SUFs in encouraging an efficient use of spectrum, as the expectation is that if there is an alternative user who values the spectrum more than the current holder, then a transaction would take place. However, spectrum transfers will only occur if negotiations and transactions take place, which some times may only be triggered when there is a sufficiently large value difference between the buyer and the seller. In this context, SUFs complement the secondary market enabled by spectrum transfers by providing a financial outflow (i.e. the SUF), which may in practice provide a stronger incentive to trade than the expectation of revenue that could be generated from a spectrum transfer.

275. On the other hand, allocating a large part of the minimum fees to SUFs (leading to correspondingly lower SAFs) reduces the cost associated with acquiring too many lots. Bidders who acquire too many lots face a low upfront payment relative to a scenario where a greater portion of the minimum price is allocated to reserve prices, and can return some spectrum at a later date, thus avoiding any outstanding SUFs. As such, higher SUFs could encourage bidders to acquire spectrum in excess, for example if the value of spectrum is uncertain (as the bidder would return it at a later date if the benefits from retaining such spectrum fell below the cost of annual SUFs), or for hoarding purposes (as the bidder could hold onto excess spectrum to deny it to competitors for a few years, but return it once it had consolidated its market position).

276. The risk that bidders may acquire more spectrum than it would be appropriate for an efficient use of the available frequencies could be a concern for the upcoming award if a large amount of spectrum is offered in the auction with a relatively low minimum price, as this could possibly lead to over-acquisition to the detriment of potential new uses not yet developed. In this case, it may be appropriate to set minimum prices that take into account the value of retaining spectrum for future awards and allocate a greater proportion

[89] Paragraph A10.69 of ComReg document 12/25A

of the minimum price to reserve prices (while reducing the proportion allocated to SUFs accordingly).

6.1.4 Distortions of relative demand across bands

277. Setting a different split of minimum prices into reserve prices and SUFs across different bands might distort relative demand for substitutable spectrum, in particular from bidders who may be sensitive to alternative payment conditions. Therefore, one would ideally use the same split for substitutable bands, especially when these are close substitutes.

278. However, there may be specific reasons why a different split could be desirable in some cases, which should be assessed when determining minimum fees. For example, if the 700MHz band were also included in the award, it may be reasonable to set a different split for the 700MHz band (where higher SUFs could help encourage efficient long term use) than for the capacity bands included in the award (where higher SUFs could lead to bidders acquiring spectrum in excess). It may also be appropriate to set SUFs for 700MHz spectrum that are comparable to those for 800MHz and 900MHz spectrum, which might not necessarily apply to other capacity spectrum in this award. The specific split appropriate for each band may also need to take into account the degree of uncertainty on the value of spectrum in the band, and therefore may need to be re-considered if there are significant developments in relation to the bands included in the award (as for instance further EC guidance on harmonisation and designated use of bands, developments in the technology, equipment availability, or use of the bands in other countries).

6.2 Minimum prices

6.2.1 Approach to setting minimum prices

279. In an ideal situation, the auction would be highly competitive and there would be no need to set minimum prices, as competition would ensure that auction prices would be set at an optimal level. However, the number of potential acquirers of spectrum licences may be limited by a number of factors, such as budget limitations and the maximum number of operators that may be able to coexist in downstream markets. Because of this, low participation

scenarios are likely in spectrum auctions. In turn, this may lead to low competition, especially if bidders have incentives to bid conservatively to keep prices low. As a result, minimum prices may be necessary to:

- provide some guarantee that the spectrum will not be sold to low-value users inefficiently due to low participation (in the event that a higher value use may emerge in the near future); and
- reduce the potential gains associated with withholding competition and tacit collusion, as encouraging bidders to compete promotes efficient outcomes.

280. There are a number of alternative approaches to setting minimum prices:

a) The minimum price may be set to represent the value of the lot to the seller. This is appropriate when the seller would prefer to retain the lot than to sell it below this level.

b) The minimum price may be set by reference to an estimate of "market value", reflecting the option of a seller to find another buyer (possibly at a later date) if bidders in the auction fail to offer a price that is sufficiently high, for example due to very low competition. This ensures that the lots will not be assigned at a low price in the event of a short-run demand shortage, and most importantly provides a safeguard against assigning the lots to low-value users in these scenarios.

c) The minimum price may also be set to a level that the seller estimates to be close to buyers' valuations, if the intention is to capture as much value as possible in revenue. However, the risk here is that if the value is set above actual valuations, then the lots will remain unsold. In the case of a spectrum auction, this could lead to spectrum not being efficiently used.

281. Our working assumption, and recommendation, is that ComReg would establish minimum prices in line with an estimate of the market value, as this seems to be aligned with the objective of ensuring an efficient use of the spectrum over the whole duration of the licence period. An intended consequence of setting prices that reflect market

value is that these may be relevant in determining the outcome of the auction. [90]

6.2.2 Estimating market value

282. Setting prices that are reflective of 'market value' poses the challenge of determining market value, which is the price we expect that would be achieved in a competitive market. Prices in a competitive market would be set at the lowest level at which there is no excess demand for the lots offered. This means that the price of a lot would need to be just above the highest amount offered by bidders who failed to acquire the lot.

283. There are two relatively common approaches to estimating this value:

- One possibility is to build a valuation model for potential bidders to simulate the outcome of a competitive award process. The shortcoming of this approach is that it is highly dependent on the underlying assumptions of the model and subject to limitations in obtaining necessary input data. This exercise also requires detailed assumptions on the alternative services that might participate in the process, and also on the number of bidders of each type. It is therefore very difficult to obtain robust results under this approach.
- Another commonly used approach is *benchmarking*, which means estimating the value of lots using observed prices in concluded auctions or transactions of similar spectrum in comparable environments, and adjusting these to take account of differences between awards and transactions.

284. Overall, we favour a benchmarking approach on the basis that it is based on factual observations and is less dependent on assumptions on likely market developments. However, benchmarking market value from existing transactions also has a number of complications:

- First, there are only few, occasional spectrum transactions, often in the form of an auction or a bilateral agreement. As a fluid "market" for spectrum does not exist, we are typically confronted with only a few

[90] We note that, to date, prices established for spectrum in the 2.6GHz band have typically exceeded those for the 2.3GHz band and various spectrum around 3.5GHz.

observations that may vary greatly depending on transaction-specific factors.

- Second, observed transaction values may not reflect the valuation of actual participants in the auction. In particular, if expectations on the value of lots in previous transactions were overoptimistic or boosted by factors that are not applicable for this award, then there is a risk of overestimating value. This could lead to excessive prices that could choke off demand.
- Also, observed transaction values only provide information about current value and demand, but not about the likely value and demand over a wider time period if new services and demand are expected to develop. However, the expectation would be that this should be sufficient to set a conservative lower bound estimate of market value.

6.2.3 Adjustment to market value estimates

285. Because of the uncertainty when estimating market value, minimum fees are typically set conservatively in relation to value estimates to mitigate the risk of setting excessively high prices that could choke off demand. Often, more conservative prices will be used when there is more uncertainty about the value of lots. However, provided that ComReg has a clear plan for releasing any unassigned spectrum in the relevant bands as new demand might develop, using a conservative price may not be necessary, as bidders subject to great uncertainty could simply defer their demand to future awards. Conversely, setting reserve prices that reflect market value could be desirable on the grounds that it might allow for a better use of spectrum in the long run without needing to rely on spectrum transfer.

286. The appropriate level of the minimum price will depend on ComReg's views on whether to prioritise early use of the available frequencies or conversely to ensure that future uses are not foreclosed by existing users. If ComReg wishes to ensure that spectrum is used as much as possible in the short run, then prices should be set more conservatively to minimise the risk of choking off demand if market value estimates are too high. Conversely, if ComReg is concerned that a premature award of spectrum may inefficiently displace valuable future uses, or lead to excessive take up simply because the spectrum is offered at a relatively low price, then a better outcome might be achieved by setting the price closer to the estimated market value and having a clear release plan for any unassigned frequencies. This may also reduce the risk that bidders may acquire more spectrum

rights of use than it would be appropriate for an efficient use of the available frequencies.

6.2.4 Relative minimum prices in multi-band awards

287. As discussed above, different bands may be complements or substitutes to one another. In order to ensure efficient assignment of spectrum, minimum prices in the award should not distort relative demand for spectrum in different bands. Therefore, relative minimum prices should ideally reflect likely relative market value of different lots and not use different levels of discount over market values.

288. However, relying on market estimates is dangerous if estimates are obtained from different observations, as differences in the estimates might be driven by many factors other than the actual value of spectrum, as for instance the time of the award, the level of competition in the corresponding auction or country-specific details. Therefore, unless it is possible to estimate robust values from a rich dataset, it may be better to average value estimate across close substitutes and allow the auction process to determine relative prices. Equally, it is sensible to establish likely relative values for imperfect substitutes and ensure that minimum prices are set to levels that are consistent with this. For example, in the MBSA, the minimum prices for 800MHz and 900MHz spectrum were set on the basis of the same value estimate, while the minimum price of 1800MHz spectrum was set to half that of sub-1GHz spectrum.

289. Minimum prices should also reflect any other differences across lot categories that might affect value. For example, the start date of a licence or other differences in licence conditions (like coverage obligations or usage restrictions) are likely to affect the value of a licence. Therefore, where lots in different bands are grouped for the purpose of estimating the value of spectrum but are offered under different licence conditions, it would be appropriate to adjust their minimum prices to reflect such differences.

290. In the upcoming award it is reasonable to expect value differences across bands. In particular:

- Potential users may have a different value per MHz for a given amount of spectrum depending on whether it is paired or unpaired;
- the greater development and availability of applications using spectrum in the 2.6GHz band might drive its value above that of spectrum in other capacity bands all other things being equal; and

- the greater propagation characteristics of 700MHz spectrum may drive the value of this band above the value of any other spectrum offered in the award.

291. However, estimating the value for different capacity bands individually might be difficult due to the paucity of data available. Therefore, it may be necessary to group unpaired capacity spectrum in different bands to obtain a common value estimate, and possibly set their value with reference to the value of spectrum in the 2.6GHz band.

6.2.5 Estimating market value for the current award

292. The effectiveness of benchmarking is limited by the scope and quality of available data.

293. In the MBSA, the value of sub-1GHz spectrum in Ireland was estimated on the basis of a combination of simple averages and a linear regression of the value of spectrum on a number of value drivers. Particular emphasis was placed on more recent, European auction results. 800MHz, 900MHz, 1800MHz, 2.1GHz and 2.6GHz spectrum auction prices were used to produce a lower bound estimate of sub-1GHz value.

Benchmarks for 2.6GHz spectrum

294. The value of 2.6GHz spectrum is unlikely to be directly comparable to the value of 800MHz, 900MHz and 1800MHz bands offered in the MBSA. Therefore, it would seem appropriate to estimate the value of 2.6GHz spectrum with reference to a narrower sample of 2.6GHz auctions. This sample is, however, considerably smaller than that used to estimate the market value of sub-1GHz spectrum in the MBSA. Furthermore, producing band-specific price benchmarks requires prices that are applied to that specific band only. This excludes most price points from multi-band combinatorial awards, where prices are set for packages that include spectrum in a number of bands, as in many cases it is not possible to break down package prices into band-specific values without detailed bid data in the auction (which may

not be available). This further limits the available sample of relevant benchmarks.[91]

295. Given that only a few observations are available, a statistical estimation using a similar approach to that used in the MBSA may not provide robust results. Therefore, estimating the value of 2.6GHz spectrum may require placing greater emphasis on those observations that are considered to be most relevant. For example, auction prices of 2.6GHz spectrum have varied considerably since the first European award of spectrum in this band (Norway, 2008). Accordingly, it may be appropriate to place greater weight on later observations, which should reflect the value of the band after the availability of the 800MHz and 1800MHz bands for LTE.

296. Despite the small amount of data available, estimating the market value using a benchmarking approach placing greater weight on the most relevant observations would still provide, in our view, more objective value estimates than a business modelling exercise, as estimates would not be dependent on modelling assumptions. Accordingly, we would recommend a benchmarking approach.

Benchmarks for unpaired spectrum in other capacity bands

297. Data for the other capacity bands that might be included in this award is even more sparse and of little relevance for estimating the current value of these bands:

- We are aware of just one auction of 1.4GHz spectrum to date (the UK L-band auction in 2008). Similarly, Norway appears to be the only European country to have auctioned the 2.3GHz band (in 2006). Both of these data points are quite old and may provide a poor reference for the current value of these bands, which is likely to have increased substantially after greater clarity over the technological paths and intended wireless broadband use for these bands was identified by the RSPG in mid-2013.
- The situation is similar in relation to 3.6GHz spectrum, where any observations are also rather old. The most recent award of spectrum in this band is the Portuguese

[91] Nonetheless, the results from combinatorial auctions can be used as a cross-check of band specific value estimates. To date, this exercise suggests that the package prices obtained in combinatorial auctions are broadly consistent the estimates for the lots in the package obtained from band-specific benchmarks.

auction, in 2010. Since then, this band has also been identified for wireless broadband use and technical conditions for its use have been defined. Therefore while there are more observations to draw on to estimate the value of 3.6GHz spectrum than for the 1.4GHz and 2.3GHz bands, these benchmarks may not present a contemporary forward-looking view of market value.

298. Given the lack of suitable data points in the 1.4GHz, 2.3GHz and 3.6GHz bands, and that these bands have similar characteristics and have been designated for a similar use as 2.6GHz band, it may be appropriate to set a common minimum price for these bands, based on the estimated value of unpaired 2.6GHz spectrum (in fact, the more recent 2.6GHz band auction benchmarks may provide the most relevant benchmarks of spectrum value of these bands). Alternatively, one could set the value of these bands on the basis of a discount relative to the price of unpaired 2.6GHz spectrum.

Benchmarks for spectrum in the 700MHz band

299. Owing to its different characteristics, the value of spectrum in the 700MHz band may be materially different to that of spectrum in the 2.6GHz and other high-frequency capacity bands. However, no European country has auctioned 700MHz spectrum yet.

300. The only benchmarks available for 700MHz spectrum are from the auctions in US, Canada, Australia, New Zealand and Fiji. Although the 700MHz band plans in these countries are likely to be different to that proposed for Europe, the results from auctions in these countries should still be a good indication of the potential value of the 700MHz band in Europe.

301. In addition, the value of spectrum in the 700MHz band might also be set with reference to the neighbouring 800MHz and 900MHz bands.

Annex A International practice in setting coverage obligations

Table 1: Coverage and roll-out obligations on the 2.6GHz spectrum band in European auctions since 2010

Country	Date completed	Multiband auction?	Geographic coverage of licences	Licence duration in years	Coverage obligation classification	Coverage obligation and roll-out requirement summary
Germany	May 2010	Yes	National	15	Basic	An assignee using spectrum in the bands 1.8GHz, 2GHz or 2.6GHz is required to cover at least 25% of the population by 1 January 2014 and at least 50% by 1 January 2016 using these frequencies. The parameters that measure whether the coverage obligation has been met (e.g. speed levels) depend on the technology deployed.
Denmark	May 2010	No	National	20	No coverage	-
Netherlands	April 2010	No	National	20	Basic	Each licensee must offer a public electronic communications service within 2 years of award of a licence. The coverage area over which licensees are required to provide this service depends on the amount of spectrum won - a licensee has to cover an area of 20Km^2 per 5MHz of 2.6GHz spectrum won (e.g., if a licensee wins 40MHz in total he must cover an area of 160Km^2).
Austria	September 2010	No	National	16	Basic	Each licensee was required to cover at least 25% of the national population by December 31, 2013. In the areas covered, the service must be offered with a data transmission rate of at least 1 Mbit/s on

						the downlink and at least 256 Kbit/s on the uplink.
Spain	July 2011	Yes	Seven national lots and 37 regional lots	18	No coverage	-
Italy	September 2011	Yes	National	18	Basic	Each incumbent licensee has to provide coverage of wireless broadband service to 20% of the national population within 24 months from the assignment of rights of use of this frequency band and 40% within 48 months, provided that the population covered is distributed across all Italian regions, with at least 5% of population covered in each region. An entrant that acquires this spectrum has to fulfil the same coverage but has one more year to meet each target. If a licensee is assigned a single block of 15MHz TDD or FDD or less in this band, the coverage obligation targets are reduced by 30%. Coverage implies the provision of the service to download data of at least 2 Mb/s per user.
Spain	November 2011	Yes	Three national lots and four regional lots	18	No coverage	-
Portugal	November 2011	Yes	National	15	No coverage	-
Belgium	November 2011	No	National	15	No coverage	-
Switzerland	February 2012	Yes	National	18	No coverage	-
Romania	September	Yes	National	15	Basic	Winners of spectrum in the 2.6GHz band are subject to different coverage obligation targets, depending on whether they commit to

	2012					offer access to MVNOs. Also, if they additionally win sub-1GHz in the award, they will also suffer from harsher coverage obligations. Winners of spectrum in the 2.6GHz that do not commit to offer access to MVNOs: - For the existing operators who hold 2G/3G networks in the 900MHz or 1800MHz bands: provide voice services for 80% of population by 5 April 2017 and coverage with broadband data services, with a downlink data transfer speed of at least 2 Mb/s and 95% probability of indoor reception, of areas inhabited by at least 30% of the population, including the coverage achieved by means of the 3G network in the 2100MHz band in case they have one, until 5 April 2019 at the latest. - For the existing operators that hold a 3G network in the 2100MHz band: provide voice services for 80% of population by 5 April 2019 and coverage with broadband data services, with a downlink data transfer speed of at least 2 Mb/s and 95% probability of indoor reception, of areas inhabited by at least 30% of the population, including the coverage achieved by means of the 3G network in the 2100MHz band in case they have one until 5 April 2019 at the latest. - For a new-entrant: provide voice services for 30% of population by 5 April 2021 and provide broadband data services, with a downlink data transfer speed of at least 2 Mb/s and 95% probability of indoor reception, for 15% of the population by 5 April 2019, and 30% by 5 April 2012, at the latest. On the other hand, for winners of 1800/2600MHz who commit to offer access to MVNOs: - For the existing operators who hold 2G/3G networks in the 900MHz or 1800MHz bands: provide voice services for 80% of population by 5 April 2017 and coverage with broadband data services, with a downlink data transfer speed of at least 1 Mb/s and 95% probability of indoor reception, of areas inhabited by at least 30% of the population, including the coverage achieved by means of the 3G network in the 2100MHz band in case they have one, until 5 April 2019 at the latest and the same of at least 2 MB/s by 5 April 2021 at

						the latest. - For the existing operators that hold a 3G network in the 2100MHz band: provide voice services for 80% of population by 5 April 2019 and coverage with broadband data services, with a downlink data transfer speed of at least 1 Mb/s and 95% probability of indoor reception, of areas inhabited by at least 30% of the population, including the coverage achieved by means of the 3G network in the 2100MHz band in case they have one, until 5 April 2019 at the latest and the same of at least 2 MB/s by 5 April 2021 at the latest. - For a new-entrant: provide voice services for 30% of population by 5 April 2021 and provide broadband data services, with a downlink data transfer speed of at least 1 Mb/s and 95% probability of indoor reception, of areas inhabited by at least 15% of the population, by 5 April 2019, and the same by at least 30% by 5 April 2021, and 2Mb/s to at least 30% of the population by 5 April 2023.
United Kingdom	February 2013	Yes	National	20	No coverage	-
Czech Republic	November 2013	Yes	National	15	Basic	Winners of 2.6GHz spectrum must, within 7 years from obtaining the licence, cover at least 30% of the national population. Coverage is understood to mean the operation of a public electronic communications network using the own frequencies assignments in the 2600MHz band acquired to provide the high-speed Internet access service with the following minimum required speeds of service: within 7 years, 2 Mbit/s (download); from that point onwards it should achieve 5 Mbit/s (download). If a licensee in the 2.6GHz does not have a 900MHz licence, the coverage obligation period targets are extended by 1 year.
Slovak Republic	December 2013	Yes	National	15	Basic	Winners of 2.6GHz spectrum have to achieve coverage of 10% of the population by 31 December 2015, 25% of the population by 31 December 2018. Service requirement includes access speeds of 2 Mbit/s for downlink and 256 Kbit/s for uplink.

Sources: Germany - http://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Sachgebiete/Telekommunikation/Unternehmen_Institutionen/Frequenzen/OffentlicheNetze/VergabeverfDrahtloserNetzzugang2010/PraesKammerEntschg_Id17404pdf.pdf;jsessionid=BEB2C0B278798A7F932CD155DED11C67?__blob=publicationFile&v=1; Denmark - http://erhvervsstyrelsen.dk/file/308679/info_memo_2g5hz.pdf; Spain - http://www.minetur.gob.es/telecomunicaciones/es-ES/Novedades/Documents/Pliego_segunda_subasta_espectro.pdf and http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:163:0037:0041:EN:PDF, http://www.boe.es/boe/dias/2011/04/02/pdfs/BOE-A-2011-5936.pdf, http://www.minetur.gob.es/telecomunicaciones/es-ES/Novedades/Documents/Pliego_segunda_subasta_espectro.pdf and http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:163:0037:0041:EN:PDF and http://www.boe.es/boe/dias/2011/04/02/pdfs/BOE-A-2011-5936.pdf; Italy - http://www.key4biz.it/files/000171/00017194.pdf and http://www.agcom.it/Default.aspx?message=visualizzadocument&DocID=6447 and http://www.agcom.it/Default.aspx?message=visualizzadocument&DocID=6560; Portugal - http://www.anacom.pt/streaming/english_version_Auction_Regulation.pdf?contentId=1101807&field=ATTACHED_FILE; Belgium - http://www.auction2011.be/images/stories/documents/memorandum4guk.pdf; Switzerland - http://www.bakom.admin.ch/themen/frequenzen/03569/03901/index.html?lang=en; Romania - http://www.ancom.org.ro/en/uploads/links_files/Caiet_de_sarcini_procedura_multibanda_800_900_1800_2600_2_07_2012_en.pdf; United Kingdom - http://www.ctu.cz/cs/download/vyberova_rizeni/invitation_to_tender_12_07_2012.pdf; Czech Republic - http://www.ctu.cz/cs/download/vyberova_rizeni/invitation_to_tender_12_07_2012.pdf; Slovak Republic - http://www.teleoff.gov.sk/data/files/35571.pdf