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Liberalisation of spectrum in the 900MHz and 1800MHz bands

Final Report to ComReg

ComReg Document
Number: 09/99c

21 December 2009

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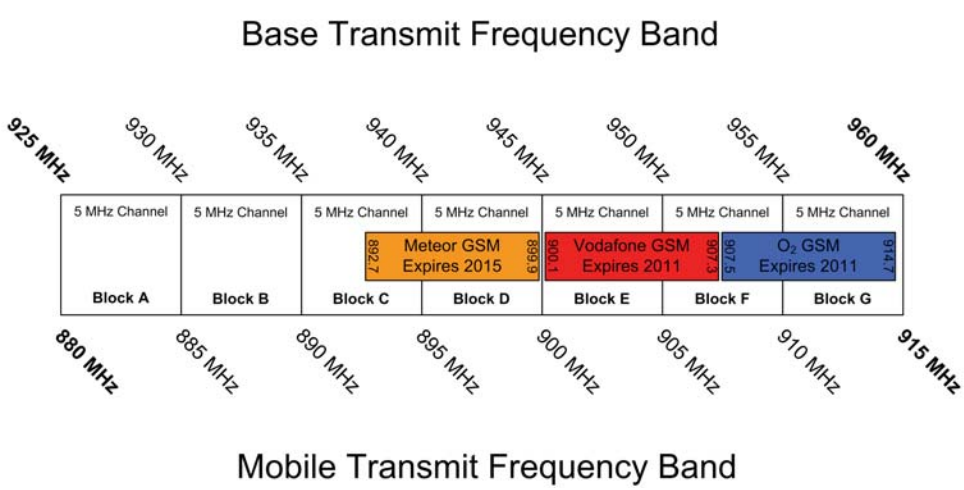
Executive Summary

Background

1. DotEcon has been commissioned by the Commission for Communications Regulation (ComReg) to provide advice on spectrum liberalisation in the 900MHz and 1800MHz bands in the Republic of Ireland. This document represents DotEcon's final report. The views expressed in this report are those of DotEcon only; they do not necessarily represent the views of ComReg.

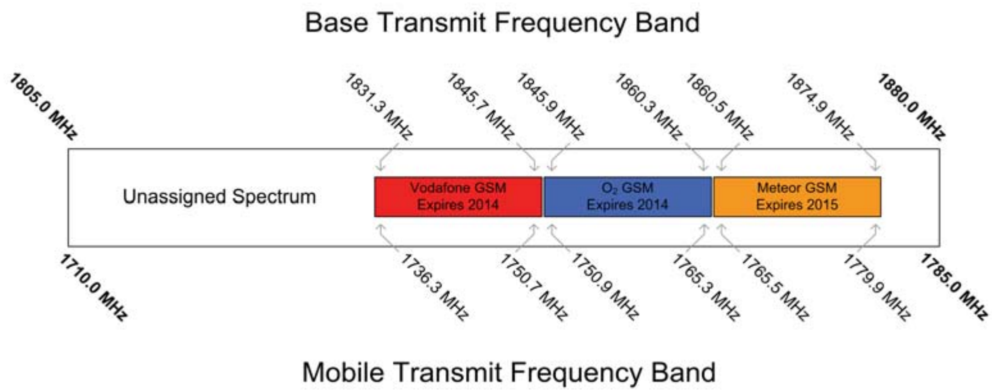
2. Until recently, the GSM Directive (Directive 87/372/EC) has required that the 900MHz band be harmonised for GSM use across the EU. However, following a process of consultation the European Commission has recently published a Commission Decision on the harmonisation of the 900 MHz and 1800 MHz frequency bands for terrestrial systems capable of providing pan-European electronic communications services in the Community (2009/766/EC) (the 'EC Decision') and the EU has adopted a new Directive (Directive 2009/114/EC) (the 'Amending Directive') which amends the existing GSM Directive on this matter. The Amending Directive provides that any spectrum made available in the 900MHz band from now on will be usable not just for GSM, but also for UMTS and other technologies that can coexist with GSM systems.[1].

3. At present, three of the four mobile network operators in Ireland hold spectrum licences within the 900MHz band that permit only GSM use. These licences will expire at different times, leading to staggered availability of the spectrum for re-award on liberalised terms. Both O2 and Vodafone have licences that expire in 2011 and Meteor has a licence that expires in 2015. In addition, some spectrum in the 900MHz band is currently unallocated. The current position is shown in the figure below.



[1] Article 1, Amending Directive

4. Vodafone and O2 also hold licences in the 1800MHz band that expire in 2014 and Meteor a licence expiring in 2015, as shown below. There is significant spectrum in the 1800MHz band that is currently unused. Following its consultations on this, ComReg has concluded that 'there is not a pressing requirement to hold a competitive award process for 1800MHz spectrum at this time', and that 'holding a competitive award process for assignment of 1800MHz frequencies closer to 2013 would provide greater clarity to applicants on spectrum developments in other bands of interest for wideband data transmission'.[2] As a result, ComReg is not minded to include 1800MHz spectrum in an integrated auction process.



5. Existing GSM operators are likely to place significant value on continued access to 900MHz spectrum beyond the expiry of existing licences, not least to provide the option of running legacy 2G services and to ease migration of existing 2G consumers to 3G. Looking further forward, access to spectrum below 1GHz for 3G services is likely to be important for providing in-building and wide-area data services. The 900MHz band is an important source of such spectrum. Although in the long-run the supply of sub-1GHz spectrum is likely to be boosted by the digital dividend, the 900MHz band has particular importance. The 900MHz band has become available for licensing of 3G services across the EU and equipment manufacturers are likely to prioritise this band.

Objectives for the award process

6. ComReg has various obligations and objectives due to domestic and European law when designing an award process. It has objectives, *inter alia*, to promote competition and ensure that spectrum is efficiently used. ComReg is required to ensure that the allocation and assignment of radio frequencies is based on objective, transparent, non-discriminatory criteria[3] and pursuant to open, transparent and non-discriminatory procedures.[4] In addition, where the demand for radio frequencies in a specific range

[2] ComReg (March 2009), "Liberalising the future use of the 900MHz and 1800MHz band and spectrum release options", ComReg Consultation 09/14, Page 52.

[3] Regulation 23 of the Framework Regulations (SI 307 of 2003).

[4] Regulation 9 of Authorisation Regulations (SI 306 of 2003).

exceeds their availability, appropriate and transparent assignment procedures should be used to avoid any discrimination and optimise the use of those scarce resources.[5]

7. Auction mechanisms provide a means of meeting these objectives by providing economic incentives for efficient spectrum use. In designing an auction mechanism, we have sought to maximise the flexibility provided to bidders as far as possible and to provide the means for the market to explore various outcomes without prior restrictions. However, there are unusual challenges to designing this process created by the staggered availability of spectrum as existing licences expire.

Consultations conducted by ComReg

8. To date, ComReg has conducted two consultations on the future award of spectrum in the 900MHz and 1800MHz bands. These consultations have already established certain basic policy positions.

9. First, ComReg has indicated its intention to apply a cap of 2x10MHz on any future spectrum awarded in the 900MHz band. This cap would include both any existing unliberalised spectrum and any spectrum awarded under new liberalised licences. This cap is intended to protect competition in mobile services given the particular importance of sub-1GHz spectrum for data services.

10. Second, ComReg has stated that no liberalised spectrum should be awarded unless this is by means of a process of open competition. This ensures that new licences should be efficiently used and that licensees pay the opportunity cost of their spectrum.

11. In these consultations, ComReg presented a number of broad options for how an award process might be structured. In particular, ComReg's last consultation presented two options:

- "Option 1", where there would be a simultaneous award of licences commencing at various dates reflecting the staggered availability of spectrum;
- "Option 2", where there would be three phased auctions as spectrum becomes available, but with a provision for O2 and Vodafone to retain part of their current endowment to safeguard legacy services.

12. Option 2 has a number of problems. Splitting the award into a sequence of auctions is poor for economic efficiency and may potentially disadvantage a new entrant wanting to compete for the spectrum, as its opportunities to compete are spread over time. Rolling over existing licences would need to be at a price based on opportunity cost in order to be fair to both existing licensees and other parties. This should be the opportunity cost of liberalised use, whether or not the rolled-over licence is itself liberalised. However, such a price is difficult to estimate given available information.

13. The proposals presented here are close to Option 1, in that we propose a simultaneous award of all future spectrum in a single process. This approach is likely to be much superior for economic efficiency.

[5] Authorisation Directive (2002/20/EC)

Spectrum packaging

14. From the previous consultations, there is general consensus that spectrum should be made available on a paired basis in 2x5MHz lots. This would be compatible with the carrier sizes needed for both GSM and UMTS use.

15. With this packaging, seven lots would be available in total in the 900MHz band, though with staggered availability. As a result, the auction design we propose later has a temporal dimension to its lots. There would be five lots each providing access to 2x5MHz of spectrum from 2011 to 2015, and seven lots each providing access to 2x5MHz from 2015 onwards.

Early liberalisation and competition in mobile services

16. The proposed auction mechanism also allows for incumbent operators to liberalise their current licences prior to expiry at a competitively determined price. Under our proposals, this option would be available to Meteor, specifically in respect of its licence for 900MHz spectrum covering the 2011-2015 period. This option of early liberalisation would provide an additional flexibility not anticipated in either of ComReg's two consultation options. This would be useful in neutralising some of the potential competitive distortions in both mobile service markets and potentially also in the auction that could otherwise result from existing licences terminating at different dates.

17. In the absence of a mechanism to allow early liberalisation, O2 and Vodafone might gain a 4-year lead on Meteor in terms of offering 3G services using sub-1GHz spectrum. Access to sub-1GHz spectrum is likely to be necessary to offer advanced data services over wide areas (especially rural areas) and to provide in-building coverage. This could create differentiation in quality of service that could be detrimental to competition in the provision of mobile data services.

18. There is little point in providing an option for GSM incumbents to relinquish licences unconditionally prior to the auction. This would create unacceptable business continuity risk, as there would be no guarantee of winning back liberalised licences later. No one would be likely to exercise such an option.

19. Therefore, the auction design would allow existing licence holders to relinquish spectrum contingent on winning liberalised spectrum back for the same time period. This can be implemented easily by considering a bid for liberalised spectrum by an existing licensee for spectrum as a linked offer to relinquish its existing GSM licence.

20. We need to create appropriate incentives for early liberalisation and create a level-playing field between those upgrading an existing licence as compared with buying afresh. If an existing licence is relinquished, a rebate should be given on the price of a liberalised licence reflecting the value of the residual term of the GSM-only licence returned. In practice, this rebate would need to be determined from the amount originally paid for the licence, adjusting for inflation and the time remaining to expiry.

21. This early liberalisation process is compatible with the principle already stated by ComReg that liberalised licences should not be earned without open competition. For a bidder to win back liberalised spectrum it has itself released, it needs to make a bid large enough to beat other potential users of that spectrum. If this bid is unsuccessful, then the released spectrum reverts to the GSM licensee on an unliberalised basis for the remaining term of its licence.

Interference between different technologies

22. This award is unusual as there are different technologies that licensees might use (GSM, UMTS and other compatible technologies) during the life of a licence. To avoid unnecessary risk for bidders, it is necessary to create a system of spectrum usage rights that ensure there is sufficient separation between different users to avoid harmful interference regardless of what technology licensees at adjacent frequencies use. The required separations are defined in the EC Decision.

23. We propose that licences provide the following usage rights:

- Spectrum is made available in 2x5MHz blocks;
- UMTS users will have similar emission rights to existing 3G licences;
- In the absence of agreement from the neighbouring user, GSM users will need to leave one GSM channel (200kHz) unused at the edge of their frequency assignment in order to protect possible adjacent UMTS users from interference and comply with the parameters of the EC Decision.

24. It is possible that coordination between neighbouring users can bring additional spectrum into use at the boundaries of licences. However, the usage right scheme above ensures that the loss to bidders if such coordination is not achieved is small. Typically this means that 23 rather than 24 GSM channels can be deployed in a 5MHz block if coordination is not achieved and that UMTS use is not at risk.

25. Any alternative scheme that sought to impose guard blocks required to separate UMTS and GSM users on the UMTS licensee would create unacceptable risks on the UMTS licensee. This would not only be unfair to UMTS users, but also greatly complicate the auction design.

Combinatorial auction mechanism

26. A combinatorial auction format, in which bidders bid for packages of lots that are never subdivided, is ideal for this award. This is because bidders are likely to have valuations for a contiguous 2x10MHz block of spectrum that are more than double that of a 2x5MHz block. A similar format was used in ComReg's 26GHz auction and in all recent Ofcom auctions.

27. A combinatorial auction format can also deal naturally with the availability of different spectrum blocks from different dates by introducing the idea of *time slices*. The time slices would be:

- 2011 – 2015 (where 5 lots are available);
- 2015 to a common termination date for all liberalised licences (where all 7 lots are available).

28. The auction would consist of two stages:

- A *Main Stage* that would determine the number of lots (and so the amount of spectrum) that a bidder wins in each time slice;
- An *Assignment Stage,* which then determines the specific frequencies at which a winner's blocks would be located within each time slice.

29. In the Main Stage, bidders would submit multiple package bids. Each package bid would specify demand for zero, one or two generic frequency blocks in each time slice

and an associated overall bid amount. Each package bid must satisfy the spectrum cap and, in the case of Meteor, may include the option to release some, or all, of its existing GSM spectrum. Each package bid is indivisible and winning bidders will never receive only part of a winning package bid.

30. Winning bids would be chosen to maximise the total value of winning bids, subject to accepting at most one winning bid from each bidder and allocating no more lots in each time slice than are available. This rule selects the most efficient outcome given the bids received.

31. The winning bidders would pay prices determined using a second price rule analogous to that used in the Irish 26GHz auction. Under this rule, prices are determined by opportunity costs, so that each winner (and collectively each group of winners) pays the minimum amount such that there are no unsatisfied losers. This rule can also be interpreted as winners paying the smallest amount such that their bids would have won if made at that level. This pricing rule gives bidders incentives to bid close to their estimated value of packages and not engage in strategic bidding behaviour.

Open auction versus sealed bid

32. It is possible to run the Main Stage as either an open, multiple-round auction or as a single-round sealed bid. The open auction (a so-called combinatorial clock auction) provides a mechanism for price discovery and reduces the impact of common value uncertainty on the efficiency of outcomes. However, for this award common value uncertainty is not a central concern as there are significant differences in the starting positions of potential bidders that will idiosyncratically affect valuations. The more substantial concern is that competition may be weak in this auction, as the most likely bidders are the existing mobile network operators. Any open auction might be susceptible to distortion by strategic behaviour by bidders exploiting potentially weak and predictable demand.

33. Given this risk, we recommend the use of a sealed bid combinatorial auction (as used for the 26GHz award in Ireland) rather than a combinatorial clock auction. Moreover, measures should be taken to ensure that prior to the Main Stage of the auction, bidders are not aware of who else might have registered to participate in the auction.

Assignment Stage

34. After the Main Stage, the identity of the winning and losing bidders would be announced, together with the number of lots won in each time slice.

35. The Assignment Stage needs to determine the frequencies at which the generic lots won by bidders in the main stage will be located. There are scenarios where, because of the different expiry dates of current licences, it is impossible to accommodate all winners with unchanging frequency allocations across all time slices; sometimes a winner must change frequencies from one time slice to the next if all winners are to be fitted in with contiguous frequency allocations. The Assignment Stage provides a market mechanism to determine who needs to bear this burden of moving (if necessary) and to allow any preferences for specific frequencies to be expressed.

36. To run the Assignment Stage, we first compute all the ways of rearranging the winners within the band for each time slice (taking existing licences as fixed if the early liberalisation option is not used by Meteor). For each time slice, each winner has a number of possible frequency locations. Each winner then makes a number of assignment bids, which are in effect package bids for a particular location in each time

slice; each assignment bid can be thought of as a bid for a "frequency path". If a bidder wishes to try to avoid moving frequencies during the life of the new licence, it can bid a premium on paths in which it has the same frequency location in each time slice.

37. Winners of the Assignment Stage and prices to be paid are determined in an analogous manner to the Main Stage.

Reserve prices

38. The minimum amount a bidder needs to pay for a licence even if there is no competition depends on the reserve price set for the auction and also any annual fees over the term of the licence. We do not wish to set this minimum price so high that there is any risk of it choking off demand. Our approach to setting a minimum price is to first find an appropriate minimum price level using suitable benchmarks and then to consider how best this might be broken into an up-front reserve price (payable after the auction) and an on-going stream of payments (such as an annual spectrum usage fee (SUF)).

39. Benchmarking against other countries produces a predicted licence value range of €16m to €34m for a 2x5MHz 15-year licence for 900MHz spectrum in Ireland. This range can be considered a lower bound as there is no data on liberalised, 3G spectrum below 1GHz. It is important that the minimum price is set at a level high enough to reflect the true opportunity cost of the spectrum as discussed in the following paragraphs. This has to be balanced against setting minimum prices too high such that it chokes off demand. Given these concerns, we would recommend setting a minimum price in the range of €25m-€30m for 2x5MHz of 900MHz spectrum, which is towards the upper end of our benchmarked value range for 900MHz spectrum. Given that these estimates are likely to be too low in any case (as the benefit of spectrum being both liberalised and below 1GHz cannot be easily measured from the data), the risks of setting minimum prices too high should be modest at this level.

40. Due to the absence of spectrum trading in Ireland, spectrum usage fees (SUFs) serve a role in encouraging the return of any unused frequencies. For SUFs to serve this purpose, they would need to be set at a level that approximates the opportunity cost of spectrum. Such a level cannot be set as it is unknown, but it does suggest that there is some benefit in recovering the minimum price to a large degree through the SUF to encourage return of under-utilised spectrum to ComReg.

Payment deferral options

41. To guard against unexpected financing problems (for example due to capital market upheaval) there should be an option for deferral of some auction payments. We propose that all of the reserve price should be payable immediately after the auction, together with 50% of the excess of a bidder's winning price over the reserve price. The remaining 50% could optionally be deferred until the spectrum was available for use, when three equal payments would be required in the first, second and third years of the licence.

Licence conditions

42. Moving to a liberalised regime does create some potential complications for framing licence conditions, as to make them reasonably future-proof reference to specific services and especially specific technologies needs to be kept to a minimum.

43. Perhaps the most difficult issue for licence conditions for new 900MHz licences is the setting of coverage obligations and whether these should in any way be differentiated

according to whether a licensee previously held a 900MHz GSM licence. In particular, should existing obligations on voice coverage in current GSM licences endure?

44. Competition between GSM operators has already delivered coverage in excess of licence requirements. Therefore, there is reason to be optimistic about the ability of competition to deliver acceptable coverage. Further, there is no reason to expect existing voice coverage to be rolled back as a result of liberalising spectrum. Therefore, we do not recommend trying to continue existing coverage obligations in GSM 900MHz licences, as there is little benefit in terms of forcing high coverage and taking on the downside risk associated with this.

45. Such downside risk arises as any attempt to apply existing coverage obligations would necessarily involve the award of heterogeneous licences. This is because the imposition of equally high coverage obligations for all bidders would greatly discourage participation by new entrants in the award process. However, setting different conditions for different licensees risks complaint, as it might be argued that this approach is unjustified or discriminatory. The merits of these various arguments are debateable, but if the replication of existing GSM licence coverage obligations is considered to be of limited benefit anyway, there may be little point in adopting a potentially contentious approach.

46. Rather, we recommend imposing coverage and roll-out obligations at a moderate level, that is, the level of area coverage sufficient to serve 25-35% of the population within 3 years of a licence award and area coverage sufficient to serve 50-70% of the population within 5 years. Ideally, these obligations would be expressed in terms of geographical coverage, rather than population coverage, to give better incentives for operators to provide coverage where it is most valued. These levels of coverage are proposed with the expectation that the market would deliver much higher coverage levels in practice; existing operators are unlikely to reduce current levels of voice coverage. This level of coverage obligation would require roll-out in urban areas and protect against excessive cherry-picking. With regard to mobile broadband, the National Broadband Scheme and the associated obligation on H3GI to extend coverage beyond the level of coverage considered commercially viable sets a clear upper bound on a viable level of coverage obligation.

47. A coverage obligation at these levels would provide some safeguard ensuring that spectrum is used and prevent cherry-picking entry focussed solely on high-margin urban areas, whilst still leaving a licence reasonably attractive for a potential data-centric entrant. This obligation could be imposed on both voice calls and mobile broadband where either service is provided. However, if these levels were to be set differently for each service, ComReg might want to consider triggering this coverage obligation only if the relevant service is provided, so as to avoid the risk of compelling coverage of the higher level set on all new licensees in practice.

48. Whilst it might be possible to continue defining coverage in terms of transmitter field strength, a more future-proof approach would be to define coverage in terms of a required probability of a service being available. We recommend that coverage obligations focus on outdoor coverage given forthcoming technological changes in the delivery of indoor coverage.

49. We recommend ComReg consider providing some flexibility to allow operators to use their portfolio of spectrum holdings across different frequency band to meet obligations imposed as a result of holding a licence in one particular band. For example, obligations would result from holding a 900MHz licence but 900MHz

licensees would have the discretion to meet this obligation using any or all of its spectrum holdings.

50. We recommend that ComReg does not impose a "use it or lose it" condition, as this would be unnecessary with a coverage obligation in place and in any case, the tight spectrum cap mitigates concerns about hoarding.

51. Provisions for emergency calls should be applied when voice calls are offered. The detailed obligations may need to be modified to take account of requirements for location information and to provide flexibility to deal with future technological changes.

52. Minimum quality standards for voice calls are not technology dependent, so could be maintained in their current form, but harmonised at the tightest requirements current in licences. Conditions on billing can be maintained even in a service-neutral environment if these are expressed as generic requirements (i.e. disaggregation, transparency, etc.)

53. A range of proportionate penalties is needed to enforce licence conditions. We propose that for severe breaches, the licence term is curtailed. This needs to be backed up by an alternative scheme for punishing less serious breaches for which licence curtailment may not be a credible threat. ComReg has previously used performance bonds, which could provide such a scheme. Minor infractions would result in a forfeit of all or part of the performance bond. We estimate that a bond of €2-3 million would be adequate for this purpose.

54. A penalties regime would need to be supported by compliance and reporting obligations. There are already wide powers for ComReg to require data from operators to monitor licence condition compliance in existing licences. We recommend that the current condition be maintained, and that the type of information to be reviewed by ComReg is revised at intervals deemed appropriate by ComReg in light of technological developments and the use of these technologies in the 900MHz band.

1 Introduction

55. DotEcon has been commissioned by the Commission for Communications Regulation (ComReg) to provide advice on the design for a process to award spectrum in the 900MHz and 1800MHz bands in the Republic of Ireland.[6]

56. This document represents our final report. It includes:

- an assessment of possible formats for a 900MHz award;
- a recommendation on an auction format;
- set of auction rules implementing our recommended format; and
- a recommendation on reserve prices, spectrum fees and licence conditions.

57. The views expressed in this report are those of DotEcon only and do not necessarily represent the views of ComReg.

1.1 Background

58. Two of the three licences currently assigned for GSM use in the 900MHz band are scheduled to expire in 2011, with the third expiring in 2015. The current licences were issued under the GSM Directive, which required the 900MHz band to be harmonised for GSM use only. The European Commission has recently issued a Directive amending the GSM Directive (the 'Amending Directive') that allows other technologies compatible with GSM to be used in the 900MHz band. This will allow, at minimum, UMTS technologies to operate alongside legacy GSM services. As a result of these proposed changes to European legislation, any future licences issued in the 900MHz band will need to be offered on a liberalised basis.

59. The 900MHz band is likely to be central to the medium-term development of mobile data services. The propagation characteristics of spectrum below 1GHz make it attractive for providing wide-area and in-building coverage. The 900MHz band is likely to be the first band below 1GHz for which 3G network equipment and terminals will become widely available. Therefore, this band may be particularly important to network operators for creating a competitive data proposition for their customers. Both existing GSM operators in this band and prospective entrants have expressed their interest in operating 3G services at these frequencies.

60. To date, ComReg has run two consultations on liberalisation of the 900MHz and 1800MHz bands and possible release options:

- the **initial consultation** - 08/57 "Liberalising the use of the 900MHz and 1800MHz spectrum bands";
- the **follow-up consultation** – 09/14 "Liberalising the future use of the 900MHz and 1800MHz band and spectrum release options".

[6] ITT: Spectrum Liberalisation in the 900MHz and 1800MHz bands 09/40.

61. Additionally, ComReg has held a series of bilateral meetings with parties that responded to one or both consultations on this matter, providing them an opportunity to articulate their written response.

- The minutes of bilateral meetings - 09/73 "Liberalising the future use of the 900 MHz and 1800 MHz spectrum band & Spectrum release options – Publication of the non-confidential minutes of bilateral meetings"

62. We have had regard to both of these consultations, the minutes of the bilateral meetings, and the submissions of respondents to these consultations, as well as a wide variety of publicly available material regarding spectrum policy and spectrum awards in these and other relevant bands in Ireland and in other countries, and the prevailing conditions in Ireland that may affect a future spectrum award.

1.2 Structure of this report

63. The document is organised in four main parts:

- Part A considers various issues affecting the choice of auction format and the packaging of lots;
- Part B provides a set of outline auction rules;
- Part C considers appropriate reserve prices and spectrum usage fees for this award;
- Part D considers potential licence conditions that might be associated with future licences awarded in this band.

PART A: Background issues for auction design

2 Supply and demand conditions

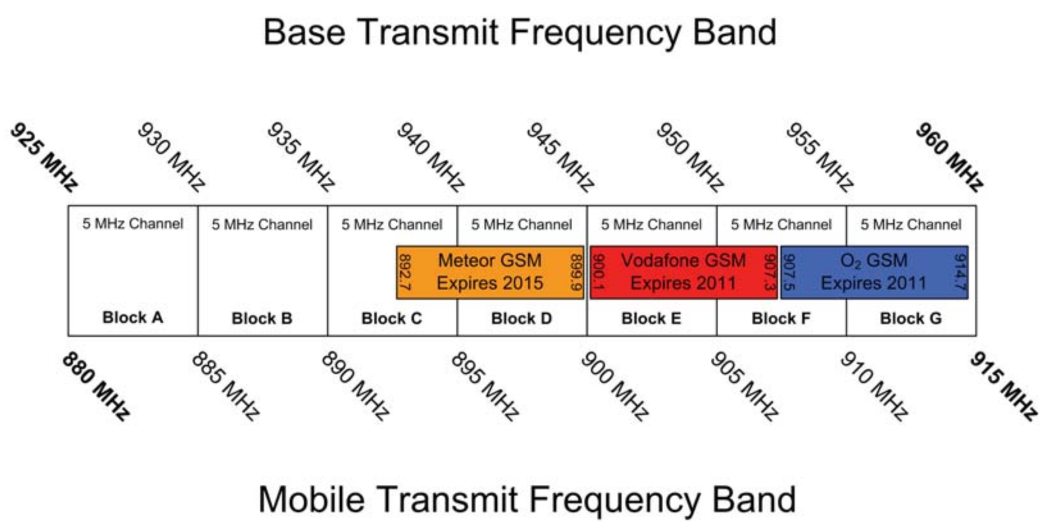
64. In this section, we consider the spectrum that may be available for award at 900MHz, 1800MHz and, over the foreseeable future, in related bands. We also consider the likely extent of demand for the 900MHz and 1800MHz bands. These are key considerations for both the packaging of spectrum into lots and ultimately for the design of an efficient award process.

2.1 Spectrum availability and constraints on its use

2.1.1 Spectrum available in the 900MHz band

65. The 900MHz band contains 2x35MHz of paired spectrum (880-915MHz paired with 925-960MHz). This band is illustrated in Figure 1 below:

Figure 1: 900MHz band



66. At present, there are three mobile network operators with spectrum licences within the 900MHz band: O2; Vodafone and Meteor. Each licence provides 2x7.2MHz of paired spectrum for GSM use. They are located at the upper end of the band with separations of 200kHz between adjacent licences. The licences have different expiry dates:

- O2's and Vodafone's licences expire in 2011; and
- Meteor's licence expires in 2015.

67. As illustrated in Figure 1, there is 2x13.4MHz of spectrum in the 900MHz band that is currently unassigned. Of this, 2x12.7MHz forms a contiguous block of currently unallocated spectrum at the lower end of the band.

68. The available supply of spectrum in the 900MHz band is limited compared with the likely future requirements of operators. In particular, technologies such as LTE will likely require at least 2x15MHz of spectrum (and more likely 2x20MHz) to operate most efficiently. Clearly it is not possible to accommodate more than two of the existing operators in this band with

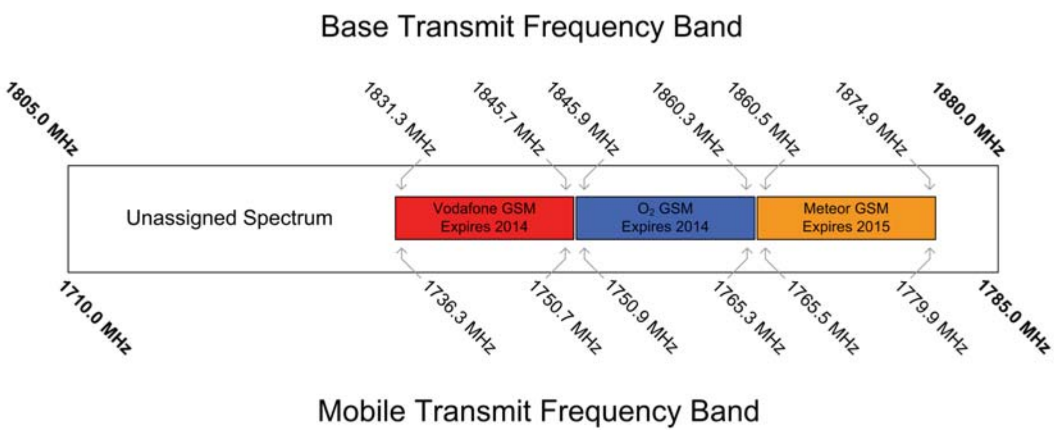
such large spectrum blocks. Therefore, in the long run, it may be necessary to use the 900MHz band alongside other spectrum below 1GHz to most effectively make use of the known efficiencies of operating 3G technologies at these frequencies.

69. The superior propagation characteristics of sub-1GHz spectrum have the potential to create significant cost savings for operators, especially by allowing fewer, larger cells in rural areas. A study of these efficiencies commissioned by ComReg concluded that 'the cost savings to be gained by an operator using 900MHz are estimated to be 26% when compared to 1800 MHz and 35% when compare to 2.1GHz.[7] At present, there is no certainty about how much other sub-1GHz spectrum might be available or when it might become available. In large part, this depends on the timing of measures to release existing analogue TV spectrum, as discussed below.

2.1.2 Spectrum available in the 1800MHz band

70. The 1800MHz band contains 2x75MHz of paired spectrum (1710-1785MHz paired with 1805-1880MHz). The band is illustrated in Figure 2 below.

Figure 2: 1800MHz band



71. This spectrum has propagation characteristics that make it a potential complement to 900MHz (and also 800MHz) spectrum. More limited propagation as compared with lower frequencies is helpful for providing extra capacity at hotspots in urban areas that supplements wide-area 900MHz coverage. However, there are a number of operators in other countries that use spectrum solely in the 1800MHz band for their GSM operations (e.g. Orange in the UK), so 1800MHz spectrum could equally be considered as a substitute to lower frequency spectrum if the latter is not available. Nevertheless, in an ideal world and starting from a clean sheet, an operator would want a mix of spectrum at different frequencies to optimise its network structure and to provide future flexibility if technological developments do not arrive in all bands at the same time.

[7] ComReg (July 2008), "Liberalising the use of the 900MHz and 1800MHz spectrum bands", ComReg Consultation 08/57

72. Existing operators in the 900MHz band have all been assigned spectrum in the 1800MHz band – 2x14.4MHz each – but for Vodafone and O2 with significantly later expiry dates than their 900MHz licences:

- O2's and Vodafone's licences expire in 2014; and
- Meteor's licence expires in 2015.

The remaining 2x31.8MHz of spectrum in this band is currently unassigned, 2x26.4MHz of which forms a contiguous block at the lower end of the band.

73. There were mixed views in response to ComReg's initial consultation on the need for an award of further spectrum in this band in the immediate future, with a number of respondents contesting ComReg's assessment that there is insufficient demand for 1800MHz spectrum assignments to warrant holding a competitive award process at present. However, ComReg has concluded that 'there is not a pressing requirement to hold a competitive award process for 1800MHz spectrum at this time', and that 'holding a competitive award process for assignment of 1800MHz frequencies closer to 2013 would provide greater clarity to applicants on spectrum developments in other bands of interest for wideband data transmission'.[8] As a result, ComReg is not minded to include 1800MHz spectrum in an integrated auction process.

2.1.3 Spectrum available in other bands

74. There are a number of other bands suitable for use by mobile network operators which might become available in the foreseeable future:

- digital dividend spectrum, including the 800MHz sub-band likely to be released across most or all of the EU for non-high power uses including mobile broadband following analogue TV switch-off; and
- the 2.6GHz band.

75. Both 800MHz and 2.6GHz bands could be of potential interest to both existing operators and potential entrants bidding for spectrum in the 900MHz band, as either a substitute or a complement. Therefore, potential bidders in a 900MHz award will ideally require information (where available) about the potential supply of spectrum in these bands in order to inform their business cases for 900MHz spectrum.

800MHz sub-band

76. The digital dividend provides the main alternative source of spectrum potentially available below 1GHz. The European Commission has set a target date for Member States of 2012 for release of TV spectrum following analogue switchover.

77. At the time of writing, an increasing number of Member States have indicated interest in creating a sub-band (790-862MHz) for mobile broadband applications. The European Commission is at present in the process of investigating the possibility of EU-wide action to facilitate creation of this sub-band. It currently appears that the 800MHz sub-band proposal

[8] ComReg (March 2009), "Liberalising the future use of the 900MHz and 1800MHz band and spectrum release options", ComReg Consultation 09/14, page 52.

has a sufficient critical mass of support to succeed. It is also possible that further EU-wide *de facto* standards might emerge for other digital dividend spectrum in the future.

78. For mobile network operators, spectrum in the 800MHz sub-band (790-862MHz) is potentially a close substitute to 900MHz spectrum. The 800MHz band has similar propagation characteristics to 900MHz, both bands being located at frequencies suitable for wide-area and in-building coverage. For operators, the key difference between 800MHz and 900MHz spectrum is timing and likely equipment availability, not the physical characteristics of the spectrum. The current proposals for creation of a sub-band would make available 2x30MHz of paired spectrum on a technology-neutral basis. Assuming that the current support for the sub-band amongst Member States continues, it is likely that this spectrum will be available for award in some Member States by 2012 and in most by 2015. These moves may help in providing greater certainty for equipment manufacturers in developing handsets and network equipment supporting the 800MHz sub-band.

79. Looking forward to the greater use of spread-spectrum technologies requiring wider contiguous blocks of spectrum, there is a potentially important role for the 800MHz band alongside the 900MHz band. In particular, if a carrier needs to be 2x15MHz or 2x20MHz wide for maximum spectral efficiency, existing mobile operators could not all fit within the 900MHz band alone. Indeed, at most two operators could fit into the available 2x35MHz at 900MHz with contiguous assignments of this size. In contrast, using the 800MHz sub-band and the 900MHz band together would allow access to larger blocks of contiguous spectrum whilst facilitating competition amongst operators, as all would have similar access to the most efficient radio technologies.

80. It is likely that 900MHz and 800MHz bands will, in the long-run, need to be considered together if operators are to hold sufficient amounts of contiguous spectrum to allow deployment of spread-spectrum technologies and avoid inefficient fragmentation of holdings across the two bands. Therefore, some reorganisation of sub-1GHz spectrum could be necessary within the lifetime of any new 900MHz licences. Spectrum trading is not possible in Ireland, but this does not necessarily preclude creating some mechanism for swapping 800MHz and 900MHz holdings at some future date as part of the award of new 800MHz spectrum (for example through return of 900MHz spectrum in turn for 800MHz spectrum).

2.6GHz band

81. Across Europe, the 2.6GHz band has been identified as being suitable for mobile services. In particular, the sub-band 2500-2570MHz paired with 2620-2690MHz is suitable for deployment of 3G and LTE. A number of countries have already awarded this spectrum (e.g. Norway and Sweden) or announced plans to do so shortly (including the Netherlands, UK[9], Denmark and Finland).

82. In Ireland, this band is currently encumbered by other uses (MMDS) until the expiry of current licences in 2012 and 2014. In its Spectrum Management Strategy Statement for 2008 through 2010 (08/50), ComReg proposes to conduct a public consultation on the future of the MMDS licences and the use of the 2.6GHz band in 2010.

[9] The UK approach to the award of 2.6GHz is currently in flex following the recent 'Digital Britain' white paper.

2.2 Interaction between 900MHz and 1800MHz bands

83. An important question for this award is whether there is benefit to offering some or all of the currently unassigned 1800MHz spectrum alongside 900MHz spectrum in a unified award. ComReg has not found evidence of significant demand for 1800MHz spectrum in either of its two recent consultations so there is no overwhelming case for releasing the spectrum at present. Rather, there are a variety of costs and benefits to including 1800MHz spectrum with the award of 900MHz spectrum.

84. The primary benefit of including 1800MHz spectrum is that this might provide greater certainty to existing mobile network operators. Existing 1800MHz licences will expire during the period of the proposed new liberalised 900MHz licences. Allowing existing operators to bid for both 900MHz and 1800MHz bands in an integrated award process could allow them to make bids reflecting the extent to which they view the two bands as substitutes or complements. This would provide clarity in both bands that may affect incumbents' plans for providing legacy GSM services.

85. The downside of including 1800MHz spectrum is that it may significantly limit options for a future spectrum award that could include a number of different bands (say 1800MHz, 800MHz and possibly 2.6GHz). Such an award could provide a rare opportunity for potential new entry and also provide incumbents with the possibility of significantly increasing spectrum holdings to provide advanced data services. Having additional higher frequency spectrum available alongside 800MHz would be important for creating contestability by potential new entrants (whether or not that was ultimately successful).

86. In principle, a similar argument could be made in regard to the 900MHz band itself – that offering 1800MHz alongside 900MHz might make it more contestable by creating a more attractive proposition for new entrants. However, the incremental benefit to strengthening competition within an auction of 900MHz spectrum is likely to be modest given the strong positions of incumbent operators. If there is likely to be modest impact from including 1800MHz spectrum in an auction of 900MHz, then it might well be better to retain 1800MHz spectrum to provide the option of running a later "big auction" with an attractive mix of spectrum bands.

87. Overall, the case for including 1800MHz spectrum with 900MHz in a single auction is not compelling. As ComReg is not currently minded to include 1800MHz spectrum in an integrated auction process, we have formulated proposals for an award of 900MHz spectrum alone in this report.

2.3 Level and structure of demand

2.3.1 Demand for 900MHz spectrum

88. As part of its initial consultation in July 2008 on the liberalisation of spectrum in the 900MHz and 1800MHz bands, ComReg sought responses from stakeholders as to their respective demand for spectrum in these bands. Regarding frequencies in the 900MHz band, six operators responded, together stating demand for at least 2x40MHz, in excess of the 2x35MHz available. Accordingly, ComReg made a provisional decision to award spectrum in this band through a competitive auction process, which it notes is its favoured solution in cases where demand exceeds supply.

89. Although the likely outcome is, indeed, that there will be excess demand for 900MHz spectrum, it is very important that the award process is robust to alternative demand

conditions. Given the spectrum cap of 2x10MHz within the auction (discussed in Section 3.2), the focus of competition could be on whether existing operators secure 2x5MHz or 2x10MHz of spectrum. Competition amongst the four existing mobile network operators is not symmetric, however, as H3GI does not have a current 900MHz licence and does not require spectrum for legacy GSM services. The combination of the number of existing operators and the spectrum cap imposed on these operators introduces the possibility that competition amongst operators may be weak, and an award mechanism would need to facilitate the reaching of an efficient outcome under each of these alternative circumstances.

2.3.2 Structure of demand

90. At present, all spectrum assigned to the three existing operators in the 900MHz band has been licensed for providing GSM services only. This is in line with the GSM Directive, which reserved the entire band for GSM services only across the EU. However, given the technological developments since the establishment of the 900MHz band for GSM services, a need developed to revise the usage rights in this band to allow for use of this spectrum by technologies capable of providing more advanced services.

91. To this end, the EC Decision and the Amending Directive published recently in the European Commission's Official Journal[10] mean that any spectrum made available in the 900MHz band from now on will be usable not just for GSM, but also for UMTS and other technologies compatible with GSM. Where GSM and 3G users find themselves deploying services in adjacent spectrum, these different users will need to be separated to avoid interference. This issue has been considered in the technical analysis supporting the EC Decision. A carrier centre to carrier centre separation of 2.8MHz will be required between GSM and 3G users in the absence of any specific coordination of networks. Where non-GSM technologies are used in spectrum adjacent to spectrum using GSM, however, it is left open as to which operator would be obligated to ensure these separation requirements. This issue is considered further in Section 5.

92. In ComReg's follow-up consultation in March 2009, all three existing operators expressed their interest in rolling out 3G technologies in the 900MHz band. In addition, it is likely that any new operators to the band that is not already a GSM operator will seek to deploy infrastructure to support 3G technologies only and not legacy GSM services. Therefore, the most likely situation is that there will be a mix of GSM and 3G use within the band following liberalisation.

93. To facilitate new technologies in this band such as UMTS and other compatible technologies, spectrum needs to be offered in blocks that are compatible with their requirements. The simplest way to do this (as used in a number of 2.6GHz auctions in the EU and already used for 3G licensing in Ireland) is to offer spectrum in 2x5MHz blocks. ComReg has already consulted on this issue and there was broad support for such packaging.

94. Existing operators in the 900MHz band will in all likelihood want to continue to serve their GSM customers for a number of years whilst they attempt to move them onto other, 3G compatible handsets. Even after this point, there may be incoming roamers with GSM-only handsets. Continuation of legacy GSM services until 2G-only handsets have been largely

[10] OJEC, 16 October 2009.

eliminated may also have public safety implications (by affecting roamers' ability to make emergency calls), though meeting public safety requirements may not necessarily require running multiple GSM networks.

95. Unlike the 5MHz wideband carriers used for 3G, GSM services use 200kHz narrowband carriers. In terms of the total amount of spectrum required to service these 2G customers, trials conducted by existing operators in this band suggest that these operators will require at least 2x5MHz for continuing to service these customers without losing service quality.[11] This is less than the current 2x7.2MHz of spectrum provided by existing licences. Therefore, the consultation responses suggest that a single 2x5MHz block may be sufficient to allow legacy GSM services to continue and that with 2x10MHz, both 3G and legacy GSM services could simultaneously be deployed by existing GSM licensees.

96. If GSM and 3G services are likely to co-exist for some time, a natural question is whether there is any case for offering spectrum in smaller blocks to provide more flexibility for GSM services. This issue was considered in ComReg's initial consultation in July 2008 and ComReg concluded that there was no benefit to offering spectrum in smaller blocks. We concur with its conclusion as:

- Ultimately, all spectrum in this band will almost certainly be used for 3G and successor technologies that require at least 5MHz carriers within the licence duration of new licences. Offering spectrum in smaller blocks risks outcomes that do not permit spectrum to be used for such services. Ireland does not currently permit secondary trading of spectrum, so there would be no mechanism in place to rectify such a situation;
- In any case, operators are initially likely to require at least 5MHz for legacy GSM services including any associated guard blocks. Therefore, smaller blocks would need to be aggregated to provide sufficient spectrum for legacy GSM services.

2.3.3 Demand for specific frequencies

97. Existing GSM operators in the 900MHz band may have a preference for specific frequencies in a future award of spectrum in this band. In particular, they may have a preference for spectrum blocks including frequencies that they are currently assigned by existing licences, although the strength of this preference may vary between operators depending on the technical ease with which they could each retune their networks to operate at a different frequency.

98. Given the size of current spectrum assignments (2x7.2MHz each) and the location of spectrum assignments within the band (at the high end of the band with guard bands of 200kHz), it would not be possible for all existing 900MHz operators, if they were to win 2x10MHz each in the auction, to remain located in the same position in the band as before; if the proposed spectrum packaging is implemented at least one operator would need to move frequencies in order to accommodate these winners in the band.

99. In order to retain the necessary flexibility to accommodate all assignment scenarios, including the one just described, ComReg has stated in its follow-up consultation on this

[11] Responses of Vodafone and Meteor to consultation 09/14 – See ComReg Document 09/51s.

band that in order to compete in the award process, incumbent bidders will be required to sign a Memorandum of Understanding that their existing frequencies may need to be realigned and that they would need to cooperate in this process. The proposals outlined in this report demonstrate that any re-planning can be effectively achieved through appropriate design of the award mechanism. This is discussed in detail in Part B. Nevertheless, providing a framework within which bidders should negotiate with operators in adjacent frequencies to minimise interference is still prudent, especially as coordination between neighbouring GSM and 3G operators might allow spectrum to be used more efficiently. This concept is discussed later in Section 5.

100. Apart from the issue of incumbent GSM operators having a preference for retaining existing frequencies, there are no other reasons to expect there to be strong preferences for particular frequencies within the band. Differences in propagation characteristics of frequencies at the top and bottom of the band are immaterial. There may be a slight preference for an existing GSM operator to hold 2x10MHz of spectrum at the edges of the band rather than the centre under the interference management proposals we develop in Section 5.3. However, again this is not likely to be a strong preference.

101. For these reasons, it seems reasonable to break the award process into two stages. The first stage would determine how much spectrum each licensee receives. The second stage would determine the specific frequencies that would be assigned to each licensee. This separation is possible as the specific frequencies to be awarded are likely to have relatively little impact on the valuation of various amounts of spectrum.

3 Key issues for an award process

102. In this section, we first review the objectives and obligations that ComReg must observe in the design of an award process. We then consider issues surrounding the liberalisation of existing GSM licences; the impetus to ensure continuity of service to GSM consumers; and spectrum efficiency and spectrum caps.

3.1 ComReg's objectives and obligations

103. We have had regard to ComReg's various objectives and obligations in compiling this report and when making our recommendations. In particular, we have considered:

- ComReg's statutory objectives set out in Section 12 of the Communications Regulation Act 2002, especially those of ensuring efficient management and use of radio spectrum, promoting competition and promoting the interests of users;
- general obligations on ComReg to ensure that measures are proportionate with regard to its objectives;
- ComReg's obligation to have regard to the directions by the Minister for Communications Energy and Natural Resources (especially that the mobile telephony industry is sustainable);
- obligations deriving from the Authorisation Directive to ensure that operators benefit from objective, transparent, non-discriminatory and proportionate rights, conditions and procedures.

104. A key issue, as with many spectrum awards, is that only imperfect information is available for a spectrum regulator to assess how spectrum might be most efficiently used. Therefore, we have tried to make full use of auction mechanisms that allow the market to determine outcomes rather than making value judgments about how spectrum should be used. Our underlying approach has been to create flexibility for potential users of spectrum with incentives for efficient allocation and use. We believe that this approach is the most appropriate for meeting ComReg's objectives.

3.2 Spectrum efficiency and caps

105. In the two consultation documents, ComReg has been clear that it expects an auction cap of 2x10MHz to apply to spectrum awarded in the 900MHz band. This cap applies to both existing holdings and any spectrum won in a foreseeable award process, meaning that existing licensees cannot win new spectrum without giving up existing licences in whole or in part. This is a cap on acquisition of rights in respect of spectrum within this particular auction, rather than an enduring rule applying to any subsequent reorganisation of the industry (e.g. a merger, which would be subject to the usual provisions of competition law and ComReg's role as the national spectrum manager).

106. Existing operators in the 900MHz band have expressed their interest in adopting LTE in this band in order to provide advanced data services to their customers. This raises a significant issue for spectrum management given the combination of circumstances surrounding a prospective award in the 900MHz band:

- Given the limited amount of spectrum available in the 900MHz band, ComReg has proposed a cap on operators of 2x10MHz, including any current 2G assignments;
- An operator using LTE in the 900MHz band may well require more than 2x10MHz for its services over time;[12]
- Options for an operator to acquire additional spectrum for LTE in the medium term exist mainly in the 800MHz sub-band;
- An operator using LTE in both the 800MHz and 900MHz bands would not be able to operate its network fully efficiently unless some reorganisation is possible to allow operators to hold larger contiguous blocks in just one band.

107. The resulting issue is how to anticipate and manage the fragmentation of spectrum holdings of those with licensed spectrum in the 900MHz band where they are also assigned spectrum in other bands such as the 800MHz sub-band in a subsequent award process. One possibility for doing this is to establish a principle of transferability of licences between these bands such that where an operator is assigned spectrum in the 900MHz band in an upcoming award and also assigned 800MHz spectrum in a subsequent award, ComReg would endeavour to provide that these frequencies would be contiguous, either in the 800MHz or the 900MHz band. However, the details of any such arrangement remain to be considered.

3.3 Early liberalisation and competition

108. The EC Decision and Amending Directive require that any new licences assigned for spectrum in the 900MHz band should be liberalised. It is believed that this will be beneficial to both operators in providing services using the most efficient technologies and to consumers through the availability of a greater breadth and quality of services. Responses to ComReg's consultations indicate that all stakeholders are in favour of a timely adoption of this policy.

109. What is more contentious is the question of how regulators might address liberalisation in this band given that existing licences do not all terminate at the same date. This feature makes this award rather different from most spectrum awards run to date. This is not an award in which bidders are starting from a blank sheet and competing for largely identical licences, unlike most of the initial 3G awards in Europe in 2000 and 2001. Rather, different bidders are in different situations as a result of the different expiry dates of existing licences and their asymmetric spectrum holdings. These differences might potentially benefit or hinder specific bidders depending on the design of the award process; therefore, we need to construct a mechanism that is both fair and efficient for different bidders.

110. There are two main issues that arise in trying to create a level playing field for bidders despite these differing expiry dates of existing licences:

- First, there may be distortions to competition in providing mobile services if we create asymmetries between operators with regard to their access to

[12] For example, see Mobile Broadband, Competition and Spectrum Caps, Arthur D. Little, prepared for the GSM Association.
http://gsmworld.com/documents/Spectrum_Caps_Report_Jan09.pdf

spectrum for the deployment of 3G technologies. Late access to sub-1GHz spectrum for providing 3G services might be a concern for Meteor, whose current licence has six more years until expiry. If O2, Vodafone and any possible new entrant to the 900MHz band had access to sub-1GHz spectrum for data services from 2011, but Meteor had no such access until 2015, there may be a risk of distorting competition in downstream mobile service markets. In particular, offering ubiquitous mobile broadband (especially in buildings) might turn out to be important for winning high-value mobile customers; if so Meteor could potentially be disadvantaged in this regard.

- Second, there may be competitive distortions within the auction itself created by differences in the expiry dates of existing licences causing incumbents to have different opportunities to compete for liberalised spectrum.

111. We shall see that the second problem of auction distortions can be mitigated with careful auction design. However, there is no completely satisfactory solution and, in any case, this does not address the more troublesome first problem of competitive distortions in mobile service markets. For these reasons, we propose a mechanism that tackles any underlying asymmetry between operators created by differing expiry dates through providing options for liberalising spectrum prior to the expiry of existing licences.

112. ComReg has stated two clear principles for liberalisation of existing GSM spectrum in its follow-up consultation:

- existing 900MHz licences (or any extensions to existing licences offered to address GSM legacy issues) will not be liberalised in the hands of their current owners; and
- new licences will be subject to open competition.

113. These principles are compatible with existing 900MHz GSM licensees gaining access to liberalised spectrum prior to the end of their current licences. However, to achieve this, operators would need to agree to return their current licences in the event of their winning new liberalised licences in open competition. This is the approach that we develop in our proposals.

3.4 Ensuring undisrupted GSM services

114. There is a general duty on ComReg (arising from Ministerial Direction) to consider the sustainability of mobile sector. A key aspect of industry sustainability is the ensuring the continuity of existing services through the expiry of one generation of spectrum licences and the issuing of new licences. However, sustainability of the industry as a whole equally requires timely access to spectrum on appropriate terms to accommodate new technologies as they develop. A balance must be struck with the potential for disruption for individual industry players.

115. There is a lack of consensus as to the level of disruption to GSM services that would exist if O2 and/or Vodafone were to lose some or all of their spectrum assignment when their current licences expire, and indeed the time requirement for an alternative solution to be found if this outcome were to become a reality.

116. Both Vodafone and O2 have stated in their responses to the follow-up consultation that it would not now be possible to allow the expiration of current 900MHz spectrum licences and at the same time avoid disruption to GSM consumers. Further, Vodafone has stated that it

would need at least four years to migrate to MVNO or roaming agreements or to adapt the use of the 1800 MHz spectrum.

117. Vodafone and Meteor have also lodged submissions with ComReg relating to the resources required to maintain 2G services whilst also providing rural broadband. These have concluded that it is not possible to accommodate the delivery of both 2G and 3G services within a spectrum assignment of 2x7.2 MHz and that devoting less than 2x5MHz to GSM services at present would have a detrimental effect on service quality.

118. The consultation responses suggest that it would be feasible for an operator to run both GSM legacy services and a single 3G carrier within a contiguous 2x10MHz block. However, ComReg may wish to consider this matter in combination with a proposal for enforcing separation requirements between adjacent GSM and UMTS operators in the absence of coordination, potentially as part of a consultation process. We consider the alternative options for separation obligations in Section 5.

119. It may be the case that operators have somewhat overstated the difficulties of sustaining legacy GSM services. In particular, H3GI states in its consultation response that in the past two years, both H3GI and O2 have completed radio access network (RAN) infrastructure swaps without disruption to customers, and that H3GI completed its RAN infrastructure swap within six months. It states that O2 completed two major swap-outs of both its 2G and 3G networks within two years. It highlights that all GSM handsets have had dual band 1800/900 capability for the last number of years and the majority, if not all, of existing GSM sites are dual band, and that any coverage holes could be covered by a national roaming agreement with another operator.

120. Unfortunately, in such circumstances, there is always potential for existing operators to use their mobile customers to enhance their bargaining position in seeking access to liberalised spectrum. In particular, operators may have incentives to overstate the difficulty of migrating customers and may also have poor incentives to invest in the migration process itself as a result. This is a somewhat risky strategy in that it commits an operator to needing access to spectrum beyond the term of the current licence. However, the operator might judge that a regulator may be unwilling to allow such consumer disruption to occur and thereby strengthen its bargaining position by behaving in this way.

121. Ultimately, taking such a bargaining position may not be credible. Ireland has an efficient and fast mobile number porting scheme. If an operator suffered degradation in service quality through brinksmanship on its GSM services, it might be costly in terms of lost customers. Meteor is a competitive constraint in this regard to O2 and Vodafone.

122. In an auction process, incumbents might place a high value on retaining spectrum if they need spectrum to avoid disruption to existing services; they would then have a correspondingly high probability of winning back spectrum. Further, only 2x5MHz would seem to be needed to allow continuity of existing GSM services. Incumbents winning back no spectrum at all would be a low probability event if there are adverse consequences on individual operators of the degree claimed in their consultation responses.

123. In any case, the existence of potential disruption if an existing licensee failed to win back spectrum is not, of itself, a compelling reason to roll over existing licences without opening them up to competition. ComReg has been clear that it intends 'to award all new licences in the 900MHz band on a liberalised basis following an open and transparent competition' and that ComReg's "option 2" relates to the extension of licences on an unliberalised basis only. Rather, given ComReg's obligations to consumers, the relevant question is how much notice existing operators need of whether or not they have been successful in winning continued

access to 900MHz spectrum, so that delivery of services to consumers is not adversely affected if consumers have to switch suppliers. An adverse impact on one particular supplier does not necessarily affect consumers greatly in a competitive market if switching is possible. Furthermore, even if there is potential for market disruption, we need to take into account how likely such a scenario is and balance this against the downsides of rolling over existing licences.

124. The auction format we propose in this report is not complex to implement and draws heavily on ComReg's experience of running the 26GHz auction. There do not appear to be any insurmountable hurdles to running an auction of 900MHz spectrum soon; the primary practical constraint on timing is the need for further consultation on the details of the award process. Therefore, it might be possible to run an auction as soon as early 2010. Vodafone and O2's licences expire in May 2011, which means that it should be feasible to conclude an auction and give a minimum of one year's notice of whether or not existing licensees would continue to enjoy access to spectrum in the 900MHz band.

125. If either Vodafone or O2 bid for 2x10MHz but failed to win any spectrum at all from 2011 onwards, this would *necessarily* mean that at least *three* 2x5MHz blocks would have been won by at least *two* operators other than the 900MHz incumbents; these could be one or more new entrants, or an existing network operator without 900MHz spectrum (i.e. H3GI). The latter may be judged a more likely outcome than the former, as an existing operator can be expected to have greater value for 900MHz spectrum that can be integrated into its network than would a greenfield entrant. In any case, for a winner of spectrum to have beaten an incumbent with a high value of retaining spectrum, the winner's business case would likely have had to have been based on bringing services to market quickly. Therefore, in this scenario, it seems likely that the 900MHz spectrum awarded would be brought into use rapidly. From a customer's perspective there would be long notice of the impending market reorganisation and the opportunity to migrate as contracts expire.

126. Overall, it does not seem as if holding an auction in early 2010 would create unreasonable risks to consumers given that the chances of one or more incumbents failing to win spectrum would seem to be low in the case that retaining access to 900MHz proved important for incumbents to compete. Moreover, even if there were disruptive entry, it is likely that there would be time to bring new capacity into the market based on the spectrum won by different operators. There would inevitably be some dislocation and migration of consumers, but this would just be part of a normal competitive discipline.

4 ComReg's proposals to date

127. This section:

- reviews ComReg's current proposals against its objectives for the award; and
- outlines potential modifications and alternatives to be pursued in the rest of Part A of our report in which we consider alternative auction formats and spectrum packaging possibilities.

128. In its initial consultation, ComReg noted that it was broadly committed to the use of auctions in licensing situations where demand is expected to exceed supply, and expressed its inclination to use an auction for the present award. As noted in its follow-up consultation, there was agreement in principle by respondents to the award of spectrum by auction with only a limited amount of objection by non-incumbents. Therefore, we take as a given ComReg's decision to award spectrum in the 900MHz band by auction.

4.1 Proposals in ComReg's initial consultation

129. In its initial consultation, ComReg set out three potential options for the assignment of spectrum in the 900MHz band. These options are summarised in Table 1 below:

Table 1: Alternative award options

Award options proposed in ComReg's initial consultation	
Option A	3 separate competitions: (1) 2x12.8MHz currently unassigned spectrum assigned mid-2009 (2) 2x15MHz of spectrum assigned from 2011 (3) 2x7.2MHz assigned from 2015
Option B	Single competition for 7 2x5MHz blocks Assignment linked to expiry of relevant 2G licences (2x2.8MHz of C block usable from 2009, remaining 2x2.2MHz usable from 2015)
Option C	Option B with a spectrum reservation for entrants One new entrant: Reservation of block A Two or more new entrants: Reservation of Block A and potentially block B

130. Thus, the main difference in the options set out for consultation was between a series of sequential auctions (Option A) to be held as and when the 2G licences expired, and a single upfront competition (Options B and C) in which all licences would be awarded at once, but with differing start dates. Under the latter option, reservation of spectrum for entrants was also considered (Option C). None of the options in ComReg's initial consultation provided for a licence extension for 2G licensees beyond 2011 (or some equivalent guarantee of 2G spectrum availability).

131. ComReg's current position, as set out in its follow-up consultation is that:

- no extensions (or their equivalent) for 2G licences on liberalised terms should be granted; and
- 2G licences should not be liberalised during their term.

Thus, ComReg's current stated position is that 2G licences will remain in their current form until their scheduled expiry and not be liberalised in the hands of their existing holders.

4.2 Proposals in ComReg's follow-up consultation

132. In its follow-up consultation, ComReg proposed two alternative assignment options for spectrum in the 900MHz band:

4.2.1 Option 1 ('Single Auction')

133. This option is a further variation of the concept of a simultaneous auction inherent in Options B and C presented in ComReg's initial consultation, but with additional measures intended to ensure that the new and existing licences are organised in a spectrally efficient way.

134. Under this option, licences commencing in 2009, 2011 and 2015 would be assigned in a single process. However, as a condition of entry to the auction, 2G licensees would be required to sign a Memorandum of Understanding (MoU) prior to the auction that they will cooperate with other licensees and ComReg on realignment of their current licensed frequency assignments to facilitate spectrally efficient use of the new assignments arising from the competition. ComReg envisages that this realignment process would be completed within six months of the completion of an award process.

135. Unlike Option C in 08/57, no reservation of spectrum for new entrants is envisaged in Option 1. However, with a cap of 2x10MHz per 900MHz licensee and 2x35MHz of spectrum available, at least 2x5MHz will be available for a new 900MHz operator.

4.2.2 Option 2 ('Multi-phased Approach')

136. This option is a variation on the concept of sequential auctions, introduced in Option A in ComReg's initial consultation, but with an additional measure to guarantee the availability of spectrum to Vodafone and O2 for 2G legacy use beyond the expiry of their GSM 900MHz licences in 2011. In addition, a post-auction re-organisation of operators within the band to ensure that spectrum assignments can be efficiently utilised, as proposed in Option 1, would also apply.

137. Under this option, ComReg would invite and evaluate submissions from O2 and Vodafone, which would be confidential where necessary, on their need to maintain part or all of their current spectrum assignments in the 900MHz band beyond the scheduled expiry of their licences in 2011. Based on its evaluation, ComReg would then determine how much spectrum each could retain in order to serve legacy 2G consumers. Ongoing needs would be reassessed annually and no spectrum would be retained beyond 2015. No other uses would be permitted in the frequencies retained and the beneficiaries would be charged an upfront spectrum access fee and an annual spectrum usage fee, which would be substantially greater than the fee currently charged.

138. Secondly, the same MoU as in Option 1 for cooperation in realigning frequencies following the award would also be required.

139. The auction of new 900MHz licences would then proceed in stages as follows:

- Phase 1 (2009): Auction of the two 2x5MHz blocks of spectrum currently unassigned
- Phase 2 (2011): Auction of as many 2x5MHz blocks as possible given spectrum retained by O2 or Vodafone to address 2G legacy issues
- Phase 3 (2015): Auction of two 2x5MHz blocks of spectrum currently assigned to Meteor plus any 2x5MHz blocks retained by O2 or Vodafone beyond licence expiry.

140. A summary of the two award options proposed by ComReg in its follow-up consultation is presented in Table 2.

Table 2: Alternative award options II

Award options proposed in ComReg's follow-up consultation	
Option 1	Simultaneous award process Where applicable, licence commencement would depend on expiry of current licences: • 2 2x5MHz licences commencing in 2009 • 3 2x5MHz licences commencing in 2011 • 2 2x5MHz licences commencing in 2015 One or more operators re-assigned alternative frequencies
Option 2	Sequential award process: Three distinct stages • Phase 1 (2009): Auction of 2 2x5MHz blocks • Phase 2 (2011): Auction of as many 2x5MHz blocks as possible given spectrum retained for 2G legacy issues • Phase 3 (2015): Auction of remaining 2x5MHz blocks

4.3 Assessment of existing proposals

141. We see certain drawbacks to some of the elements within the current proposals:

- sequential auctions would be likely to produce inefficient outcomes;
- frequency realignments would be dependent on negotiation, rather than using an explicit market mechanism;
- some of the options involve administration allocation of rolled-over spectrum to incumbents, which would be problematic for pricing efficiently and fairly; and
- there would be no mechanism for liberalisation spectrum prior to expiry of existing licences.

142. We deal with each of these points in turn in the following sections. We then discuss what aspects of ComReg's proposals to date we carry over to the proposed auction format developed in Part B.

4.3.1 Simultaneous vs. sequential awards

143. ComReg has previously considered both simultaneous and sequential auctions as part of the alternative award processes proposed in its consultations, where adopting a sequential process has involved auctioning lots in separate processes according to their start date:

- *Simultaneous*: Options B and C (initial consultation) and Option 1 (follow-up consultation);
- *Sequential:* Option A (initial consultation) and Option 2 (follow-up consultation).

144. When determining whether to auction lots simultaneously or sequentially, a key consideration is the extent to which lots are substitutes and/or complements[13]. When there is substitutability and/or complementarity between lots, then the value of each lot depends on the prices and availability of substitute/complementary lots. For this reason, when lots are close substitutes and/or complements, as is the case here, then they should be sold together rather than in separate auctions, as this allows bidders to express their preferences without the risk created by having to form expectations of the pricing and availability of lots in future auctions.

145. Substitutable frequency lots are normally sold simultaneously so as to allow bidders to bid for different lots and switch their demand on the basis of their relative prices.[14] If the lots instead were sold sequentially, then bidders would be exposed to substitution risks, either by buying one lot when they would have preferred another at the end prices; or by dropping out from bidding for a lot at a price below their value but then failing to buy a substitute lot later. Thus, there would be a significant likelihood of inefficient outcomes in which the auction does not allocate spectrum to the highest value users.

146. Similar reasoning applies to complementary lots. Depending on the auction format and rules, selling complementary licences in the same auction may provide an opportunity for bidders to express their synergy value between lots. With complementarity between lots, the value of a standalone lot may be substantially lower than the value of the lot when included in a package. Under such circumstances, bidders participating in a sequential award where such lots are sold separately may be unable to express their full value for the combination of lots in the first auction, when they are unaware of the competition they may be facing for the second lot (so-called aggregation risk). An undesirable outcome would be

[13] Substitutes are goods (such as a bus ticket and train ticket for the same journey) whose combined value is less than the sum of the values for each item if acquired without the other. Complements are goods (such as a left and a right shoe) whose combined value is greater than the sum of their individual values. It is possible to have both substitutes and complements simultaneously. For example, there could be a number of lots amongst which a bidder has no preference, making them strong substitutes, but the bidder might value two lots more than twice as highly a single lot, also making them complements.

[14] In an open auction, the bidder might switch back and forth between lots depending on relative price. In an appropriately structured sealed bid (such as a combinatorial seal bid) auction, the bidder would be able to express valuations for a number of mutually exclusive options and the auction mechanism would determine which was won, against allowing preferences for substitutes to be expressed.

when a bidder may obtain a lot in the first auction but then fail to obtain the complementary lot in a following auction, regretting its purchase and potentially have ousted a bidder who could have made more valuable use of the standalone lot. Another undesirable outcome is where a bidder bids too cautiously in the first auction and fails to acquire a package of lots which, in hindsight after the second auction, it could have achieved. A simultaneous award allows bidders to better assess their chances of obtaining both lots and thus to adjust their bidding accordingly, lowering the risk of such inefficient outcomes.

147. As both substitutability and complementarity between lots is the norm in spectrum auctions, most auctions to date have used simultaneous awards. Some of the rare examples of sequential spectrum auctions have not had efficient outcomes. For example, each licence was sold sequentially in the 1999 Swiss WLL award. The result of the award process was that similar licences were sold for widely varying prices, a strong indicator that the outcome was inefficient.

148. For this award, both substitution and complementarity are important. Therefore, based on this assessment and our analysis of substitutes and complements, we are concerned that the sequential award considered by ComReg may unduly expose Ireland to an inefficient award outcome. Specifically, were a sequential process to be used, bidders would be unable to switch between licences with different start dates according to their relative value if such licences are offered in different awards. There is an objection that this is particularly disadvantageous to any entrant, as they cannot bid across all the available options in a single auction.

149. The role of complementarities in this award process depends on how spectrum is packaged. If spectrum is offered in blocks of time, e.g. 2011-2015 and then 2015 onwards, there is a clear need for some bidders to want to aggregate the earlier and later lots. A further issue is that two 2x5MHz blocks are likely to be worth more than double a single block, exposing bidders wanting two blocks to aggregation risks.

150. Simultaneously auctioning all lots would also allow for mitigating aggregation risks for bidders who may opt for attempting to acquire contiguous lots with a different start date. Furthermore, as we shall see in Part B, using a combinatorial auction format with one single auction eliminates all the various sources of aggregation and substitution risk. Accordingly, we recommend that ComReg undertakes a simultaneous award process including all available 900MHz lots.

4.3.2 Secondary negotiations on frequency realignment

151. The two options currently proposed by ComReg in its follow-up consultation provide for multilateral post-auction negotiations aimed at re-assigning frequencies among new licence winners and existing 2G licence holders in order to achieve a spectrally efficient final assignment. This envisaged re-alignment process would involve at least one existing operator having to move to alternative frequencies within the band. This is because it is impossible for all incumbents to win two 2x5MHz blocks that are contiguous and include their current GSM900 allocations. An efficient realignment would involve maximising contiguity, minimising spectrum required as guard blocks between spectrum used for 2G and 3G services and minimising disruption to existing 2G services, or at least achieving a balance between these three goals.

152. Such a process of re-alignment of frequencies may involve the incurrence of costs by those operators that will be required to move within the band. Therefore, it is practical to assume that all operators would choose to opt out of moving within the band where possible. Thus,

however well organised by ComReg, "horsetrading" of frequencies may be difficult to coordinate and may lead to delay, poor outcomes or even legal challenges.

153. If possible, therefore, it would be preferable for final frequency assignments to be decided within the auction itself, relying on the principle of allowing bids to express demand, and hence to determine the most efficient outcome not just in terms of the identity of the licensees, but also their specific assignments. Generally, bidding on specifically identified lots (in this case, 2x5MHz channels) creates a much more complex bidding environment for bidders. However, proven auction formats exist in which specific frequency assignments can be efficiently resolved within the auction itself in a way that need not lead to excessive complexity of the auction process.

154. In particular, the sealed-bid combinatorial format used for the auction of 26GHz frequencies for ComReg, adopts an effective compromise between the requirement for bidders to express preferences for contiguous spectrum and/or particular channel locations, and the significant additional complexity of having them bid on identified channels or groups of channels in the main body of the auction. It does so by treating spectrum as generic until winners are determined, whereupon a follow-up Assignment Stage is held in which the winning bidders in the auction can bid for particular frequencies. This auction format is discussed in further detail in Part B. This approach can be readily adapted to ensure that all winners acquire contiguous spectrum assignments while minimising disruption to established spectrum use, and we recommend that it be used in the 900MHz auction in place of the post-auction negotiation process currently envisaged.

4.3.3 Administrative reservation for continued 2G use

155. ComReg's Option 2 seems to be designed to ensure undisrupted continuity of services to 2G users through the potential for a *de facto* extension of Vodafone's and O2's GSM licences beyond 2011, while requiring these operators to pay the opportunity cost of the retained spectrum. While ComReg's desire to prevent disruption and welfare loss to existing 2G users is understandable and appropriate, we have concerns about this approach as discussed previously in Section 4.3.1.

156. First, this approach might be seen as inconsistent with the position adopted by ComReg on the issue of licence extensions articulated elsewhere in its consultation. Under the proposal, provided Vodafone and O2 can demonstrate a "need" for continued access to spectrum in the 900MHz band, they would be offered it on terms proposed by ComReg, and only should they decline would the spectrum become available to other candidates. This equates to a right of first refusal on unlicensed spectrum, which prioritises the spectrum demand of two operators over that of other potential users.

157. Second, it is open to argument that such a process would not be transparent, particularly since all or part of the operators' submissions would be treated confidentially so as to avoid disclosure of business-sensitive information.

158. Third, it might be difficult to quantify the need for continued availability of 2G spectrum, the moving costs associated with migrating consumers to alternative frequency bands such as 1800MHz, and the opportunity cost of the spectrum during the period in which it is retained for 2G use.

159. Auctions rely on binding financial bids to elicit credible "information" from bidders as to the value they attach to licences as a basis for an efficient outcome. No such incentives for truthful revelation exist in the case of reported information. As is typical of firms involved in regulatory interactions, the operators involved would have an incentive to overstate the

"need" for extended availability of 2G spectrum in order to secure an outcome that favours them.

160. Establishing the opportunity cost of the spectrum requires identifying the value of the best alternative use of the spectrum. In this case the relevant opportunity cost is the value of the spectrum, over the period in which it is retained by Vodafone and O2, to the highest-valuing potential user who is marginalised from the 900MHz band as a result of their continued use. This is likewise a difficult task. Also, the calculation of an administrative spectrum fee is conceptually difficult.

161. Fourth and most important, there appears to be a conceptual inconsistency between charging the full opportunity cost of the spectrum and "safeguarding" access to the spectrum for continued 2G use. If the charge is set appropriately, and thus fully reflects the maximum value of the spectrum to an alternative user, then the proposed solution should not in fact provide any additional guarantee, relative to an auction-based assignment, that the incumbent 2G operators would retain the spectrum. This is because the price that these operators would have to pay to win the spectrum in an auction is precisely this opportunity cost, as expressed in the highest losing bid. Thus, relative to an auction-based outcome, the only situation in which the provision for 2G licence extensions set out under Option 2 can safeguard the continued availability of spectrum for 2G use is if the administrative price charged to the incumbents is lower than the opportunity cost of the spectrum. By the same logic, any measure to provide additional security of access to 2G spectrum for the current licensees relative to an auction could potentially be viewed as discriminatory in the sense of offering them access to the spectrum at a price lower than what an outside bidder would be prepared to pay.

162. Rather than temporarily extending the duration of the existing 2G licensees by an administrative intervention, it would be possible to use an auction in which the spectrum is divided into blocks not only by frequency, but also by time period. Specifically, it is possible to split each of the licences for Blocks E to G, currently used by Vodafone and O2 to provide 2G services, into separate rights for the period 2011-2015 and for 2015 onwards. We call this "temporal packaging" of the spectrum in the later sections of this report in which we present our proposed auction design.

163. In this way, Vodafone and O2 would compete for licence 'extensions' with alternative users of the spectrum, choosing to outbid them if the value to them of retaining their current 2G assignments is greater than the value of the spectrum to other bidders, or otherwise relinquishing them. In this way Vodafone or O2 could end up temporarily either retaining the spectrum before it is passed on to a new user in 2015, winning the licences for the full term from 2011, or not winning licences for this period at all.

164. Our proposal achieves the same outcome as requiring the two operators to pay the opportunity cost in the form of an administrative charge if they wish to keep running 2G services beyond 2011 in their current spectrum allocations, while obviating the need to determine the opportunity cost administratively without access to the relevant information. Setting a robust price administratively for continued access to spectrum by incumbents would be difficult and resource-intensive for ComReg and may be open to challenge. Our proposal also has the advantage of allowing the operators, if they win the spectrum, to manage the transition from 2G to 3G technologies within the framework of liberalised licences, rather than constraining them to use the spectrum for 2G only.

4.3.4 Opportunity for efficient liberalisation

165. None of the options currently or previously proposed by ComReg include a provision for Meteor to swap or convert its GSM licence to a liberalised licence that would permit it to mount broadband services in the 900MHz band before 2015. This could be inefficient if it delays this spectrum being used to deliver the most valuable services demanded by consumers, and if it distorts the competitive mobile broadband sector by reducing the number of players in the first few years.

166. Economic efficiency suggests that the spectrum should be put to its most valuable use; thus, if spectrum that is currently restricted to 2G use until 2015 could be released for a more valuable use such as mobile broadband or a combination of mobile broadband and 2G, ComReg's objectives for the award of 900MHz spectrum suggest that this option should be considered, provided that it neither damages Meteor's existing spectrum rights nor assigns new rights to it in an inequitable (and potentially inefficient) way.

167. ComReg has not adopted a policy of liberalising existing licences due to the potential distortions to competition that this may create in the absence of a competitive award process (in follow-up consultation Section 5.1.3). However, an option potentially exists for Meteor, should it wish, to effectively upgrade its licence at the economically appropriate price (by engaging in a competitive award process). Moreover, this could be achieved in an efficient, transparent and non-discriminatory manner within the auction, in which Meteor would be exposed to bidding competition for liberalised access to the spectrum from other candidate users on equal terms, and could potentially be outbid by a more efficient user. Further advantages of this proposal are that it would free up the 2x2.8MHz of unused spectrum within Block C for productive use earlier than 2015. Further, it would create an incentive for Meteor to cooperate in moving its current assignment down by 100kHz, which may be important in achieving a spectrally efficient licence assignment[15].

168. We develop a mechanism in Part B that would allow Meteor to release its existing licence contingent on winning liberalised spectrum prior to 2015. In effect, Meteor would be allowed to bid on similar terms to other bidders for spectrum prior to 2015, subject to the requirement that it forgoes the remaining term of its existing licence.

4.4 Relationship with our proposals

169. ComReg is committed to an auction-based award of new licences in the 900MHz band based on an expectation of excess demand and on solid principles of efficiency, transparency, non-discrimination, and technology and service-neutrality. Its current proposals are designed to

[15] The auction design proposed in subsequent sections is relatively simple provided that the E block is not affected by Meteor's existing licence prior to 2015. In fact, Meteor has a current right to use spectrum for GSM until 2015 in frequencies that run right to 100kHz of the upper edge of the E block. This potentially sterilises the entire E block for UMTS use until 2015 as the minimum separation required between GSM and UMTS users specified in the EC Decision could not otherwise be achieved. This problem can be avoided if Meteor's existing frequency range were shifted downwards by 100kHz. We understand that ComReg has powers to modify frequency assignments under both the Amending Directive and the Authorisation Directive. Meteor would in any case have the option of avoiding such a frequency realignment if it made use of the early liberalisation option. If Meteor is not moved, this would likely require amendment of the auction design to include block E as a separate category of lot, as its value would be diminished for a potential UMTS user. See sub-section 8.2.2 regarding the mechanics of early liberalisation where applicable.

address two of the major complications in the award process arising from the legacy position of 2G licensees, namely, the likely need to reorganise current 2G frequency assignments to ensure efficient utilisation of the new licences, and the desire to ensure continuity of services to Ireland's substantial 2G consumer base.

170. However, the proposed solutions are to varying degrees based on administrative processes outside the auction itself, which could lead to inefficient and contentious outcomes. Our view is that both of these issues could be addressed by market mechanisms within an auction in a manner more consistent with ComReg's spectrum licensing objectives.

171. The proposals that we make in Part B are akin to ComReg's Option 1 outlined in its follow-up consultation. The key feature is that there is a single auction to resolve the future of 900MHz spectrum that provides maximum flexibility for bidders, but equally provides the earliest possible resolution of uncertainty about future access to spectrum beyond the expiry of existing GSM licences. A single integrated process gives the best opportunities for allowing bidders to express preferences for substitutes and complements amongst the available spectrum blocks.

172. Our proposed auction format described in Part B varies from ComReg's proposals to date in a number of respects. First, we have ignored the possibility of allocating the two currently unused 2x5MHz blocks in the 900MHz band earlier than 2011. Given the lead time in preparing an auction and running it, there seems little point in bringing in additional complexity to the auction through creating yet another category of spectrum available prior to 2011 (which in practice might mean licensed for less than a year). Nevertheless, it is easy to amend our proposed format to include these blocks if that were necessary.

173. Second, we have augmented ComReg's proposals to include the possibility of early liberalisation of licences prior to the expiry of current GSM licences provided that liberalised licences are won in open competition. This is compatible with the general principles outlined in ComReg's consultation documents and provides a boost for competition and flexibility in use of the spectrum.

174. Third, we have used a market mechanism to allow the frequency realignment that would inevitably be needed, as we describe in Part B. ComReg's original proposal relied on negotiation amongst licensees, but this is problematic as achieving an efficient frequency plan is complex. Moving one licensee in the frequency plan has knock-on effects on all others, so it is unrealistic to try to achieve an efficient outcome through sequences of bilateral negotiations. Simultaneous determination of the frequency arrangement through an auction is, therefore, preferable.

PART B: Proposed auction rules

5 2G/3G coexistence and lot design

175. Before considering any auction design issues, we start by setting out the general issues that arise from GSM and UMTS use of 900MHz spectrum both being possible with the same licence and the need for licensees to coordinate that this might create. This has implications for the relative value of spectrum at the interior and the edges of the frequency band that need to be analysed in order to determine what different categories of lots would need to be differentiated between within an auction.

5.1 Coordination and bargaining inefficiency

176. There are additional complications for design of an award process that result from future 900MHz licensees having flexibility to use GSM, UMTS (or indeed other compatible technologies). This section is concerned with understanding the general issues that arise from flexible technology choices and the consequent need for licensees to coordinate.

5.1.1 Guard block requirements and coordination

177. In most spectrum auctions, it is possible to define a *lot* to be a frequency block that confers certain defined rights to use the spectrum. These usage rights will be subject to limitations to ensure that users of adjacent frequencies are not subject to harmful interference.

178. In previous GSM and 3G licence awards across the EU, technical usage restrictions (such as guard blocks, limits on out-of-block emissions, limits on power levels and antennas placement) have provided a high degree of certainty that different operators within a band can co-exist without adverse interference. For instance, with existing 900MHz licences, keeping 100kHz as a guard block at the boundary of each operator's licence ensures that there is a 200kHz separation between the closest GSM channels of different operators. Because the technology in use in the band is determinate, there is no difficulty in deciding what this guard block at licence edges should be. Moreover, there is certainty for bidders, as they know what technology will be deployed at adjacent frequencies and that guard blocks should ensure that any spectrum purchased is usable.

179. This benign situation does not apply to the future award of spectrum in the 900MHz band on a technologically neutral basis. The difficulty is that there is no determinate technology to be used in the band; it must accommodate GSM, UMTS and any other technologies deemed compatible. Ideally, we need to define guard block requirements that allow for the coexistence of every type of feasible winner, including:

- GSM only operators (with 2x5MHz or 2x10MHz);
- 3G only operators (with 2x5MHz or 2x10MHz);
- GSM only operators transitioning to 3G (with 2x5MHz or 2x10MHz); and
- operators simultaneously deploying GSM and 3G in the same spectrum assignment (which will likely require 2x10MHz).

180. The guard block requirements between GSM and UMTS operators are greater than those between two GSM operators or two UMTS operators. We discuss the implications in the

following section, but the key feature is that it is no longer possible simply to set fixed guard blocks as the optimum size depends on what technologies are deployed by neighbouring operators.[16]

181. One approach to technology-neutral spectrum allocation is to require operators to nominate the technology they will use and then to use the auction mechanism to determine an optimal layout of different users that minimises the overall requirements for guard blocks.[17] This typically means keeping together mutually compatible technologies and keeping apart technologies that require larger guard blocks to separate them. The engineering constraints on how different technologies can fit together can then be codified in the auction rules. However, this approach is of no use here, as we want to allow fluid migration from GSM to UMTS within the term of a licence; there is no fixed technology associated with each licence throughout its life and we cannot ask bidders to nominate just one technology.

5.1.2 Bargaining inefficiencies and coordination

182. In this award, there is no option but to rely to some extent on coordination between users. It is certainly possible to define a set of conservative guard block requirements that ensure that spectrum is usable *regardless* of the technology deployed in adjacent spectrum. However, these guard blocks would likely be based on pessimistic assumptions and in practice it may be possible to relax these depending on exactly what technologies are chosen by licensees. Typically, there would be some inefficiency in how spectrum is used unless there is coordination between licensees, as the worse case would be planned for, not the typical case and larger guard blocks would be left than might be needed.

183. To reclaim excess spectrum left fallow to deal with the worst-case conjunctions of different technologies, licensees need to coordinate their use with adjacent licensees. Changes may be needed over time as operators migrate from one technology to another. Therefore, the auction outcome sets a default position in the absence of any coordination, but hopefully coordination can occur to improve on the initial outcome.[18]

184. If we could be sure that efficient coordination between neighbouring licensees would always be achieved, then it might not matter much if the auction mechanism produced

[16] To be precise, suppose $s(t_1,t_2)$ is the frequency separation required between two adjacent technologies t_1 and t_2 (measured on a carrier edge to carrier edge basis). The question is whether it is possible to implement these separations by association guard blocks with each respective licence. Suppose that a licensee using technology t is required to have a guard block $g(t)$ at each frequency boundary of the licence. Then we would need that $s(t_1,t_2)=g(t_1)+g(t_2)$ for the separations to be implemented without any waste of spectrum. In the case of the 900MHz with GSM and UMTS technologies, the separation requirements are such that no such function g exists. This is because the GMS-UMTS separation is greater than the average of the GSM-GSM and UMTS-UMTS separations.

[17] For example, see the plans for a combinatorial clock auction for digital dividend spectrum proposed by Ofcom (but now superseded by the Digital Britain white paper).

[18] In effect, the auction outcome defines the property rights of licensees, who have certain rights to transmit and certain rights to be protected from other's transmissions. This initial outcome is not necessarily efficient, but forms the starting point for coordination between winners. Given that there is no guarantee that the benefits of coordination will be achieved, there is clearly much value in trying to ensure that the initial outcome involves spectrum being reasonably efficiently used.

situations in which restrictions on spectrum use at the boundaries of licensees were too tight; we could rely on coordination to find an efficient resolution.[19] However, achieving these coordination benefits involves striking a bargain between neighbouring licensees. There is no guarantee that bargaining will conclude successfully, as each party may try to grab too large a share of the potential benefits. This is always a possibility where bargaining occurs between parties who do not know the benefit of a deal to the counterparty.[20]

185. A further problem is that some forms of coordination may involve more than just two neighbouring licensees. For example, where licensees are running both GSM and UMTS in a 2x10MHz block of spectrum, where the two technologies are located within the block affects both neighbours. If those neighbours are themselves using both GSM and UMTS in a 2x10MHz block, then the effects of one licensee changing the positions of GSM and UMTS within its block might ripple out to other licensees. In such a case, coordination might need to be multilateral, rather than just bilateral. As the number of parties that need to coordinate increases, it would become more difficult to achieve an efficient outcome through bargaining. Fortunately in the case of the 900MHz band, the limited amount of spectrum means that these multilateral coordination issues are not too important.

5.1.3 Coordination risks

186. Whenever coordination is needed to extract the full benefits of spectrum, there is corresponding risk created for bidders. We call this the **coordination risk**. It is the value at risk for a bidder if it fails to coordinate with its neighbours or if the benefits of coordination are less than expected (for example, a neighbour might capture all the coordination benefits), i.e.

- the expected value achievable from spectrum if efficient coordination can be achieved with neighbours, **less**
- the minimum value achievable if there is no coordination.

187. This coordination risk can be roughly characterised by looking at how much additional spectrum might need to be left fallow if coordination is unsuccessful. Obviously this does not directly measure the financial risk to a bidder (as this depends on the bidder's business case), but does at least give a commensurate measure of coordination risk for different types of bidders.

188. We need to design a scheme of guard block requirements that keep this coordination risk to a minimum. This means that to a large extent it is possible for bidders to value spectrum on an autarkic basis, i.e. independent of what their neighbours do. There may be a small unexpected loss or benefit if a bidder's expectation about its ability to coordinate turn out

[19] This is the so-called Coase theorem: that the definition of property rights do not (under certain optimistic assumptions) affect the eventual outcome, but rather only set an initial position from which negotiation and trading can reach an efficient outcome. See Coase, Ronald H. (1960) "The Problem of Social Cost", Journal of Law and Economics 3 (1): 1–44. The Coase theorem is of little relevance here, as it does not consider the issue of bargaining inefficiencies and is agnostic about the distributional consequences of property rights.

[20] This is bargaining under imperfect information. There is always a probability that trades may not occur, even when they are efficient. See Myerson, Roger B, Mark A. Satterthwaite (1983) "Efficient Mechanisms for Bilateral Trading", Journal of Economic Theory 29: 265–281.

to be wrong, but this should be a small proportion of the overall value of the spectrum. We will see subsequently that it is fairly easy to design such a scheme, but that there are other plausible guard block schemes that would fail to control coordination risks.

5.1.4 Implications for auction design

189. In this spectrum award, we can to a large degree control, but not completely eliminate, these coordination risks. It is impossible to construct an auction in which bidders are entirely indifferent about who their eventual neighbours (in frequency space) might be. One obvious issue is that some licensees would have only one neighbour (if they are assigned frequencies at the end of the band) whereas others would have two neighbours (if they are in the middle of the band). Having two neighbours may mean having a greater coordination risk than having one.

190. We should distinguish two issues:

- coordination risk primarily associated with where in the band the licensee is located (e.g. middle vs. end), which we call **location dependency**;
- even if the location of a licensee within the band is known, there may still be residual risk associated with the identity of the adjacent licensees, which we call **neighbour dependency**.

191. Location dependency is fairly easy to manage in an auction; it is a matter of allowing bids to be contingent on where in the band the bidder might be located. This does not necessarily mean that an auction would need to introduce bidding on lots that are linked to specific frequencies, but a mechanism would be needed to allow the valuation differences of different locations in the band to be expressed. This might involve a further stage of bidding (an A*ssignment Stage*) once it has been determined how much spectrum each bidder will get.

192. Neighbour dependency is much more difficult to manage. To eliminate this, one would need to allow bids that are contingent on who adjacent winners of spectrum might be. Any such scheme would be complex. It may raise significant risks of anti-competitive behaviour, as it may create much greater opportunities to leverage particular outcomes and opportunities to disadvantage other bidders. Therefore, we do not propose to deal with neighbour dependency issues in the proposals developed here.

5.2 EU separation requirements

193. We base our recommendations for auction design and our analysis of the issues relating to co-existence of GSM and 3G technologies on the separation requirements outlined in the EC Decision. These matters may need to be subject to consultation with potential bidders to ensure that all relevant practical issues to do with interference management have been considered and that there is reasonable consensus that the needs of spectrum users would be satisfied by the lot design proposed here.

5.2.1 Protection against interference

194. The EC Decision covers in several places the concept of non-GSM users providing adjacent GSM users protection against interference caused by their use of technologies other than GSM (in paragraphs (7), (8), (10), (12), (13)). However, while UMTS can be operated in spectrum adjacent to a GSM operator causing only negligible interference to this GSM

operator, the opposite is not true. Yet, where GSM users cause interference to adjacent UMTS users, the EC Decision leaves it open which party should provide protection against interference:

> "The terrestrial systems capable of providing electronic communications services that can coexist with GSM systems in the 900 MHz band within the meaning of Article 1(1) of Directive 87/372/EEC are listed in the Annex. They shall be subject to the conditions and the implementation deadlines laid down therein."
>
> *Article 3, EC Decision*
>
> "Member States may designate and make available the 900 MHz and 1 800 MHz bands for other terrestrial systems not listed in the Annex, provided that they ensure that:
>
> (a) such systems can coexist with GSM systems;
>
> (b) such systems can coexist with other systems listed in the Annex, both on their own territory and in neighbouring Member States. "
>
> *Article 5(1), EC Decision*

195. Article 5(1) is clear that there is an obligation on the Member State to ensure that spectrum is made available such that UMTS and GSM can coexist, but it does not specify how the burden of creating guard blocks might be shared amongst different types of user. Whatever scheme is used to ensure spectrum users in this band do not suffer harmful interference it should be designed to promote the efficient use of spectrum, rather than to favour (or disfavour) any particular technology.

5.2.2 Separation requirements

196. The guard block requirements between GSM and 3G operators are presented in the Annex to the EC Decision, which states that:

> "The following technical parameters shall be applied as an essential component of conditions necessary to ensure co-existence in the absence of bilateral or multilateral agreements between neighbouring networks, without precluding less stringent technical parameters if agreed among the operators of such networks."

Systems	**Technical Parameters**	**Implementation deadlines**
UMTS complying with UMTS Standards, as published by ETSI, in particular EN 301 908-1, EN 301 908-2, EN 301 908-3 and EN 301 908-11	1) A carrier separation of 5 MHz or more between two neighbouring UMTS networks; 2) A carrier separation of 2.8 MHz or more between a neighbouring UMTS network and a GSM network.	9 May 2010

Source: Annex to the EC Decision

197. This table provides the separation requirement between adjacent uncoordinated GSM and UMTS systems for preventing interference. These requirements are expressed in terms of the distance required between the *centres* of adjacent channels, rather than in terms of the size of guard blocks required *between* the edges of adjacent channels.

198. Based on the EC Decision in conjunction with these reports, our understanding is that given the use of UMTS in 5MHz channels and GSM is operated in 200kHz channels in the 900MHz and 1800MHz bands, the following guard blocks would be needed:

- Given that UMTS is operated in 5MHz channels and the required separation between adjacent UMTS operators to ensure no interference is 5MHz, a UMTS operator does not require a guard block to separate it from adjacent UMTS operators.
- Where two adjacent operators both use GSM, one GSM channel (i.e. 200kHz) must be left unused as a guard block between them.
- UMTS has a negligible effect on adjacent GSM carriers, even when operating UMTS across a 5MHz wideband carrier. However, GSM can interfere with UMTS if it is too close. To avoid such interference, the centre frequency of a GSM carrier must be at least 2.8MHz away from the centre frequency of an adjacent UMTS 5MHz carrier. This effectively means that a guard block of 200kHz is required between the edge of a GSM channel and the nearest edge of an adjacent UMTS carrier.

199. Our understanding is that these separation requirements are calculated based on the centre frequencies of the respective adjacent channels and assume a 5MHz UMTS carrier and a 200kHz GSM carrier (for one GSM channel). It is possible to imagine compressing a UMTS carrier into less than 5MHz, in which case these centre-to-centre separation requirements would presumably not be the same. However, this possibility is not one that is reflected in the EC Decision and, therefore, we have supposed that even if compression of a UMTS carrier is technically possible, the centre-to-centre separation of 2.8MHz between UMTS and GSM would remain in force. There would be nothing to prevent licensees from deploying techniques such as narrower UMTS carriers (if technically feasible) as a means of managing interference with neighbours by mutual agreement, but the EC Decision does foresee any obligation on UMTS users to do so.

5.2.3 Coordination risk

200. These separation requirements assume no coordination between adjacent operators to reduce the need for a 200kHz guard block between adjacent GSM and UMTS operator. Coordination could take a number of different forms:

- Geographical separation of base stations operating at frequencies at the boundaries of adjacent licences;
- Where operators have mixed GSM and UMTS networks, coordinating which frequencies are used for each type of network to reduce the number of GSM to UMTS boundaries each requiring a guard block;
- Shrinking the width of the UMTS carrier to allow adjacent GSM use;
- Adjacent licensees simultaneously migrating from GSM to 3G to avoid creating a temporary UMTS to GSM boundary.

201. However, without coordination between adjacent licensees, there would be need for a guard block and, depending on the obligations this creates on each licensee, this could have an impact on the value of spectrum to bidders. Whether this would be a significant risk for the licensee would depend on how the guard block requirement is implemented and how the burden is distributed across the two licensees at the boundary of dissimilar technologies.

202. In the following sections we consider two options for imposing guard block requirements on operators:

(i) an obligation to provide guard blocks between UMTS and GSM falling on the GSM operator; and

(ii) an obligation to provide guard blocks between UMTS and GSM falling on UMTS operators.

These two options represent the extremes of the range of possibilities, though there are clearly other intermediate arrangements that split guard blocks across adjacent operators using dissimilar technologies. We will see in due course that any attempt to impose guard block requirements on the UMTS user would likely be fraught with difficulty.

5.3 Option (i): Guard blocks fall on GSM operators

203. In this subsection we examine a scheme where, if GSM and UMTS operators are adjacent, the additional guard block requirements would fall on the GSM operator. This scheme has much to recommend it, as even without coordination between adjacent users of dissimilar technologies, the large majority of awarded spectrum would still be useable and the coordination risk small.

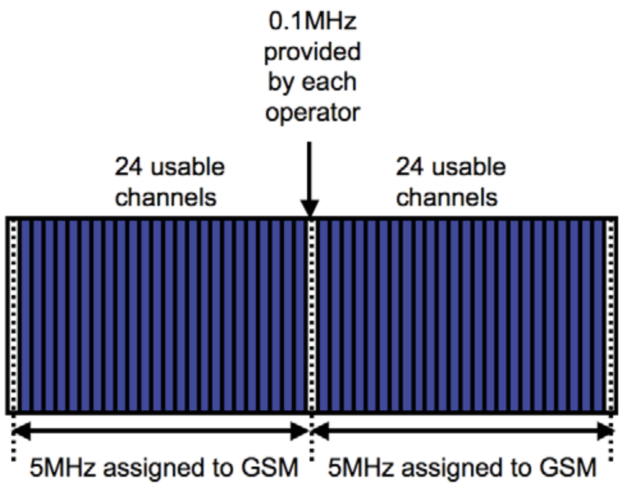
5.3.1 Separation requirements at boundaries between licensees

204. We now consider the separations needed depending on the technologies meeting at a frequency boundary between licensees. This follows the requirements set out in the EC Decision.

Adjacent GSM operators

205. Where two operators using GSM at the edges of their assigned frequency blocks are located adjacent to one another in the band, a separation of 200kHz between the operators would be required (one GSM channel). Therefore, both operators would need to leave unused a 100kHz guard block at the edge of their frequency assignment. This is illustrated in Figure 3 below and is the situation with current, non-liberalised 900MHz licences.

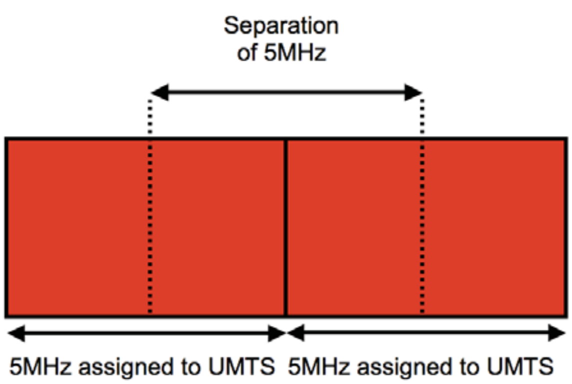
Figure 3: Standard separation between GSM operators



Adjacent UMTS operators

206. Where two operators using UMTS adjacent to one another in the band, each operator would need to ensure that the centre frequency of its UMTS channels are nominally 2.5MHz from the edges of its frequency assignment. Given the use of UMTS technologies in 5MHz channels, where UMTS operators are adjacent to one another the 5MHz separation between their respective centre frequencies would automatically be satisfied. This is illustrated in Figure 4 below.

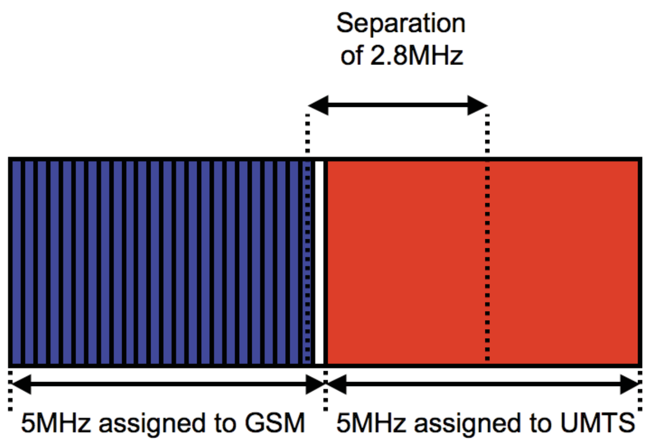
Figure 4: Standard separation between 3G operators



Adjacent GSM and UMTS operators

207. In contrast, where a GSM operator is adjacent to a 3G user, there would need to be a separation of 2.8MHz between the centre of the 3G channel and the centre of the nearest GSM channel. If this separation requirement were imposed only on the GSM operator, it would have to leave one full GSM channel (200kHz) unused at the end of its spectrum assignment to make up the required 2.8MHz separation. This is shown in Figure 5 below:

Figure 5: Standard separation between GSM and 3G



5.3.2 Impact on the amount of usable spectrum

208. Given these separation requirements, we now consider how much of the spectrum acquired would actually be useable for different types of operator. This allows us to assess the extent of coordination risk with this guard block scheme.

GSM operators

209. Where a GSM operator is sandwiched between two adjacent GSM operators, leaving 100kHz unused at each edge of its frequency assignment would be sufficient to provide the required separation. Thus, in this case, the middle GSM operator would only be unable to use 200kHz (one GSM channel) of its overall frequency assignment, as shown in Figure 6A.

210. Due to the indivisibility of GSM channels (which need to be 200kHz), where a GSM operator is adjacent to a 3G operator at one edge of its frequency assignment, it would need to give up 200kHz on each side regardless of whether the other adjacent operator deploys GSM or 3G technology, as is shown in Figure 6B and C below. Therefore, once the GSM operator has one adjacent 3G user, the technology used by the other adjacent operator is irrelevant to the total amount of spectrum sterilised for that user.

Figure 6A: Separation between a GSM operator and its adjacent users

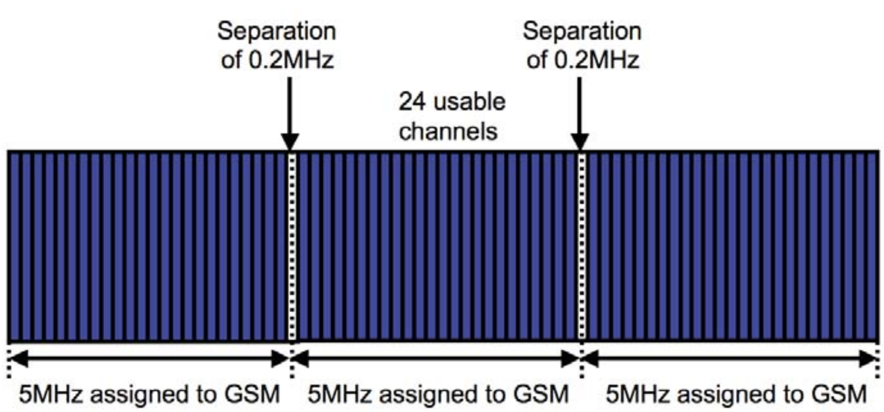


Figure 6B:

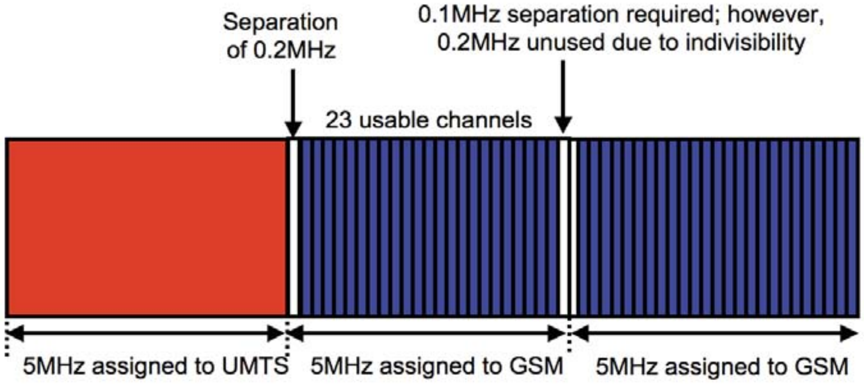
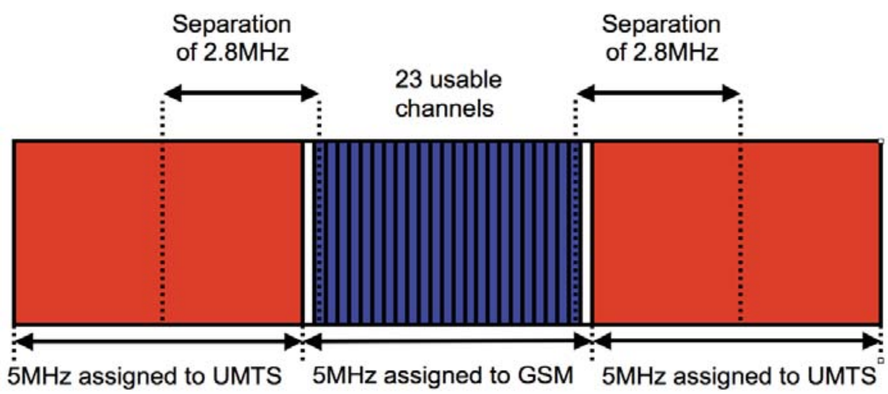


Figure 6C:



211. In summary, if the guard block were provided out of the spectrum assigned to GSM operators:

- the maximum number of GSM channels that the operator can use without coordination would be achieved when the operator is located between two adjacent GSM operators, in which case the GSM operator would only be required to leave a single channel unused;
- the additional cost to the GSM operator of being adjacent to **any number** of 3G operators would be one lost 200kHz GSM channel.

3G operators

212. Under this scheme, 3G operators would always be able to use their entire frequency assignment for deploying their services.

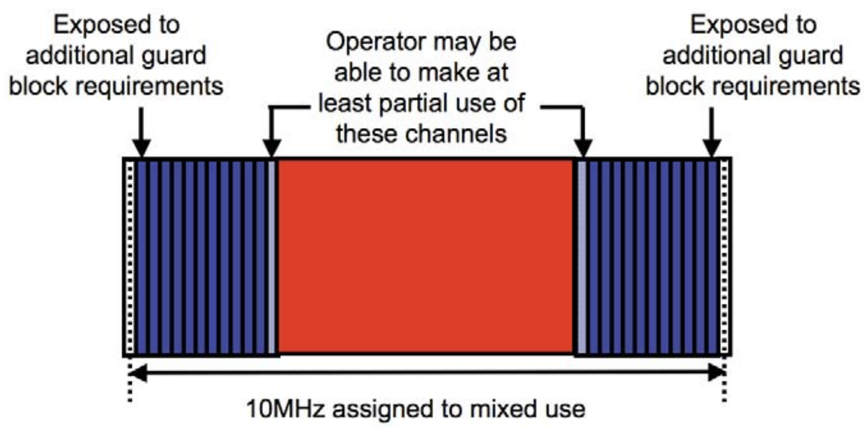
Operators deploying both GSM and 3G

213. It would be feasible for an operator assigned 2x10MHz to deploy both GSM and UMTS technologies within that spectrum (what we call a **mixed use** operator).

214. One possible arrangement suggested by existing GSM operators in the 900MHz band is that if they are assigned 2x10MHz, they might choose to operate their 3G services in a 5MHz

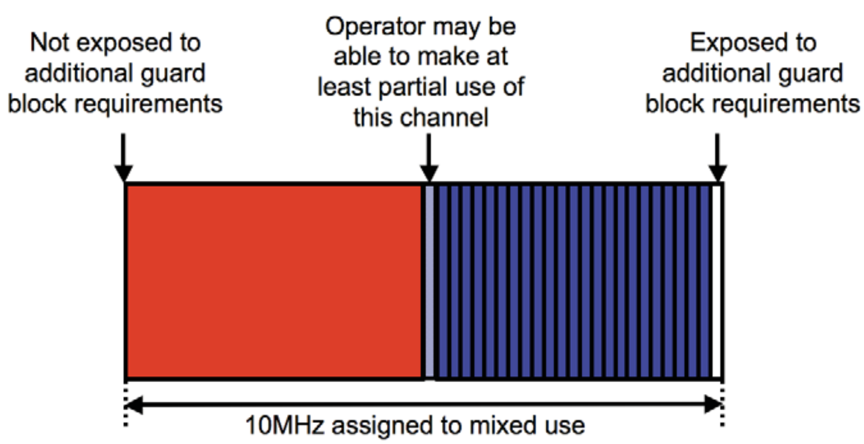
block in the interior of the assignment to protect it from adjacent GSM use, as shown in Figure 7. With this arrangement, the mixed-use operator would in all cases be unable to use 200kHz of its frequency assignment (100kHz on each edge of its frequency assignment if it had two GSM neighbours), and potentially 400kHz of its frequency assignment (if either of the adjacent operators were a 3G operator, a 200kHz guard block is needed).

Figure 7: Mixed use operator placing its 3G channel in the centre of its frequency assignment



215. However, it is possible to improve this arrangement even without coordination. If the adjacent user is a 3G operator, such a mixed operator might be able to reduce its exposure to guard block requirements by placing its 3G channel at an edge of its frequency assignment, as shown in Figure 8. By doing so, the mixed-use operator would only be subject to guard block requirements on one side of its frequency assignment. With this arrangement, the mixed-use operator would in all cases be unable to use 200kHz of its frequency assignment regardless of the technology used by the adjacent operators. This is never worse than the best possible outcome under the previous arrangement shown in Figure 7.

Figure 8: Mixed use operator placing its 3G channel at the edge of its frequency assignment



5.4 Option (ii): Guard blocks fall on UMTS operators

216. In this section, we suppose instead that the additional guard block requirements where GMS and UMTS are adjacent were imposed entirely on UMTS operators. There are other alternatives in which the additional guard blocks needed between GSM and UMTS operators are in some way split across the two adjacent operators; the scheme considered here represents the most extreme of these alternatives. Nevertheless, it is useful to start with this case as it illustrates clearly the problems that could result for imposing *any* of this additional guard block requirement on UMTS operators. This approach would create much larger coordination risks, in that UMTS operators (especially those using UMTS only, as opposed to mixed operators) depend to a great extent to coordinating with neighbouring licensees for their spectrum to be fully usable.

5.4.1 Separation requirements at boundaries between licensees

217. As before, we look first at the three different cases according the technologies meeting at the frequency boundary of two licences.

Adjacent GSM operators

218. If the guard block requirements for avoiding interference between adjacent GSM and 3G operators fall on the 3G operator, the separation requirement between adjacent GSM operators would remain unchanged at 200kHz.

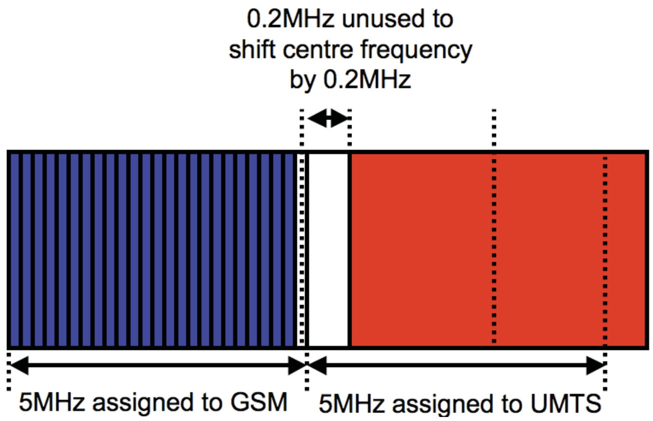
Adjacent 3G operators

219. The requirement for the provision of guard blocks falling on 3G operators instead of GSM operators would also leave unchanged the separation requirements in the case of adjacent 3G operators.

Adjacent 3G and GSM operators

220. The separation requirement between the *centre* of the 3G operator's 5MHz channel and the centre of the nearest GSM channel is 2.8MHz. Where this separation requirement is imposed only on the 3G operator, the 3G operator would have to leave 2.7MHz between the frequency assignment of the adjacent GSM operator and the centre of its 3G channel located nearest to the GSM operator. This is shown in Figure 9 below. This effectively means that the 5MHz UMTS carrier would need to be offset by 200kHz from the edge of the UMTS operator's frequency assignment. Obviously, this may not be possible unless the UMTS operator also controls the adjacent 5MHz block into which the offset carrier could move.

Figure 9: Standard separation between 3G and GSM

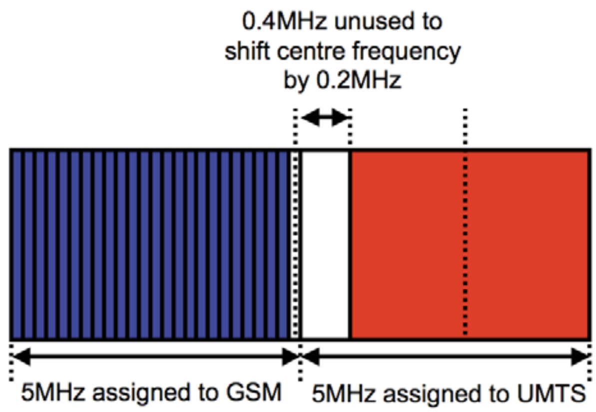


221. We have not considered the possibility that the 5MHz UMTS carrier might be compressed into a smaller range. We understand that this might be technically possible, at least for a small amount of compression, though would reduce the available capacity for the UMTS operator.[21] For example, reducing the carrier width to 4.6MHz and shifting the channel 400kHz would allow the centre to shift by the required 200kHz, as shown in Figure 10. However, in this case, it would be impossible then to accommodate any other user (GSM or UMTS) on the other side (i.e. the right hand side of Figure 10) within the separation criteria set in the EC Decision.

222. Therefore, we can see that this approach to guard blocks would create serious problems for UMTS operators, especially those using UMTS only (as opposed to mixed GSM and UMTS use in a single frequency range) and those with just 2x5MHz of spectrum. Similar problems would occur even if only part of the additional guard block requirement between GSM and UMTS fell onto UMTS operators. Indeed, if UMTS carriers are not compressible to less than 5MHz width, the scale of detriment to the UMTS operator is the same regardless of whether the entirety or just part of the additional guard block requirement were to fall onto the UMTS operator.

[21] 3rd Generation Partnership Project (2005), "Technical Specification Group Radio Access Network: UMTS 900MHz Work Item Technical Report", Release 9.

Figure 10: Standard separation between 3G and GSM, with channel compression



5.4.2 Impact of separation requirements on the amount of usable spectrum for operators

223. We now look at the coordination risks that this scheme would create for different types of operators. Unsurprisingly, UMTS operators face significant coordination risks, as much of their spectrum may be dependent on successful coordination with neighbouring licensees to be useable.

GSM operators

224. With this scheme, GSM operators would always be able to use all their frequency assignment except for 100kHz on each edge. Therefore, GSM operators would be able to use all of their frequency assignment less 200kHz.

3G operators

225. If guard block requirements were imposed on 3G operators, then 3G operators would need to leave a separation between the centre of their channels and the edges of their frequency assignment of at least 2.5MHz (in the case that that the adjacent operator in that side is a 3G operator), and up to 2.7MHz if the adjacent operator deploys GSM. This means that if guard block requirements were imposed on 3G operators, a 3G operator would only have sufficient usable spectrum to be able to deploy services in the following limited number of circumstances:

- The 3G operator were assigned 10MHz of contiguous spectrum. If the operator has an adjacent GSM user, the spectrum available for 3G use would be constrained as follows:
    1. if the operator were able to deploy a 3G channel with only 4.6MHz of spectrum, the operator might be able to deploy two 3G channels and bring the centres of these channels closer to the centre of its frequency assignment, as shown in Figure 11A;
    2. if the 3G operator requires 5MHz for deploying a channel, only one 3G channel would be feasible.
- All adjacent operators to its frequency assignment were also 3G operators, as shown in Figure 11B.

- It only has one operator adjacent to it (e.g. it is located at an edge of the 900MHz spectrum band), and it were able to deploy a 3G channel with only 4.6MHz of spectrum if faced with a GSM neighbour, as shown in Figure 11C.

Figure 11A: Separation between 3G operator and its adjacent users

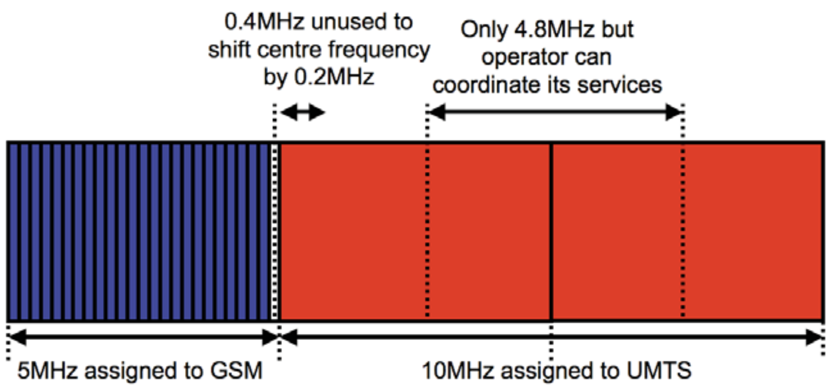


Figure 11B:

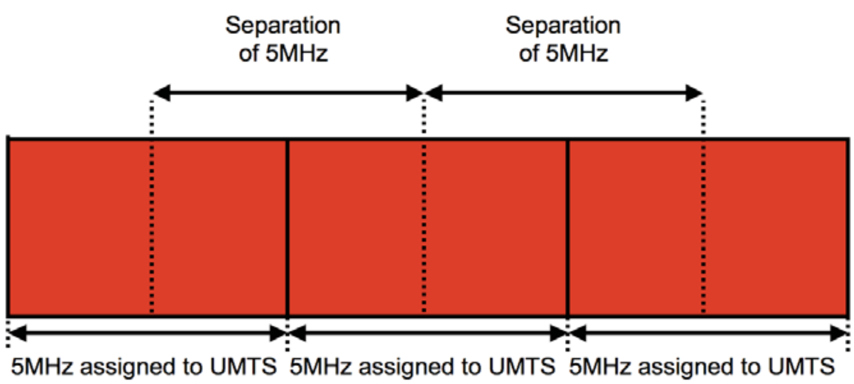
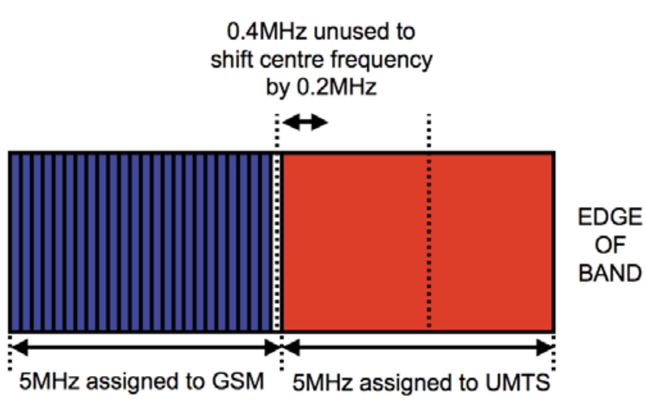


Figure 11C:



226. In summary, if a 3G operator were required to carve out guard bands between itself and GSM operators from 5MHz blocks, this would substantially limit the possibilities for 3G operators successfully operating 3G services in this band. In particular, a 3G operator winning a single 5MHz lot would have no guarantee that it could use the allocated spectrum for deploying 3G at all.

Mixed-use operators deploying both GSM and 3G

227. Unlike the case (considered in Section 5.3) where additional guard block requirements fall on GSM users, where these fall on UMTS operators, a mixed use operator might have incentives to place its 3G channel in the middle of its frequency assignment (as previously shown in Figure 7). In particular, this would be the only feasible arrangement for deploying 3G services if both adjacent operators to the mixed use operator were deploying GSM at the edges adjacent to the mixed use operator. However, if an adjacent operator deployed 3G services, then there might be benefits for coordination to place their 3G channels at their common boundary. Such coordination would reduce the number of 3G/GSM boundaries, and therefore the amount of spectrum that would be required as guard blocks.

228. It is clear that a mixed use operator would have much more possibility to accommodate different types of operators as it neighbours than does a pure UMTS operator. Therefore, a particular concern about this scheme (in which UMTS operators provide the additional guard blocks) is that it would be unfair to pure UMTS operators. In the context of the current Irish market situation, this would be worrying, as this approach would seem to enhance the position of the GSM incumbents at the expense of the 3G-only operator and entrants.

5.5 Assessment of alternative guard block obligations

229. The benefit of coordination between adjacent operators, and consequently the *coordination risk* (i.e. the potential loss of value for an operator that fails to coordinate with adjacent operators), is greatly affected by the guard block scheme. The impact on the potential value of the lots to bidders introduces uncertainties for bidders and increases the likelihood of an inefficient outcome to the allocation process.

230. This section assesses the benefits and limitations of the two alternative guard block schemes discussed above, and the impact that each alternative may have on the value of lots to operators given the likely coordination possibilities. We find that there are strong arguments for imposing the additional guard block needed to separate GSM and UMTS on the GSM operator.

5.5.1 Benefits of coordination under option (i)

231. There would be benefits from coordination between adjacent operators where one operator deploys GSM at the edge of its frequency assignment and the other deploys 3G in the adjacent spectrum.

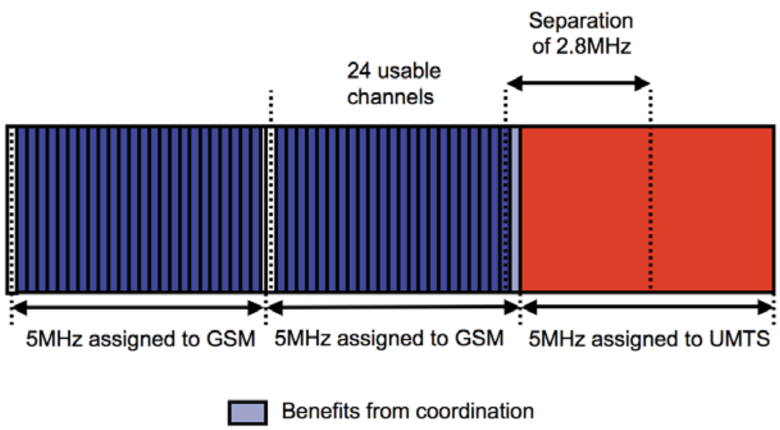
Benefits for a GSM operator

232. Through coordination, it may be possible to reduce the distance between the centres of neighbouring GSM and 3G channels from 2.8MHz to 2.6MHz.[22] This might allow GSM operators to increase the amount of spectrum available for GSM, by making the 200kHz required as a guard block usable for GSM. Under this assumption, it would always be possible for a GSM operator to recover 200kHz of spectrum by coordinating with one neighbour, regardless of the technology used by the other neighbour.

233. To understand this, suppose that we had a GSM operator with an adjacent UMTS operator to the right. There are various cases according to the situation with the left-hand neighbouring operator:

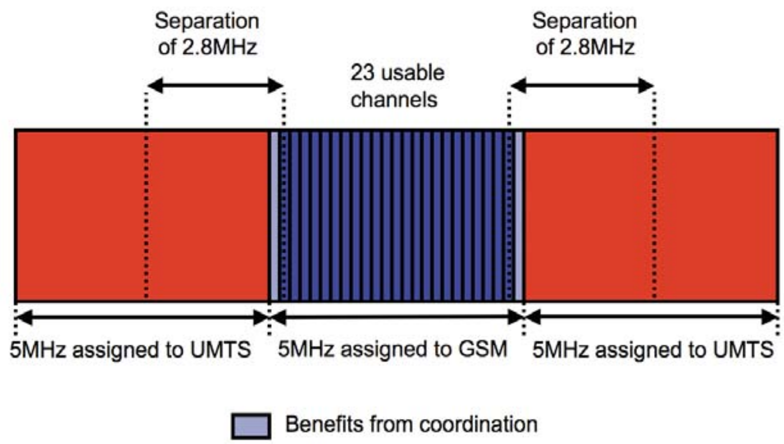
- Where the left-hand operator deployed GSM services, the previous uncoordinated requirement for a total of 0.3MHz of spectrum (i.e. 100kHz for the left-hand GSM operator and 200kHz for the right-hand UMTS operator) to be used as guard blocks (which due to indivisibility of GSM channels would imply the loss of two GSM channels) would be reduced to 100kHz with coordination (thus, a single GSM channel). This is shown in Figure 12A.
- In the case where the left-hand operator deployed 3G, the uncoordinated requirement of 400kHz of spectrum (i.e. 200kHz for each UMTS neighbour) being used as guard blocks would be reduced to 200kHz (if the GSM operator were only able to coordinate with only one of the adjacent 3G operators) or even to zero (if the GSM operator were able to coordinate with both adjacent 3G operators). Coordination would recover one or two additional GSM channels. This is shown in Figure 12B.

Figure 12A: Coordination benefits for a GSM operator



[22] 3rd Generation Partnership Project (2005), "Technical Specification Group Radio Access Network: UMTS 900MHz Work Item Technical Report", Release 9.

Figure 12B:

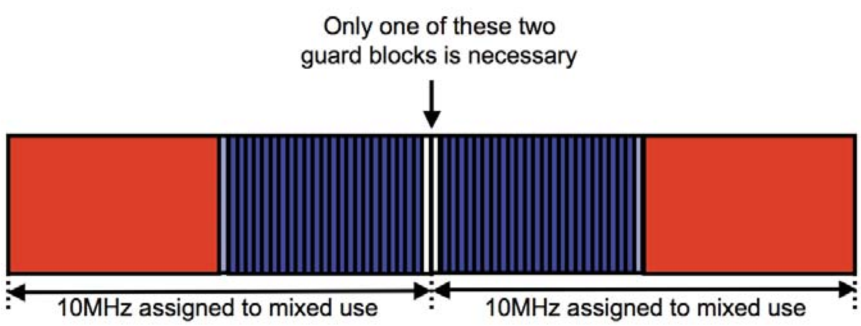


Benefits for a mixed-use operator

234. As discussed above, an operator placing the 3G channel next to the boundary of its frequency assignment would only have one boundary exposed to guard block requirements. Even if the neighbouring operator at that boundary were deploying GSM, the 100kHz guard block required would result in one lost GSM channel due to indivisibility.

235. However, where there are mixed-use operators, it may be possible to reduce the number of GSM/3G boundaries and, therefore, the need for guard blocks between adjacent 3G and GSM channels. The mixed operators could coordinate so that adjacent operators place the same technology at the common boundary of their spectrum assignments. This might allow for reducing the number of GSM channels lost due to guard block requirements as shown in the example in Figure 13.

Figure 13: Minimising GSM/3G boundaries between mixed-use operators



236. Due to the indivisibility of GSM channels, only one of the two adjacent GSM operators could benefit from an additional channel, and the lost due to the guard block would need to be borne by the other operator. It may be difficult to achieve such coordination through bilateral negotiations. Alternatively, a mixed-use operator might benefit from placing its GSM channels next to a 3G operator if it could coordinate with such operator in order to use the 200kHz of spectrum next to this boundary.

5.5.2 Benefits of coordination under option (ii)

237. If the guard block obligations were imposed on 3G users, the benefits of coordination between adjacent operators would be much larger. Through coordination, 3G operators might be able to agree with adjacent GSM users to place the centre of their channel at less than 2.7MHz from at least one edge. In some cases, the effect of coordination could be to make a whole 2x5MHz block available for UMTS that would not otherwise have been usable.

Large coordination risks for 3G only operators

238. As discussed in Section 5.4, the separation requirements needed if there were a failure to coordinate with adjacent operators might substantially reduce the amount of spectrum available for 3G use. In some extreme outcomes, 3G operators allocated 2x5MHz could be unable to use their spectrum for 3G altogether if they must place the centre of their channel further than 2.7MHz away from at least one boundary of their frequency assignment. Similarly, 3G-only operators that have been allocated 2x10MHz might be only able to deploy a single 3G channel, unless they could agree to reduce the separation requirement from the edges with adjacent operators, or unless they could effectively deploy 3G channels with 4.6MHz wide carriers in order to bring their centres away from the edges of its frequency assignment.

Low risks for mixed operators

239. Mixed-use operators (that have been allocated 2x10MHz of spectrum used for both GSM and UMTS) could protect their 3G channel by placing it at the centre of their frequency assignment. However, they might be able to benefit from coordinating with neighbouring operators deploying 3G in order to reduce the number of 3G/GSM boundaries.

Competitive neutrality concerns with option (ii)

240. Overall, there is great variance of the amount of usable spectrum available for 3G only when UMTS operators must provide the additional guard block required to separate UMTS from GSM. UMTS-only operators would be very dependent on coordination with neighbours to make full use of their spectrum. For this reason, this guard block scheme might create outcomes that may raise concerns about competition in the provision of mobile services, where GSM operators (whether pure GSM or mixed operators) might have the ability to foreclose a potential UMTS-only operator.

241. Consider, for example, the case where the three existing operators were assigned 2x10MHz each and an entrant to the 900MHz band were assigned 2x5MHz, which it intended to use for providing 3G services. Of the potential assignment options for these four operators within the band, a number of these would not be consistent with the 2x5MHz operator being able to use its assigned spectrum for providing 3G services due to the existence of GSM services in adjacent frequencies and its consequent requirement to provide the necessary guard bands.

242. This undesirable outcome could also be manufactured by existing operators where these continue providing GSM services alongside 3G services in this band for a number of years. If existing operators deployed both GSM and 3G services within their spectrum assignment, they might opt to deploy GSM services using frequencies adjacent to the 2x5MHz operator, which might sterilise the spectrum allocated to the 3G entrant for 3G use.

5.5.3 Comparison of schemes

243. In summary, with the first guard block scheme, option (i) where responsibility for providing guard blocks falls on GSM operators, the difference between the worst-case scenario for a particular bidder without coordination with neighbours and the scenario where it coordinates fully with neighbours is small. Therefore, the **coordination risk** is small in this case.

244. In contrast, with the second guard block scheme, option (ii) where responsibility for providing guard blocks falls on UMTS operators, the amount of usable spectrum for UMTS-only operators varies dramatically depending on the technology deployed by neighbours. The coordination risk is large in this case. This gives rise to a number of serious concerns:

- this scheme might result in outcomes where a substantial amount of spectrum is sterilised;
- the variance in the amount of spectrum that might be usable for 3G use imposes excessive uncertainty on the value of lots for 3G operators, thus increasing the likelihood of an inefficient allocation of spectrum between bidders and unfairness for 3G-only operators;
- it may result in opportunities for anti-competitive behaviour, where GSM operators may be able to foreclose or substantially reduce the spectrum available for 3G use by new entrants.

245. We believe that these concerns render the second scheme unviable. Very similar arguments would apply to a situation in which only part of the additional guard block requirement needed to separate GSM and UMTS fell onto UMTS operators.

5.6 Generic lot categories with option (i)

246. As we discussed in the following sections, in order to mitigate bidder aggregation and fragmentation risks, we recommend awarding the 900MHz spectrum using a two-stage combinatorial auction process:

- In the first stage, bidders would bid for a number of generic lots;
- In the second stage, winners of generic lots in the first stage would be able to express their preferences for specific frequency assignments consistent with the number of generic lots won in the first stage.

247. When defining the generic lot categories, it is important that lots within each category would be of similar value to bidders. If the lots within a generic lot category have different value for a bidder, then the bidder might not bid the full value of its preferred specific lot in that generic category, as they need to consider the possibility that they will win a specific lot of lower value in this generic lot category in the Assignment Stage. This may lead to an inefficient allocation and unnecessary risk for bidders.

248. In the 900MHz spectrum award, an important source of uncertainty in value of generic lots may be due to the guard block obligations that operators would be subject to depending on the use of spectrum by adjacent operators. Given the potential impact of being adjacent to other licensees, a significant uncertainty would be whether the operator is awarded a frequency range adjacent to only one operator (e.g. frequency ranges at an edge of the band), or adjacent to two operators (interior blocks).

249. In this section, we only consider the potential value differences between the different spectrum blocks making the simplifying assumption that all blocks were available immediately. Although existing licences in the 900MHz band complicate the award by introducing further differences in the value of different spectrum blocks due to timing (and additional complexity related to co-existence of existing licences with the new licences), this provides a good starting point for our analysis of lot packaging options.

250. In Table 3, we consider the potential variation in the amount of spectrum usable by GSM operators depending on:

- whether the operator had been awarded a frequency range with only one adjacent operator (an "exterior" frequency assignment) or a frequency range between two adjacent operators (an "interior" frequency assignment);
- the technology deployed by the adjacent operators; and
- whether coordination with the adjacent operator were achieved.

This provides a rough metric of the coordination risk associated with lots interior to the 900MHz as compared with lots at the edges of the band; coordination risk is measured in terms of the amount of spectrum that would not be useable.

Table 3: Spectrum sterilised due to separation requirements imposed on GSM use[23]

	GSM only / Mixed use with GSM at edges		**Mixed use (2 5MHz blocks, polarised use)**	
	Coordinated	*Uncoordinated*	*Coordinated*	*Uncoordinated*
Exterior block, adjacent to 3G operator	0*	0.2*	0	0*
Exterior block, adjacent to GSM operator	0.2	0.2	0*	0*
Interior block, adjacent to 3G operators on both sides	0	0.4	0	0.2
Interior block, adjacent to one GSM operator and one 3G operator	0.2	0.4	0.2	0.2
Interior block, adjacent to GSM operators on both sides	0.2	0.2	0.2	0.2

*Assuming that GSM deployed in exterior blocks does not need to provide 0.1MHz separation between the edge of the band and the nearest GSM channel.

251. The variation in the amount of usable spectrum for operators of different types would be modest with this guard block scheme. It seems reasonable to conclude that the value difference between exterior and interior lots is unlikely to be large enough to warrant separate generic lot categories for exterior and interior lots.

252. This conclusion is critically dependent on the guard block scheme used (i.e. that GSM operators provide any additional separation needed against UMTS operators). Alternative schemes (such as Option (ii) discussed above) may have more severe coordination risks, in which case it may be unsafe to assume that interior and exterior lots will have similar values.

[23] The guard block requirements imposed on GSM operators on a GSM to GSM boundary may be further reduced by 200kHz by coordination if the adjacent operator is already providing a full 200kHz guard block due to indivisibility requirements and agrees to such an arrangement (see Section 5.5.1). This potential benefit has not been reflected in the table.

5.7 Conclusions

253. While ComReg's policy regarding interference in this band as stated in its follow-up consultation is that 'each operator will be responsible for the management of their interference within their spectrum assignments', and that 'no guard bands will be set aside by ComReg', it is recommended that ComReg clarify its view on this guard band issue prior to any licence competition.

254. There are compelling arguments for adopting a lot design in which the burden of providing 200kHz guard block required to separate UMTS and GSM users would fall onto the GSM user. The proposed solution is to:

- Allow UMTS use to the edges of a 2x5MHz block ;
- Allow GSM use in the entirety of a licensee's frequency allocation on similar terms to current GSM licences, except for within 200kHz of the boundaries of the allocation;
- Within 200kHz of the boundary of a frequency allocation, GSM use would be possible only with the agreement of the neighbouring user;
- Any other technology allowed by the EC Decision would have to allow neighbouring users to deploy UMTS across their entire frequency allocation and GSM to within 200kHz of the boundary of their allocation.

255. Although there is some coordination risk for GSM users, in the sense that getting the maximum possible use out of their spectrum may require coordination with neighbouring users, the impact on spectrum valuation is limited. The impact of failing to agree coordination measures with neighbours is typically limited to the loss of one GSM channel (200kHz) or, in the worst case, two channels. Therefore, the impact on licence valuation of GSM users needing to coordinate with neighbours is small.

256. With this lot design, there would be little difference between the value of interior frequency allocations (i.e. those with two neighbours) and exterior frequency allocation (i.e. those at the boundaries of the band and so with only one neighbour). This means that we do not need to distinguish interior and exterior lots and can largely treat one 5MHz block as being similar to another.

257. So far we have not taken account of the issue that Meteor's existing licence may be an encumbrance on any adjacent liberalised licence. We will return to this issue subsequently.

6 Candidate auction formats

258. In this section, we provide a high-level description and assessment of commonly used candidate auction formats based on a number of objectives that a desirable auction format should be able to fulfil. The candidate auction formats that we consider in detail are:

- Standard simultaneous multiple-round ascending (SMRA) auction;
- SMRA with augmented switching;
- Combinatorial clock auction (CCA); and
- Sealed-bid combinatorial auction.

259. We will see that many of the common auction formats are in fact inapplicable to the very particular problem that the reallocation of the 900MHz band in Ireland creates. In particular, if bidders wish to bid for two 2x5MHz blocks (the amount of spectrum required to maintain legacy GSM services and deploy UMTS), the efficiency and desirability of such an assignment hinges on these 2x5MHz spectrum blocks being located in adjacent spectrum. This is not ensured by a number of conventional formats (e.g. SMRA auction format). Achieving auction outcomes where winner's resulting spectrum assignments are contiguous is further complicated in this case where different parts of the 900MHz band are to be licensed for use from different dates, and an overall spectrum cap applies making some licences more attractive than others to existing operators in the band.

260. Furthermore, it is possible that a bidder could value 2x10MHz of spectrum at more than twice 2x5MHz. In this case, bidders would face aggregation risks if a more traditional SMRA is used. Similar concerns about aggregation risks have motivated an increasing number of regulators to move to combinatorial auction formats.

261. We recommend the use of an auction format that allows for package bidding (the CCA or sealed-bid combinatorial format) in order to reduce the possibility of fragmented outcomes and to eliminate aggregation risks. This format can also deal naturally with different licence start dates.

6.1 Objectives for a candidate auction format

262. The auction format selected for the award of 900MHz spectrum should aim to ensure an efficient outcome in which spectrum is assigned to the users that will ensure the most efficient use of spectrum and thus generate the greatest value for mobile consumers in Ireland. Therefore, the selected auction format should aim to achieve the following objectives:

- As well as promoting high-value broadband services, the auction outcome must allow for a smooth transition of spectrum use from GSM to 3G services, such that existing GSM services are not terminated too quickly and undue disruption to consumers is avoided. This requires the coexistence of different technologies with an efficient assignment of frequencies to minimise interference costs. The proposed lot design discussed in Section 5 already goes a long way to facilitating coexistence of different technologies.
- The auction format and rules should minimise the risk of undesirable assignment outcomes for bidders seeking multiple 2x5MHz lots on a contiguous basis. Therefore, the format should mitigate both:

1) aggregation risks, that is, where a bidder requires multiple blocks of spectrum but is awarded 'stranded' licences (unwanted subsets of demand, one 2x5MHz block where a bidder sought two blocks in this case); and
2) fragmentation risks, that is where a bidder wins two 2x5MHz blocks that are not contiguous, which might significantly reduce the bidder's value of the spectrum.

- Where relevant, the auction process should try to minimise common value uncertainty, which may exist where bidders use the available spectrum to deploy new technologies.
- The allocation process should aim to minimise migration costs, thus minimising the outcomes where bidders might be unnecessarily awarded different frequency blocks over time.
- The auction should avoid outcomes where spectrum goes unsold despite there being demand for that spectrum.
- The auction should encourage participation in the process, and mitigate concerns about bidder asymmetries both between the incumbent operators and between incumbents and potential entrants.
- The auction should promote incentives for bidders to bid in a straightforward manner, and not to engage in strategic behaviour or tacit collusion.
- The auction should provide a high level of clarity and certainty for bidders as to the level of expenditure that they are liable for as a result of the bids that they place.
- The auction process should be as simple and transparent to bidders as possible, in light of the above factors.

263. There may be some tension between these various objectives. In particular, minimising the impact of common value uncertainty usually requires an open, multiple-round auction. This allows bidders to update their valuation estimates as the auction progresses and so reduces such uncertainty. However, such a framework may facilitate tacit collusion or predatory bidding as it is possible to respond dynamically depending how other bidders behave. Conversely, one-shot sealed bids are good for destablising tacit collusion, but poor for providing price discovery and reducing common value uncertainty. Given the particular circumstance of this award, we have particular concerns about the intensity of competition for spectrum and rather weaker concerns about common value uncertainty.

6.2 Simultaneous multiple-round ascending auction (SMRA)

264. This format was first developed and used by the US FCC and has subsequently been adopted by many other regulators since the 1990s.

265. In the context of the award of 900MHz spectrum, a typical implementation of an SMRA would involve bids being made for the seven specific frequency blocks within the band. There would be just one auction process that determined both the number of blocks won and the specific frequencies awarded.

6.2.1 Mechanics of the auction

266. In an SMRA auction, bidders bid for specific frequency blocks, each of which we call a lot. The auction consists of a number of scheduled rounds. Bidders may submit a bid in each round. Bidders are allowed to bid for as many lots as they wish, subject to any caps on their bidding defined before the commencement of the auction. (Caps on overall bidding are often implemented through a system of eligibility points, explained below).

267. When a round is scheduled, the auctioneer announces a price for each specific lot. This is generally a fixed amount. Bidders then specify whether they wish to place a bid for a lot at the specified bid amount.

268. At the end of the round, the highest bid on each lot (submitted in that or any previous round) becomes the standing high bid on the lot (a tie-breaking rule is applied where there is more than one bid at the highest bid amount), and the bidder that submitted this bid is declared to be the 'standing high bidder' on that lot.

269. In the following rounds, prices are increased only on the specific lots that received at least one new bid in the previous round. Standing high bidders may be out-bid by other bidders submitting higher bids. Bidders may also be allowed (depending on the auction rules) to withdraw their standing high bids if they wish to switch their demand to a different lot. There are usually tight limits on the number of withdrawals allowed and often also financial penalties if a withdrawal then leads to a lot not being sold. Allowing for the withdrawal of bids mitigates aggregation risks and the risk of a fragmented outcome. However, allowing bidders to withdraw bids might also allow for strategic bidding that may distort the auction outcome. In order to provide flexibility to bidders and also discourage collusive behaviour, withdrawals can be permitted subject to penalties, or limited to a specified number of withdrawals allowed per bidder.

270. Bidders can shift their demand to different lots over successive rounds, subject to certain activity rules. In essence, the purpose of activity rules is to constrain bidding behaviour so that as bid amounts increase bidders can only maintain or reduce their demand. A consequence of this is that it is not possible for bidders to hide their demand in the early stages of the auction. This facilitates price discovery during the auction.

271. A common method of implementing this type of activity rule is through a system of eligibility points:

- Before the commencement of the auction, each lot is assigned a number of eligibility points by the auctioneer (which remains constant during the auction). Attributing different numbers of eligibility points to different lots is often used as a method of reflecting differences in the estimated value of different lots;
- Each bidder begins the auction with an 'initial eligibility' of a specified number of eligibility points requested by the bidder as part of the bidder application process and approved by the auctioneer. This initial eligibility will limit bidders' subsequent ability to make bids (as described below);
- The activity of a bidder in a round is equal to:
    1. In round 1, the eligibility points associated with the lots upon which it places a bid; and
    2. In round 2 onwards, the net number of eligibility points associated with:

i. lots where the bidder held a standing high bid at the start of the round;
ii. plus lots where the bidder did not hold a standing high bid at the start of the round and for which the bidder submits a bid in this round;
iii. less lots where the bidder withdraws a standing high bid.

- In any one round, the activity of a bidder cannot exceed that bidder's 'eligibility level', that is, the number of eligibility points associated with it, at the start of that round;
- Where a bidder's activity in a round is less than its eligibility, this bidder's eligibility is adjusted downward. The amount of the downward adjustment of eligibility points depends on the activity rules of the auction.
- The most straightforward activity rule is that the activity of a bidder in a round must be equal to its eligibility level at the beginning of the round. In this case, the bidder's eligibility level at the start of a round would be reduced by the full amount of the difference between the bidder's eligibility level and its activity in the previous round;
- However, in order to allow bidders to switch between lots of different numbers of eligibility points during the auction as information is revealed about the relative prices of lots, a more flexible activity rule can be adopted – that the activity of a bidder in a round must be equal to a proportion of its eligibility level at the beginning of the round.
- Where the more flexible activity rule is employed, the proportion of its eligibility level that a bidder's activity must constitute increases as the auction progresses. This 'activity requirement' must be 100% before the auction can end.

272. In addition to the 100% activity criterion, in order for a round to constitute the last round of the auction, the round must close with no new bids having been placed and no withdrawals being made for any lots.

273. When the auction ends, each lot is awarded to the bidder that holds the standing highest bid on the lot at the price of its standing high bid.

6.2.2 Advantages and disadvantages of the SMRA auction format

274. The SMRA auction format has a number of positive qualities:

- In its basic form, this auction format is relatively simple; while in its implementation the basic SMRA format is often complicated by the introduction of withdrawals and a staged activity requirement (discussed above), the result is still relatively straightforward when compared with the likely alternatives. There is wide experience of running SMRAs.
- The implementation of withdrawals allow bidders a level of flexibility:
  1. Flexibility to switch between lots as information is revealed about prices; and

   2. Flexibility to reduce fragmentation risks (where the bidder seeks not only to win two 2x5MHz blocks but values having these blocks located adjacent to one another).

- Introducing a staged activity requirement allows bidders the flexibility to hold back a proportion of demand and corresponding expenditure until after a certain amount of information regarding prices is revealed.
- As bidders are only liable for lots on which they are standing high bidder at any given time and can only become liable for further lots where they place new bids, there is a high degree of clarity and certainty as to the level of expenditure committed by the bidder at all times during the auction. Together with simplicity, this feature may encourage the participation of interested parties that might be deterred as a result of fixed budgets or limited resources to devote to a bidding strategy.

275. However, the standard SMRA format has a number of quite significant drawbacks:

- The greatest problem associated with SMRA auctions is that this auction format is poorly suited to dealing with aggregation risks. In a standard SMRA auction, bidders bidding on a combination of lots may be exposed to the risk of ending up being the standing high bidder for some but not all of the lots on which they wished to win. In this case, bidders may be 'stranded' on a subset of the combination of lots they wanted. This may lead to inefficient outcomes:
   1. If the bidder places bids that reflect the synergy value associated with winning a combination of lots, then bids may be above the value that the bidder placed on the lots on a standalone basis. Consider, for example, an existing operator in the 900MHz band in Ireland. It is probable that this operator would have a valuation for 2x10MHz that is more than twice its valuation for 2x5MHz given the efficiencies gained using 3G technologies over 2x10MHz relative to 2x5MHz. In such cases, if the bidder is stranded on a subset of the lots upon which it bid (only one 2x5MHz lot in this case), the bidder may face prices that are above its valuation of the lots won. Such an outcome could be inefficient, as there could be other bidders who placed a value on such lots at a level between the winner's valuation for the lot and the price paid.
   2. In order to prevent such an outcome, in an SMRA, bidders may choose not to raise bids for any lots beyond their standalone value. However, such a strategy would mean that bidders would not express their synergy value for a combination of lots, and might then also lead to inefficiencies.

  Aggregation risks may be somewhat mitigated by introducing the possibility of withdrawing bids. However, unless penalties are applied, allowing withdrawal of bids may create perverse incentives for strategic bidding and subsequent withdrawal. Conversely, where penalties on withdrawals are applied, bidders may still be subject to a cost for withdrawing bids from unwanted lots.

- Where bidders may bid for more than one lot and withdrawals are not permitted, the SMRA also imposes significant fragmentation risks on bidders. For example, if a bidder is bidding for two lots (say two 2x5MHz blocks) and gets overbid on one of these, it might want to shift to a different area of band. Hopefully, it would subsequently get overbid on the other lot and can again make bids for contiguous lots. However, there is no guarantee of this. If the bidder wishes to switch multiple bids from one frequency range to another, it may need to shift bids one at a time and be exposed to non-contiguous bids in one or more rounds. Towards the end of an auction, it becomes very likely that one or more bidders will be exposed to this risk if they are seeking to bid for multiple lots in line with price differentials.

- There is a risk of lots inefficiently going unsold following withdrawal of bids by standing high bidders. For example, a bidder might withdraw a standing high bid at a point in the auction when all other bidders that might want the lot had already lost their eligibility to bid for the lot.
- Where bidders have an interest in specific lots, this can facilitate a collusive outcome where these operators do not bid on one another's currently held lots and vice versa. A typical SMRA has a high degree of transparency and is very easy to formulate gaming strategies aimed at reducing competition and trying to establish tacitly collusive arrangements. SMRA in both the US and Canada with regional licence structures have been plagued by this problem. It is possible to limit transparency to reduce this problem (e.g. by not revealing the identity of the standing highest bidders), but this makes the problem of aggregation and fragmentation risks worse as bidders have less information to assess the chances of being stranded as the highest bidder.

276. The disadvantages of the SMRA are quite severe and there has been a general trend towards better alternatives for spectrum auctions that deal with fragmentation and aggregation risks. For this award, the disadvantages of the SMRA are particularly severe. Not only are fragmentation and aggregation risks important here, but also there are real concerns about the ease of tacit collusion that an SMRA would allow.

6.3 SMRA format with augmented switching

277. This is a variant of the standard SMRA which was initially designed for the Norwegian 3.5GHz award. It has subsequently been used by both Norway and Sweden for awards of spectrum in the 2.6GHz band. The modification is intended to deal with the problem of fragmentation risk.

278. In summary, the augmented switching variant of the SMRA was designed with the aim of providing bidders with flexibility to switch across substitutable lots. It does this by allowing bidders to withdraw bids, but places a corresponding obligation on them to place new bids in the same round.

6.3.1 Mechanics of the auction

279. The augmented switching variant of the SMRA format has the following additional features relative to the standard SMRA format:

- In the first round, bidders place their initial bids. The number of eligibility points associated to a bidder's bids in this round sets the maximum eligibility level for that bidder for subsequent rounds of the auction, and thus sets the maximum number of eligibility points that the bidder may have committed at the end of the auction.

- All bids placed are committing unless withdrawn and switched to a different lot. This means that bids placed in the early rounds of the auction in effect endure throughout the auction.
- In all rounds after round 1, bidders have a limited amount of choice as to what kind of bids they can make. Given a bidder's maximum eligibility level, the bidder can:
  1. raise (some or all) of its bids;
  2. leave (some or all) of its bids unchanged; or
  3. switch (some or all) of its bids to lots on which it does not hold a bid.
- In order to switch a bid, a bidder needs to withdraw an existing bid on one lot and place a new bid on a lot on which it has never bid subject to the following rule: the number of eligibility points associated with all withdrawn bids must be equal to the number of eligibility points associated with new bids. In effect, the combination of withdrawals and new bids is used to 'switch' a number of bids from one set of lots to another at the same time. It is this feature that avoids fragmentation risks, as a bidder can switch a number of bids that span a contiguous frequency range to another set of bids that span a different contiguous range in one round.
- Only the standing high bid on a lot is eligible to be withdrawn.
- This potential for bidders to withdraw bids creates an important consequence for bidders - even if higher bids have been received on a lot, a bidder's bid on that lot may be re-activated and become the standing high bid if all higher bids on the lot are withdrawn in subsequent rounds.
- Bidders may only raise or switch bids subject to standard SMRA activity rules. For these purposes we take account of *net* bids, i.e. count standing bids and new bids count positively, but count withdrawals negatively.
- However, the notion of re-activation of bids raises the issue of how this interacts with eligibility point rules. In the case where a bidder is re-activated on a lot where it had previously been superseded as standing high bidder, the bidder's eligibility may need to increase in order to facilitate this development in addition to its other bids already committed. This facility for a bidder's eligibility to increase during the auction under certain circumstances is however still constrained by the activity rule that a bidder's eligibility cannot at any point be greater than its initial eligibility established in the first round.
- A round would constitute the last round of the auction if:
  1. There are no new bids; and
  2. There are no withdrawals.

6.3.2 Advantages and disadvantages of the SMRA format with augmented switching

280. Relative to the standard SMRA, the augmented switching format greatly reduces fragmentation risks for bidders (especially if compared with a standard SMRA with no withdrawals). Allowing bidders to switch all their bids without any associated penalties allows them to move their full sets of bids in order to target contiguous spectrum more effectively. This means that where bidders want a number of lots in a contiguous frequency

block, they can switch around in response to price differences and pursue substitution strategies.

281. However, SMRA format with augmented switching has many of the original problems of the traditional SMRA and some new ones as well. The main shortcomings of this auction format are as follows:

- The bidding process is complex. The switching rules associated with this format are complex and not very intuitive. In particular, when bidders are at a stage where they have dropped eligibility relative to their initial eligibility, it may be difficult for bidders to understand the limitations on what bids they can switch and what bids they can raise. Bidding in an auction with an SMRA format with augmented switching becomes particularly difficult when bidders can bid on a large number of lots, and when lots have different numbers of eligibility points associated to them, as there are numerous combinations of withdrawals and bids but only a few options conform with the auction rules.
- It is difficult for bidders to bid within their budget constraints. As all bids may be re-activated at any time during the auction due to withdrawals submitted by other bidders, it is difficult for bidders to contract demand in response to price increases in a manner that truly reflects their budget constraints. Consider the following example where two lots are being auctioned, A and B. Suppose that a bidder may be willing to bid 16 for winning both lots A and B, and 10 for winning a single lot (either A or B), with a budget constraint of 16. Straightforward bidding would allow such a bidder to bid for two lots until the price of a lot exceeded 8, at which point it would reduce demand to one lot, and cease bidding on any lots once the price per lot exceeded 10. Now consider the SMRA format with augmented switching. Assume that the bid amounts for A and B have reached 8, and that the bidder has raised its bids up to this amount. In subsequent rounds, the bidder will need to reduce its demand, as bidding for both A and B would not be within the bidder's budget. Suppose that the bidder then raises its bid for A alone, and that bid amounts for both lots go up to 10. The bidder is willing to acquire lot A at this price, which also is within its budget constraint. However, if in the following round the bidder's bid for B is re-activated, then the bidder is liable for a total amount of 18 (10 from its bid for lot A plus 8 from its bid for lot B). In this case, the bidder would be over its budget constraint. If bidders have flexible budget constraints, they may be prepared to risk such situations. However, bidders with fixed budget constraints may have to drop out at an earlier stage in order to ensure that it does not end up in such a position. In the example discussed, the bidder would have had to drop out from the auction when the bid amounts reached 8 for each lot, even though the bidder had a valuation of 10 for one of those lots alone.
- The SMRA with augmented switching format has been proposed on many occasions for awards where bidders might be exposed to the risk of undesirable assignment outcomes. However, while the risk of fragmentation is mitigated with this variant of the SMRA format, it is not removed altogether.
- The aggregation risks are just as much of a problem as with the standard SMRA. There is still a danger that at the end of the auction, a bidder is left with some, but not all, of its target lots and is unable to exit cleanly.

282. Overall, although the SMRA with augmented switching format has desirable features and may effectively help to mitigate bidder fragmentation risks, we do not consider this to be the best way to address such risks within an SMRA format. It does not get the heart of the problem with the SMRA: that there are standing highest bidders until such time as they are overbid by someone else and that this creates aggregation risk.

6.4 Combinatorial clock auction (CCA) format

283. The problem of aggregation risks can be eliminated entirely by moving to a format in which bidders make bids for packages of lots. A package bid is atomic, in the sense that it either wins in its entirety or fails in its entirety. The auction mechanism would never allot a bidder only part of its package bid. By making a number of mutually exclusive package bids, a bidder can full express any preferences over complements or substitutes. For example, suppose that a bidder wants two lots, but not one, but otherwise does not care which lots it receives. It can then make bids for all packages containing two lots. It will either win one of these two lot packages or nothing at all.

284. Combinatorial auctions are more complex to implement that traditional SMRAs (or variants) as they require some mechanism for collecting multiple package bids from individual bidders. These need then to be processed by an algorithm to determine which of these many bids will be winning bids (so-called winner determination) and another algorithm used to determine what bidders pay. However, the additional complexity is entirely on the auctioneer's side, as the benefit is that decision-making by bidders is greatly simplified and there is a much-reduced role for gaming behaviour.

285. The combinatorial clock auction (CCA) is an open format developed by DotEcon and Ofcom for the UK auctions of 10-40GHz spectrum and frequencies in the L-band (1452-1492MHz), and is scheduled to be used for the upcoming award of spectrum in the 2.6GHz band in the Netherlands. It is also closely related to the clock-proxy auction proposed by Ausubel, Cramton and Milgrom.[24] Although this is a novel format, its use is spreading quite rapidly as it provides a practical means of running a combinatorial auction that is not excessively complex.

6.4.1 Mechanics of the auction

286. The combinatorial clock auction format consists of two distinct bidding stages:

- a clock stage, which consists of a number of rounds (the primary bid rounds);
- a supplementary bids round, where bidders can revise and submit their best offer for all possible package combinations.

The CCA may be used to auction generic lots (as explained below), in which case there is scope for a follow-up assignment stage to determine the specific lots to be awarded to each winner of generic lots. For the UK awards, lots of similar types were placed in generic lot categories and this format was used to sell lots in multiple categories simultaneously.

[24] See: Peter Cramton, Yoav Shoham, and Richard Steinberg (eds.), Combinatorial Auctions, Section 5, 115-138, MIT Press, 2006.

Primary bid rounds

287. The primary bid rounds follow a 'clock auction' format. In the first primary bid round, the auctioneer sets a price for each category of lot. The bidder then states its demand for each category of lot based on these prices (subject, where applicable, to bidding constraints, e.g. 2x10MHz maximum spectrum assignment at any given time).

288. If there is excess demand for any category of lot, the auctioneer will schedule another round. For this round, the price set by the auctioneer for categories of lots that had excess demand in the previous round will be increased for the scheduled round in line with some pricing rule set out before the commencement of the auction. The price set by the auctioneer for categories of lots that did not have excess demand in the previous round will generally be unchanged for the scheduled round (again, this depends on the pricing rule). During the scheduled round, bidders then state their demand for each category of lot based on these new round prices. This process continues until there is a round during which the aggregate demand for each category of lot can be met by the number of lots in that category. When the primary bid rounds end, the auction will progress to the supplementary bids round.

289. The purpose of the primary bid rounds is for price discovery; given that bids in the primary bid rounds are binding, it is in the interest of bidders with a certain valuation for a package of lots not to bid above this valuation during these rounds (as they risk winning the package at a price above their valuation) or to stop bidding at prices below this valuation (as this will constrain supplementary bids for this package in the supplementary bids round). The result of these open rounds is that an approximate market-clearing price of each category of lot is established. Information about the valuations of bidders emerges over the open rounds, as bidders get to see if there is still excess demand for lots at the prevailing clock prices.

290. This price discovery stage is particularly valuable for bidders when they face common value uncertainty. This is the case where bidders' valuations are based on unknown factors and where other bidders' bidding behaviour may lead to updating of expectations about those unknown factors. For example, if demand or cost conditions are unknown but affect all bidders, then if other bidders do not reduce their demands as rapidly as expected this may lead to a bidder increasing its expected value. Reducing common value uncertainty can lead to more competitive bidding and more efficient outcomes.

291. Common value uncertainty is particularly relevant where bidders are facing common risks from uncertain demand for new services or from uncertain costs from deploying new technology. Common value uncertainty is probably relevant to all spectrum awards to a lesser or greater extent. However, in this award we do not have an entirely new technology, nor an entirely new market. Common value uncertainty is unlikely to be as important as it was for say, the first wave of 3G awards across Europe in 2000/2001.

Supplementary bids round

292. The supplementary bids round is a one-off further round of bidding following the primary bid rounds which provides an opportunity for bidders to:

- express their full value for the package that they were bidding on at the end of the primary bid rounds; and
- to bid for packages of lots that they were eligible to bid for in the primary bid rounds but that they did not bid for.

This allows bidders to place multiple bids that they did not have the opportunity to place during the primary bid rounds. Also, they may not have reached their full valuation for their most preferred package in the primary bid rounds given round prices, and there may be other packages that they have a lower value for but would still like to win at certain prices. Bids in this round are subject to constraints; bids will be subject to a minimum and in some cases a maximum based on the bidder's primary round bids. These caps depend on the specific rules of the auction (which are quite complex and not explained here). The intention of the caps is to provide incentives for truthful bidding throughout the auction.

293. At the end of the supplementary bids round, winners and prices are determined. Bids considered include all bids submitted in the primary bid rounds and all valid bids submitted in the supplementary bids round. Each bid in a bidder's full set of bids submitted is mutually exclusive and bids are only considered in their entirety (that is, a bidder can only be awarded all of the lots included in a bid it placed or none of these). Winning bids are selected, at most one from each bidder, in order to maximise the total sum of winning bids. This ensures an efficient outcome given the bids received.

294. The next step is to determine prices to be paid by winning bids. The details of the pricing rule for Ofcom auctions to date and ComReg 26GHz auction are somewhat complex, but the basic principle is that the price paid is determined by opportunity costs, not by what bidders actually bid.[25] These auctions use a generalised notion of opportunity cost that ensure that each winning bid pays at least its opportunity cost, but also each and every group of winning bidders collectively pays at least its opportunity cost. The effect of this rule is that winning bidders pay not what they bid, but the smallest amount that, if they had bid that amount instead, they would still have won.

295. This form of pricing rule provides good incentives for bidders to bid close to their true value. Whilst it is theoretically possible to reduce the amount paid by shading down bids in some cases, in most practical applications it is very difficult for bidders to assess the implications of bidding less than their true value for the risk of losing, as they do not know the bids of other bidders. The incentive to bid close to their true value, together with the winner determination step that optimises the outcome given the bids received, should lead to very efficient outcomes.

Assignment round

296. As mentioned in 6.4.1 above, the CCA format can easily be adapted to allow for the grouping of similar lots into generic lot categories. Using generic lots greatly simplifies the auction both for bidders and the auctioneer, especially when the number of feasible combinations of lots is large.

297. Under a generic lot approach, lots are grouped into the same lot category if they are considered to be substitutable. In the primary bid rounds, when a round is scheduled, prices are declared by the auctioneer for a lot in each generic lot category. During this stage, bidders can submit a bid in each round including a number of lots in each of these generic lot categories based on the unit price for lots in generic lot categories. In the supplementary bids round, bidders can then place supplementary bids specifying as part of a bid the number of generic lots it wishes to win in each category and an associated price.

[25] For an explanation of the detailed operation of winner determination and the second pricing rules for these auctions see http://www.dotecon.com/publications/dp0701.pdf.

298. At the end of the supplementary bids round, the number of generic lots assigned to each bidder is determined. However, the actual frequency blocks corresponding to each lot awarded are assigned to winning bidders in a follow-up assignment process.

299. Such an assignment stage typically consists of a single round where winners in the auction are presented with the different feasible frequency ranges they could be awarded given their winnings. This stage provides winners the opportunity to express their relative preferences (if any) as to which assignment option they are awarded. Winners can do this by placing a simple unconstrained bid for one or more of the feasible assignment options they have been presented with. Bidders are always guaranteed to be awarded the number of generic lots they won after the supplementary bids round. Where a bidder is indifferent as to its exact frequencies, it may choose not to place any bids in the assignment round.

300. After the assignment round closes, the location of winners within the band is determined by choosing the set of frequency assignments among winners that maximises the total winning bids. Prices to be paid by winners are determined using a similar second price rule. Where a bidder does not place any bids in the assignment round, its exact frequencies will be assigned from the remaining options once those bidders that have placed value on specific options have been assigned theirs. Shortly after the assignment round closes, all bidders will be informed of the location of their spectrum assignment in the band for each category of lot and any additional price to be paid for this assignment.

6.4.2 Advantages and disadvantages of the CCA

301. Given that the CCA auction format allows bidders to express demand for different combinations of lots, and each bid is only considered in its entirety (i.e. bidders will not be awarded only a subset of the package they bid for), this format allows bidder to express their full value for lot packages without facing aggregation risks.

302. The CCA provides an effective way of dealing with bidder aggregation and fragmentation risks by allowing for package bidding. As mentioned above, bidders may be awarded a package they bid for, but not any subset of that package for which they did not place a bid. Given that bidders are not exposed to being awarded only a subset of the lots they bid upon, therefore, they can safely express their full synergy values for different combinations of lots.

303. Another advantage of combinatorial auctions is that, provided that appropriate rules have been designed, package bid auctions may also support a more complete expression of bidder demand and provide less opportunity for strategic behaviour. This simplifies bidding, as bidders can focus on expressing their valuations rather than the implications of other strategic actions. This increases the likelihood of an efficient outcome.

304. The CCA format is very flexible and can be adapted to cope with a multitude of situations where bidders are competing for different amounts of spectrum and want to deploy different services and technologies. This format has the great advantage that it provides a fully efficient outcome given the bids received.

305. Although the format can accommodate either specific or generic lots, its advantages are clearest in situations where lots are organised into a small number of categories, with each category containing generic lots that can be treated as identical for the purposes of the auction:

- With large numbers of lots in different categories, the number of package options that a bidder may value is likely to be very large. This creates complexity for bidders and may also cause problems for auction implementation when the number of possible lot combinations becomes unmanageable.

- There may be different technologies that bidders could deploy in a given band and the traditional approach of packaging spectrum into fixed size lots in anticipation of a particular technology and business model being used may be inappropriate. The CCA provides a highly flexible approach in this regard.
- By removing the additional complexity to bidders of placing bids in order to target specific blocks (particularly when trying to ensure contiguity of multiple lots), the bidding process becomes easier and bidders can focus on the size of the package they wish to acquire during the Main Stage, and consider only its feasible assignment options in the assignment round based on its winnings. This is important where winners wish to deploy different technologies that may potentially create interference problems with neighbouring users. In this case, the assignment options can be restricted to those that minimise interference.
- Once spectrum winners have been determined, the format has the flexibility to restrict the assignment options for winners to only those that are efficient from a spectrum management point of view. Similarly, where bidders may want multiple lots, using generic lots may also make it easier to ensure frequency contiguity (provided that the follow-up assignment stage is designed to facilitate this).

306. One drawback of the generic approach relates to the fact that bidders cannot express any preferences for specific frequencies in their primary and supplementary bids, but rather can only express their valuation for a generic lot. The risk this generates is that if the difference in the value of specific lots within each generic lot category is large, then bidders might find it difficult to assess how much to bid for a generic lot when they have uncertainty about the specific frequencies that will be assigned to it if it wins a lot. If this problem is severe, there is the risk of an inefficient allocation where bidders whose valuation crucially depends on the specific frequencies are unable to reflect their full value in their primary and supplementary bids. Such bidders may lose to bidders with lower overall valuations but smaller differences in value across specific frequency blocks. Therefore, in order for a process based on generic lots to be efficient, lots within each generic lot category should be sufficiently substitutable so that the value of the specific lots within the category is similar.

307. Another drawback of auctions with package bidding, including the case where there are generic lots and particularly where a second price rule is employed is that, depending on the number of lots, such package bidding may introduce complexity for bidders. Under such circumstances, the outcome, even if efficient, may not be as transparent to bidders and observers as a standard SMRA, owing to the complexity of the mechanism used to identify winning bids and prices.

6.5 Sealed bid combinatorial auction

308. DotEcon first implemented a sealed bid combinatorial auction for the award of fixed wireless access (FWA) spectrum in Nigeria in 2002. More recently, DotEcon used this format for the award of the 412-414 MHz paired with 422-424MHz band in the UK (2006), and for the award of spectrum in the 26GHz band in Ireland (2008).

309. The sealed bid combinatorial auction is, in effect, a CCA without the primary bid rounds. Bidders can place bids on as many different combinations of packages as they wish, but these bids are collected in a single round with no bidder having visibility of the other bids made.

These bids are constrained only by underlying spectrum caps and a minimum of the relevant reserve prices. Unlike our three previous candidate auction formats, the sealed bid combinatorial auction does not provide for price discovery. Instead, bidders have only one opportunity to submit their best bids for the lots auctioned, and the winning bids and bidders are determined on the basis of just one round of bidding.

6.5.1 Mechanics of the auction

310. A sealed bid combinatorial auction consists of a single round where bidders are invited to submit their final bids for specified lot packages (combinations) that they would like to win. Each bid is exclusive, meaning that at most one bid from any bidder will be accepted, and is only considered in its entirety (so bidders may be awarded the whole package they bid for, but not any subset of lots they did not place a bid for).

311. The winner determination process is essentially the same as for the combinatorial clock auction. The winning bids are the set of bids amongst all bids received that maximise the total of winning bids, subject to no more lots than are available being sold. Prices are determined using a generalised notion of opportunity cost. This pricing rule means that bidders have good incentives to bid close to value.

312. As with the CCA auction format, the auction may be structured so that bidders bid for generic lots, and the assignment of particular frequencies to winners may be determined in a follow-up assignment process. The assignment stage may be designed so that bidders can express their preferences over alternative (feasible) spectrum frequency plans. However, the feasible assignment options may be constrained for spectrum management purposes:

- Depending on the rules used for the assignment of frequencies, this may allow a more efficient assignment of frequencies in cases where there are potential interference problems between neighbouring users of different technologies.
- Similarly, depending on the lots available and the lot categories used, the follow-up assignment stage may also mitigate (or suppress) the likelihood of fragmented outcomes where bidders are assigned non-contiguous frequency blocks.

6.5.2 Advantages and disadvantages of the sealed bid combinatorial auction

313. The sealed bid combinatorial auction format offers many of the same efficiency advantages as combinatorial clock auction relative to other SMRA formats:

- By allowing package bidding, it removes bidder aggregation and fragmentation risks entirely.
- If generic lots are used, and the assignment of particular frequencies is determined in an assignment stage, it can support an efficient assignment of frequencies from a spectrum management perspective (i.e. minimise coordination requirements between adjacent users and avoid unnecessary costs of moving incumbents users).

314. The sealed bid combinatorial auction has some additional advantages over the CCA:

- The process is quick to implement, as it requires just one round to determine the winning bidders (and potentially a further round to determine assignment of specific lots if specific frequencies are assigned in a follow-up assignment stage).

- The bidding process is simplified (e.g. bidding can be completed on paper forms delivered in sealed envelopes, or by electronic data files), thus reducing the costs to both bidders and the auctioneer.
- This format is the least vulnerable to strategic behaviour, especially tacit collusion as bidders cannot observe each other's behaviour over multiple rounds. Further, concerns about predatory bidding are also eased because entrants know that strong bidders do not have the opportunity to revise their business case during the auction in order to out-bid them.

315. As with the CCA, the process may be more complex and seem less transparent than the traditional SMRA auction format. In addition, the sealed bid combinatorial auction format has the disadvantage that it has no price discovery mechanism. Multi-round auctions, whereby bidders are able to submit and raise their bids over a number of rounds, allow bidders to process the information made available at the end of each round in order to update their valuations. The price discovery mechanism thus may help reducing common value uncertainty. Therefore, in conditions where there is common value uncertainty, single-round sealed bid auctions may be less efficient than formats with price discovery.

6.6 Assessment of candidate auction formats

316. The general advantages and disadvantages of the four formats discussed are summarised in Table 4. For a comprehensive understanding of the assessment presented in this table, the table should be viewed in conjunction with the analysis presented in the previous sub-sections. It can be seen from the table that there are many general advantages to the use of combinatorial auction formats as these provide a solution to the problem of aggregation and fragmentation risks that arise with the more traditional SMRA and its variants.

317. There are significant advantages to the use of a combinatorial format in this award. If we maintain the simplification that all spectrum is available from a common starting date, it would be possible to treat the 900MHz band as a collection of seven generic lots. This would permit the use of a simple sealed-bid combinatorial auction or a combinatorial clock auction, which involves open rounds of bidding. Although these assumptions are unrealistic, it is useful to keep these auction designs in mind as we progressively introduce realism in later sections.

318. A two-stage process could be used for the assignment of specific frequencies. In the first stage, bidders could simply bid for a certain number of generic 2x5MHz lots. Having won a certain number of these generic lots, the second stage would determine which frequencies were allocated to winners.

319. The first stage could be conducted either as a one-shot combinatorial sealed bid (like the ComReg 26GHz auction) or as a combinatorial clock auction (like recent Ofcom auctions). In both cases, bidders would make bids for a certain number of generic lots. Winners would then be chosen to maximise the total value of winning bids, subject to not awarding more lots than the number of lots available. Prices for winners would be determined using a second price rule (as in the 26GHz auction), which would provide reasonable incentives for bidders to bid close to their true values for packages of lots. This process may be appropriate for a future competition when 1800MHz spectrum is made available.

320. Regardless of whether a multiple round or a single round process is used for the first stage, this determines the number of generic lots won by each bidder and the price to be paid. Given the outcome of the first stage, we then determine the feasible frequency locations for winning bids on the basis that those winning multiple lots will be assigned contiguous spectrum. Winners are allowed to make bids for the lots they have won to be located at various specific frequencies. This is a so-called *assignment stage*. Winners are located to specific frequencies to maximise the value of accepted second stage bids. Prices are determined in a similar manner to the first stage (i.e. a second price rule based on opportunity costs) in order to avoid incentives to bid less than true values.

Table 4: Advantages and disadvantages of various auction formats

	SMRA	**SMRA with AS**	**CCA**	**Sealed bid combi**
Allows for coexistence of different technologies with minimal interference costs	X	X	√	√
Minimises aggregation risks	X	X	√	√
Minimises fragmentation risks	-	√	√	√
Reduces common value uncertainty	√	√	√	X
Minimises migration costs	X	X	√	√
Ensures a competitive outcome (at least 4 winners with at least 2x5MHz each)	Depends on the spectrum packaging used, the spectrum caps set on bidders, and whether any spectrum is reserved for entrants.			
Avoids unsold lots where there is demand for these	X	X	√	√
Encourages participation	-	-	√	√
Promotes straightforward bidding	X	X	√	√
Clarity and certainty on amount of committed expenditure	√	X	√	√
Simplicity and transparency of the process	√	-	X*	X*

* Lack of transparency here relates to the value of the bids of others, not a lack of transparency in the process more generally.

7 Temporal lots

321. A key issue for the design of a process to award spectrum in the 900MHz band which has been considered only superficially to this point in the report is the differing dates of expiry for the current GSM licences and the corresponding commencement of new liberalised licences. Furthermore, there are legacy issues arising from the existing licences that need to be addressed, such as the potential for existing licensees to have preferences to retain existing frequencies where possible.

322. In this section, we describe two alternatives for packaging spectrum given a frequency block size of 2x5MHz for a future award and a spectrum cap of 2x10MHz per operator including current spectrum holdings. The two options differ in how they treat the time dimension in the auction.

7.1 Time-aggregated packaging

323. This method of packaging simply breaks down the spectrum in the 900MHz band into 2x5MHz blocks, with the commencement date of proposed licences based on current constraints vis-à-vis operators holding licences for some of these blocks at present. As a result, the licensee has an automatic right to retain access to the same frequencies from the commencement of the licence until its end. Spectrum in the 900MHz band is currently set to become available for re-assignment at the following dates:

- 5 lots of 2x5MHz licensed for use from 2011;
- 2 lots of 2x5MHz licensed for use from 2015.

324. This is the spectrum packaging assumed in all of the options considered by ComReg to date in its consultation documents. It is also possible to make licences terminate at the same date if different licences are given different lengths provided that this does not lead to excessively short licences starting in 2015.

Figure 14: Time-aggregated spectrum packaging

Licence	Start date
A	2011
B	2011
C	2015
D	2015
E	2011
F	2011
G	2011

325. A potential problem of this spectrum packaging option is that it does not allow bidders to subsequently reduce the amount of spectrum that they hold. This does not seem like much of a restriction in practice provided that legacy GSM operators indeed want to migrate all their spectrum holdings to 3G only use.

7.2 Time-disaggregated packaging

326. Two issues relating to the transition from 2G to 3G could necessitate interim assignments in the period 2011-2015 that differ from the long-term assignments, or a change in the status of currently assigned spectrum:

- possible "extension" of the licences of Vodafone and O2 which are due to expire in 2011, in order to provide undisrupted services to existing 2G consumers; and
- possible early liberalisation of the spectrum currently held by Meteor.

327. It may also be desirable to allow for rearrangement of the precise frequencies held by licensees as new licences are issued in order to minimise overall guard block requirements as new licences start and to take account of any preferences licensees may have about who their neighbours are. This suggests a more temporally disaggregated approach where we treat the periods 2011-2015 and 2015 onwards separately for the purposes of determining efficient arrangements of 2G and 3G users.

328. Resolution of these issues within the auction process, in preference to a difficult and potentially contentious administrative solution, requires that the spectrum be divided into time periods as well as frequency blocks. This alternative proposes to sub-divide the seven 2x5MHz blocks in the 900MHz band into two mutually exclusive time slices:

- 2011-2015; and
- 2015-2030 (assuming a 15-year duration).

329. In this case, there would be 12 lots to be allocated in an auction: 5 licences for 2x5MHz blocks for a licence term of 2011-2015, and 7 licences for 2x5MHz blocks for a licence term of 2015-2030. This scenario is illustrated in Figure 15. Blocks currently assigned to GSM licensees are marked with white shading.

Figure 15: Time-disaggregated spectrum packaging

2011-2015	2015-2030
A1	A2
B1	B2
C1	C2
D1	D2
E1	E2
F1	F2
G1	G2

330. An extension of this scenario is where one or two of the 2x5MHz blocks currently occupied wholly or partly by Meteor are "put up" for conversion to liberalised licences before the scheduled expiry of Meteor's GSM licence in 2015. If so, a further 2 lots, C1 and D1, would also feature in the auction.

7.3 Efficient spectrum assignments and realignments

331. There are scenarios in which it may be necessary for licensees to realign frequencies. The most obvious example is that O2 and Vodafone's current licences share block F. Therefore, it

is impossible for both to receive liberalised licences that include all of their existing GSM frequencies.

332. In the case that we used time-disaggregated packaging, it is possible (though not necessarily likely) that a bidder might reduce the number of lots held from 2011-2015 moving to 2015 onwards. This means that a reorganisation of the frequency plan might be necessary in order for all bidders with 2x10MHz to have contiguous spectrum.

333. By definition, the time-aggregated packaging automatically locks in the frequency assignments in 2011 and requires that any new spectrum assigned in 2015 is compatible with the existing frequency plan (i.e. uses only block C and D). Therefore, with this approach, frequency realignment in 2015 is never necessary.

7.4 Assignment stage

334. Once the winners of lots in each generic lot category have been established in the Main Stage, the specific frequencies allocated to each winner are determined in an Assignment Stage. Bidders should be able to express their preferences for specific frequencies at this stage.

335. To achieve these aims, we need an Assignment Stage that allows for package bids in the sense of specifying frequency locations for generic lots over time. These package bids would allow bidders to define packages that satisfy frequency consistency and express their value difference between these and alternative packages.

336. Under time-disaggregated lots, the Main Stage would produce a set of winners for 12 time-differentiated licences:

- winners of the 5 licences available for the 2011-2015 time slice; and
- winners of the 7 licences available for the 2015-2030 time slice.

Many of the winners of a licence in one period will likely have also been awarded a licence in other periods.

337. In the Assignment Stage, bidders would be presented with an illustration of the potential frequencies they may be awarded for each time slice in which they have been awarded a licence. They would then be able to place an unlimited number of bids for different combinations of frequencies across the periods in which they have been awarded a licence. Bidders are always guaranteed the amount of generic lots they won in the Main Stage; where they choose not to bid for a specific frequency block for a given generic lot category in the Assignment Stage, this represents no preferences over the specific lots within this category.

338. Consider the Assignment Stage bids of an entrant to the 900MHz band that has been assigned 2x5MHz in each time slice. Assume, for example, that the bidder has the following preferences:

- the bidder has a preference for being at an edge of the band;
- the bidder wishes to have consistent frequencies across the duration of its licence; and
- the bidder has a preference for being awarded any other lot over lot E.

339. An example set of assignment bids for this bidder is presented in Table 5. The bidder has not included any bids for locations that do not match across time slices (e.g. A followed by B) so by implication these bids are taken as zero.

Table 5: Sample set of assignment bids for an entrant awarded 2x5MHz

No.	2011-2015	2015-2030	Bid (€)
1	A1	A2	13,000
2	B1	B2	10,000
3	C1	C2	10,000
4	D1	D2	10,000
5	E1	E2	6,000
6	F1	F2	10,000
7	G1	G2	13,000

340. The set of assignment bids for a bidder would be greater and more complex where:

- A bidder is awarded two 2x5MHz blocks
- A bidder has preferences for specific frequencies, for example where existing operators in this band wish to be reassigned their current frequencies

However, the options available to bidders in the Assignment Stage can be constrained to include only those packages that satisfy spectrum contiguity, therefore greatly reducing the number of combinations available and the complexity of the winner determination problem.

7.5 Analysis of temporal options

341. The main benefit of using the time-disaggregated packaging is that we would avoid any impact on competition for the 2015 onwards lots, which are open to all operators, from competition for lots starting from 2011, when Meteor might not be to able to bid unless it chooses to relinquish its current licence under certain conditions.

342. Using time-aggregated lots may lead to competition for some of the lots being muted:

- Meteor would be unable to compete for spectrum blocks with a start date prior to the expiry date of its current licences due to the spectrum caps (unless Meteor was to return at least part of the spectrum associated with its current licence);
- similarly, given the benefits of having an earlier licence, the resulting competition for lots C and D might be artificially low and Meteor may be able to renew its licence at a correspondingly low price.

343. Furthermore, with time-aggregated packaging there is a possible tacitly collusive bid strategy for incumbent operators in the 900MHz band, where incumbents bid for their currently held frequencies, with one of the incumbents currently sharing frequencies in lot

F either dropping down to bid for a single 2x5MHz block, or moving to lots A and B. This issue is compounded by the differences in the expiry dates of the licences of existing operators in the band, and by the impediments for competition on some of the time-aggregated lots discussed above.

344. By using a number of generic lot categories with only a small number of lots in each category (or maybe even a specific lot approach), the time-aggregated packaging option would facilitate operators coordinating their bids in order to accommodate each other and mute competition for spectrum. Although the process of moving frequencies may impose a cost on existing operators in the 900MHz band, and there may be benefits for incumbents to remain put in their currently frequencies, it is possible to achieve such an outcome in the Assignment Stage even with time-disaggregated lots. However, given that lots are offered under more generic terms in the Main Stage, bidders would likely find it more difficult to signal or interpret their intentions.

345. In contrast, using time-disaggregated lots would allow for all operators eligible to bid for lots covering each distinct licence term to be able to compete for all frequency blocks included in that licence term category. For this reason, we believe that under this option there would be a greater degree of competition for each lot category, and in particular the competition for spectrum blocks included in licences beyond 2015 would be more representative of the underlying demand for these lots than with time-aggregated packaging.

346. The main disadvantage of time-disaggregated packaging is that it is a little more complex. Furthermore, under certain award mechanisms it could lead to aggregation risks due to the complementarity of lots across different time slices. However, these can be entirely eliminated by using a combinatorial auction format, which allows bidders to express their value for a combination of lots as a whole, thereby protecting them from the risk of being awarded only a subset of the lots they bid for.

7.6 Conclusion

347. Time-disaggregated packaging has a number of advantages and it avoids some of the disadvantages inherent in time-aggregated packaging. Therefore, we consider time-disaggregated lots with lot categories corresponding to the two time slices (2011-2015 and 2015-2030) our preferred option. The challenge with this option is how to design an Assignment Stage that allows bidders to express their preferences for maintaining frequency consistency in order to minimise the costs to operators of moving frequency assignments. We discuss this subsequently.

8 Assessment of candidate auction formats

348. In this section, we briefly look at how some of the issues identified previously can be best addressed through the choice of auction format.

349. Clearly, both the complexity of efficiently arranging coexisting 2G and 3G users in the band, and the aggregation and fragmentation risks that bidders seeking spectrum for 2G use could be exposed to suggest that traditional SMRA auction formats should be disregarded in favour of a combinatorial auction type. Under such a format, package bidding and an optimal grouping of lots into generic categories would enhance the efficiency of the auction process.

350. However, there is still the question of whether a price discovery stage is desirable (and therefore whether a CCA or a sealed bid combinatorial auction might be more suitable to the process.

8.1 Open format vs. sealed bid

351. Frequently, auction formats used for awarding radio spectrum feature an open multiple-round bid process, where bidders may submit bids in each round. This sequential submission of bids requires bidders to submit bids round on round, and allows them to obtain information on the value of lots during the process. The extent to which bidders may obtain information during the bidding process, and the extent to which this information may be valuable to bidders, depends on the information policy in the auction and the extent to which there are common value uncertainties across bidders.

352. Common value uncertainties are shared uncertainties about the underlying value of the assets being auctioned that affect all bidders, and imply that information about one bidder's valuation revealed by its visible bidding behaviour may cause another bidder to revise its valuation of the assets. The price discovery process of open multiple-round auctions should improve efficiency in situations of common value uncertainty through this form of implicit information sharing.

353. Although auctions with a price discovery stage are usually more complex and slow, they are commonly preferred for major awards, as the potential benefits from the price discovery process are likely to outweigh the additional costs associated with the additional complexity and length of the processes that use this auction format.

354. Single-round sealed bid processes are also common for the award of radio spectrum. These processes do not feature a price discovery stage, and therefore bidders do not have an opportunity to obtain information from other bidders during the bidding stage. However, as noted in Section 3, single-round sealed bid processes are usually simple, fast and low cost, and perform very well when there is little common value uncertainty. An additional advantage of single-round sealed bid processes is that (provided that they have the appropriate pricing rules) these may be more effective in encouraging marginal bidders to participate in auctions where there are known

bidder asymmetries and weaker bidders could be subject to predatory bidding strategies in open auctions.[26]

355. Ireland has previously used a sealed bid combinatorial auction for the award of 26GHz spectrum. In this case, the sealed bid combinatorial format was chosen in preference to an open process on the basis that common value concerns appeared modest (the spectrum was expected to be used for backhaul rather than consumer services) and demand was uncertain, so a simple, low cost approach was appropriate.

356. It is certainly the case that liberalised 900MHz could be used in new ways relative to other spectrum, for example to provide better quality in-building data services. However, there is not a step change in the nature and quality of services, for example as there was when 2.1GHz spectrum was licensed and 3G services first developed. The benefits of 3G at 900MHz are incremental, with similar services being offered more cheaply and with enhanced quality. A modest step change may result with the introduction of LTE, boosting data rates significantly. However, this is again an evolutionary rather than revolutionary step.

357. When 3G licences were first awarded across Europe in 2000/1 there was great uncertainty about the potential for take-up of new services. Demand for data services has taken a long time to build, but is now growing rapidly. Uncertainty about the potential for data services is now much reduced. Underlying trends, such as demand for web browsing on the move and the laptop data dongles, are now more clearly understood.

358. In fact, many of the factors affecting valuations are likely to be idiosyncratic to individual bidders. The continuation of legacy GSM services will form an aspect of the spectrum valuation for GSM incumbents. However, plans for migration to 3G will depend on the details of existing networks and the nature of each operator's customer base. It is quite possible that GSM incumbents may take different views about the value of 900MHz spectrum, especially the incremental value of 2x10MHz vs. 2x5MHz. Therefore, even if an open auction format were used, there may be rather little updating of expected valuations in the light of the bids of others.

359. These reasons suggest that common value uncertainty due to demand and cost uncertainty is not an overwhelming consideration for this award in the same way as some of the early 3G awards. Against this we need to balance the major risks for competition that may result from an open process.

360. A clear drawback of an open multiple-round auction format is that where there is limited excess demand, open rounds may facilitate a tacitly collusive outcome where bidders tacitly agree to reduce demand. Where this is considered to be a real possibility, there is a case for a sealed-bid auction.

361. Given the particular circumstances of this auction, we would have a concern about this possibility in this award. In our opinion, in this scenario, the main focus of competition is likely to be H3GI pushing for 2x10MHz against the GSM incumbents' reluctance to drop back to 2x5MHz.

[26] Klemperer, P, 2002, *How (not) to run auctions: The European 3G telecom auctions*, European Economic Review, Elsevier, vol. 46(4-5), pages 829-845, May.

362. A further disadvantage of an open process is the possibility of low participation owing to asymmetries between incumbent 900MHz operators and other incumbents or entrants. However, this could be a problem even if using a single-round sealed bid process if the auction is unattractive to new entrants (whether or not they eventually win anything).

363. These considerations are necessarily subjective, as we need to assess the nature of competition and the structure of demand prior to the auction. Nevertheless, the prudent route is to use a combinatorial sealed bid given the concern that the competition might be susceptible to distortion by strategic behaviour by bidders exploiting weak and predictable demand.

364. Furthermore, it is worth looking at additional measures to buttress the auction against tacit collusion or strategic bidding. First, the reserve price should be set reasonably high. We discuss this in depth in Part C. By setting a higher reserve price, the incentives for tacit collusion (and explicit collusion) are reduced, as the price saving that this strategy creates is smaller.

365. Second, these competition concerns suggest limiting transparency as much as possible. In particular, it would be beneficial if bidders did not know who else was participating in the process when they came to make their Main Stage bids. This would make it much more risky to coordinate bids (whether tacitly or otherwise). This limitation on transparency only needs to be sustained until the Main Stage bids are received. It would then be possible to release full information about participation and winning and losing bidders prior to the Assignment Stage. Indeed, this information is likely to be useful during the Assignment Stage to allow bidders to consider more fully the interference environment and the likely need to coordinate GSM use with neighbours, which may affect the value of different frequency assignments.

8.2 Early liberalisation options

8.2.1 Benefits of this option

366. We now turn to the question of existing operators choosing to release spectrum early. A potential issue is that O2 and Vodafone could have access to 3G spectrum at 900MHz from 2011, whereas Meteor might not have access to 3G spectrum at 900MHz until 2015 unless there were some provision made for early liberalisation. This risks distorting competition in advanced wireless data services, as access to sub-1GHz spectrum for 3G services might be needed to offer cost-effective rural and in-building services.

367. The spectrum cap provides some incentives for release of existing spectrum if the incremental benefit of gaining liberalised spectrum is sufficiently great. However, we also need to consider:

- What risks an existing operator giving up spectrum might face and whether it could guarantee replacing this with liberalised spectrum;
- Whether it is possible to incentivise early liberalisation by compensating existing licence holders for the value of the residual term of any non-liberalised licence given up.

368. On the first issue, a reasonable working assumption is that an option to release existing spectrum that is not contingent on winning liberalisation licences would be unlikely to be taken up by operators. In particular, existing GSM operators need

continued access to spectrum to provide GSM services over the short-term. This means that there would be little point in using a scheme in which an existing licence holder were offered an option to release existing spectrum *prior to an auction*. Rather, it would be necessary to link the release of existing spectrum with winning new licences.

369. Making the release of spectrum contingent on winning new licences is largely impossible within the conventional simultaneous multiple round auction format, as the supply of lots needs to be known prior to the auction. However, it is fairly straightforward to implement such a link between buying new lots and releasing old licences within a combinatorial auction. To do this, a package bid would be augmented to include the possibility of releasing existing spectrum as well as buying lots. The spectrum cap would determine the validity of such a package bid, in that it would be necessary for an existing licensee to give up a sufficient amount of spectrum in order for bids for liberalised spectrum to be acceptable. This approach would mean that an offer to release existing spectrum would be contingent on winning new liberalised licences.

370. It would be possible to include released spectrum in this way (i.e. released licences indicated as part of a package bid for new spectrum) even without including any compensation for the loss of the residual term of the existing licence. In this case, the motive for early liberalisation would primarily be strategic rather than economic. However, this approach might give too little incentive for operators to liberalise licences early. For a GSM incumbent releasing its existing licence, its bid would be based on the 'upgrade' value of a liberalised licence relative to its existing licence. In contrast, for a bidder without a GSM licence, its bid would be based on the full value of the licence.

371. This begs the question of whether it might be possible to do better with some compensation scheme for giving up existing licences early.

372. Unfortunately, there are many complexities to creating such a scheme. In particular, it is not possible to create a scheme in which the existing holder would in effect be a 'seller' of its residual licence, as it would be able to misrepresent the value. Indeed, there are fundamental theoretical reasons why it is not possible to create an economically efficient incentive for release of existing licences.[27] Operators would be giving up a non-liberalised licence to compete for a liberalised one, so the price of licences in the auction would tell us little about the value of the spectrum being released.

373. Nevertheless, there are a number of ad hoc procedures that might improve matters and improve release incentives. The most straightforward would be for an operator giving up an existing licence to be offered a rebate based on the original purchase price of the licence and the remaining term, assuming some amortisation schedule. We recommend that this approach be adopted due to its simplicity.

[27] With release, we effectively have a two-side markets with imperfect information. An impossibility theorem (due to Myerson and Satterthwaite) shows that there is no mechanism in which receipts from buyers are passed through to sellers such that all parties have incentives to reveal their true valuations.

8.2.2 Implementation of this option

374. As outlined above, the proposed auction format could provide an option for Meteor to opt to liberalise its existing licence early. In summary, in the event that Meteor did not win any liberalised spectrum for the 2011-2015 period, it would need to move its existing spectrum allocation 100kHz lower to avoid interfering with a potential UMTS user in block E. This could be imposed upon Meteor as a condition of its participation in the auction, or otherwise imposed by ComReg in accordance with its statutory powers and rights. If Meteor were to win spectrum in the 2011-2015 period, this would create an obligation on it to give up all or part of its existing GSM spectrum as necessary.

375. More specifically, there are three alternative scenarios for Meteor's spectrum holdings in 2011-2015 were Meteor to participate in the auction. In describing these scenarios, we propose in each case some specific options for how Meteor's frequency assignment might be determined.

376. First, if Meteor were to be unsuccessful and not win any spectrum in the 2011-2015 time slice in the auction, then it would retain its existing 2x7.2MHz on an unliberalised basis. However, as noted above, if the auction is implemented as described in previous sections with block E included as a generic lot in the first stage of the auction, Meteor would be obliged to move its spectrum allocation 100kHz lower in order to avoid interfering with a potential UMTS user in block E.

377. Second, if Meteor were to win two blocks in the auction for the 2011-2015 period, it would be obliged to give up all of its existing GSM spectrum. We have proposed in the previous sub-section that where Meteor were to relinquish the remaining part of its current 900MHz licence, it would receive a rebate related to the value of the 2x7.2MHz of GSM spectrum given up prior to the end of this licence. Where this scenario were to become a reality, the Assignment Stage of the auction would be significantly simplified, as all frequency blocks in the band would be available from 2011. Further, working on the assumptions that all winners would want to have the same frequencies in 2011-2015 and after 2015, and that winners of spectrum in the 2011-2015 time slice and the time slice from 2015 onwards were the same, the Assignment Stage could be further simplified; time slices could be merged, ensuring the same frequencies for winners for both time periods.

378. Third, if Meteor were to win a single 2x5MHz block in 2011-2015, there are a number of alternative possibilities as to how this might be accommodated in practice. We propose that if this were to occur, Meteor should be allowed to choose whether to give up either block C (2x2.3MHz) or block D (2x4.9MHz). Any retained GSM spectrum would be unliberalised and subject to the obligation that it could not be used within 200kHz of the boundary of the block without coordination with its neighbouring licensees. If Meteor were to choose to retain its spectrum in block C, this interference management obligation could be met by obliging Meteor to move its remaining GSM spectrum down by 100kHz. If Meteor were to choose to retain its spectrum in block D, the obligation would have to be met by imposing guard bands. Under this scenario, we propose that Meteor would receive a rebate pro rata for the amount of GSM spectrum given up based on the rebate for Meteor's full 900MHz licence as calculated in advance of the auction. For the purpose of running the assignment round, we propose that Meteor be given the option either to put its retained GSM spectrum into the assignment round, in which case it would receive back the same amount of GSM spectrum but not necessarily at the current frequencies, or else retaining its current

frequencies for its GSM spectrum without any guarantee that its liberalised block would be contiguous with its existing frequencies. With either of these alternatives, Meteor would need to bid for specific frequencies for the 2x5MHz block of liberalised spectrum it was awarded.

8.3 Relaxation of spectrum caps with unallocated spectrum

379. Our proposals assume throughout that a 2x10MHz cap would be imposed on winners of spectrum. In the event that there was deficient demand for spectrum, it might well be desirable to relax this cap in the interests of ensuring that there was not an avoidable and inefficient outcome. For example, one possible outcome could be 2x5MHz remaining unsold whilst three 2x10MHz licences are allocated; in such a case it might be difficult to find demand for the remaining 2x5MHz block other than from the winners of 900MHz spectrum.

380. Fortunately it is simple to accommodate contingent spectrum caps within a sealed bid combinatorial auction. In this case, bids for 2x15MHz of spectrum would be allowed, but not considered unless there was reason to relax the cap. In particular, if there were three or fewer bidders, then 2x15MHz bids would be taken into account, as otherwise spectrum would certainly be left unallocated.

381. What if there were more than three bidders, but the outcome of the auction with the caps in place for some reason involved 2x5MHz of spectrum being unallocated (for example, because all bids were for 2x10MHz of spectrum)? It would be possible to take into account bids of 2x15MHz in this case, but the situation is slightly more complex, as one would not want to make any of the winners of spectrum worse off as a result of relaxation of the caps. In particular, any winner of spectrum given the outcome of the auction with the cap in place should receive at least as much spectrum if the cap is removed. Without this protection, relaxing the cap could result in the displacement of a winner of 2x10MHz (with the cap in place) by higher bids for 2x15MHz. Equally, it should not be the case that a winner of 2x10MHz should have to pay more as a result of the cap being relaxed and needing to compete with bids for 2x15MHz.

382. These principles can be implemented in the following way:

- As a first stage, winners and prices are computed ignoring any 2x15MHz bids (i.e. imposing the spectrum cap);
- In the event that there is any unsold spectrum, a follow-up allocation process is run for the unsold spectrum. This considers all bids made, include 2x15MHz bids. However, only bids for larger packages of spectrum than won in the first stage are considered. These bids are treated on an incremental basis relative to the price paid for the package won in the first stage. For example, suppose that a bidder bid 30 for 2x10MHz and won this at a price of 25. It also made a bid of 35 for 2x15MHz. This would be considered as an incremental bid of 10 for an additional 2x5MHz (i.e. bid for 2x15MHz, less price paid for 2x10MHz). For a bidder who won nothing in the first stage, all its bids would be considered.
- Taking all the bids for incremental spectrum calculated in this way, exactly the same winner determination and pricing method is applied to allocate the unsold spectrum.

- Winners pay the sum of the price from both stages (of zero if unsuccessful in one stage).

383. Whilst this approach avoids leaving 2x5MHz inefficiently unallocated, it does have the potential to create somewhat complex incentives:

- If the number of bidders can be reduced to three, those remaining bidders know they can bid for 2x15MHz. This arguably creates an incentive for collusion, though mitigating this is the knowledge that there could be vigorous competition (in that not all bidders can win 2x15MHz). In particular, it would be impossible to avoid competition on price simply by reducing the number of bidders.
- There may be some incentive not to make bids for 2x5MHz of spectrum in the hope that there is unallocated spectrum at the end of the auction and the 2x15MHz cap is relaxed. Clearly this creates opportunities for other bidders to win 2x5MHz spectrum cheaply, so it is difficult to see what the overall effect might be.

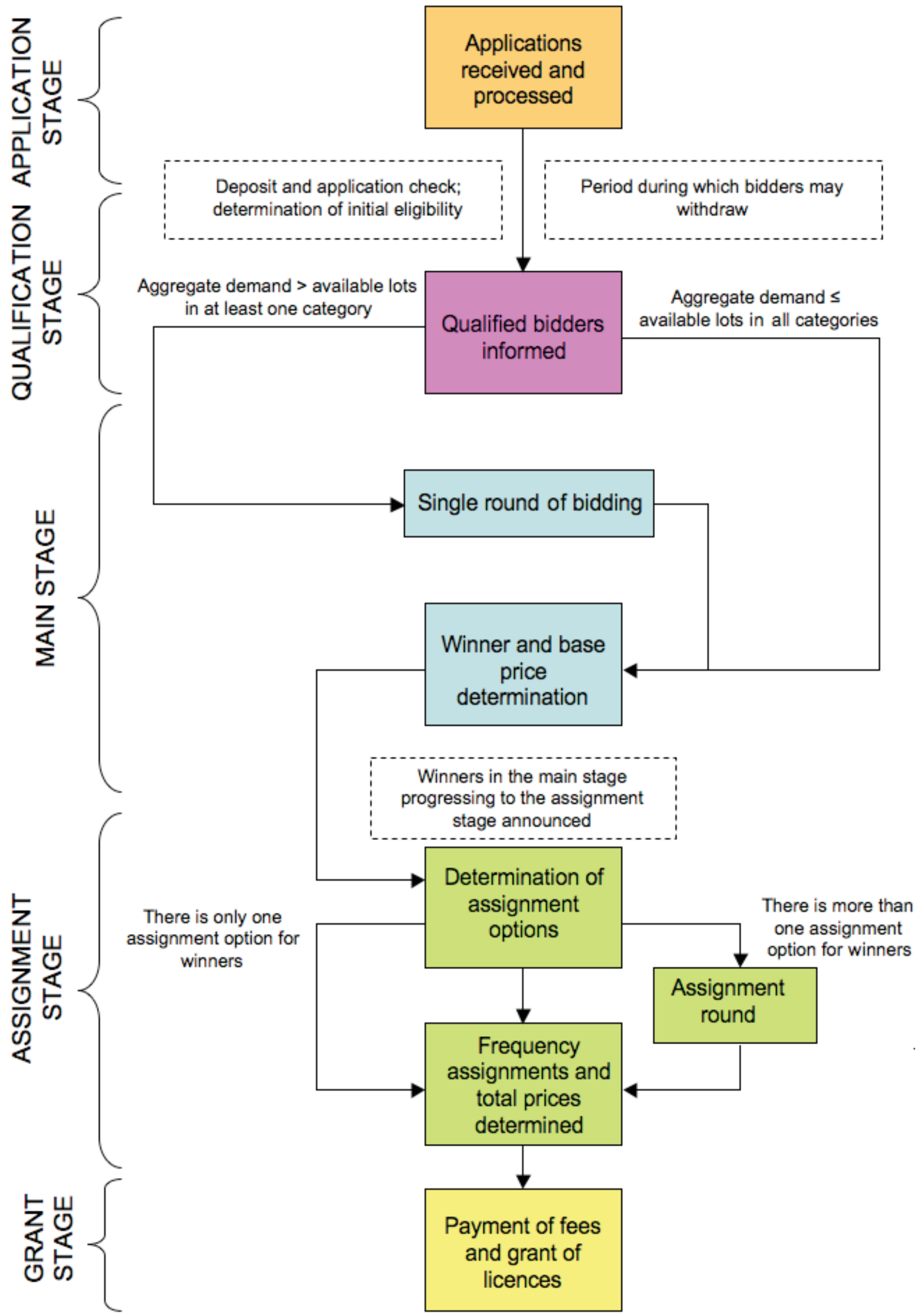
Neither of these potential problems appears to be particularly severe, so this is an option that ComReg may wish to consider.

9 Proposed auction rules

384. In this section, we describe a set of rules for implementing an award of 900MHz spectrum using a sealed-bid combinatorial format. This set of rules has been written in a way that it could, with only modest amendments, be integrated into an Information Memorandum. For purely illustrative purposes, we assume a reserve price of €100,000 for every year per lot in a category - €400,000 for a lot in the 2011-15 category and €1,500,000 for a lot in the 2015-30 category.

385. We envisage a five-stage award process, as illustrated in Figure 16. The description below focuses, in particular, on the two 'auction' stages: the Main Stage and the Assignment Stage. The other stages are described in less detail as they are more administrative in nature and would need to be integrated with ComReg's existing procedures.

Figure 16: Proposed five-stage process for 900MHz award



9.1 Application Stage

386. ComReg will announce on its website a time and day by which time all prospective bidders in the 900MHz auction must have submitted an application and associated bid deposit.

387. An application shall consist of:

- A completed bid form specifying the number of lots in each category – 2011-2015 and 2015-2030 – that the bidder is willing to purchase at the respective reserve prices for each lot category. The maximum number of lots that a bidder can apply for is four, two in each lot category.
- Administrative information, including contact information and details about ownership structure, to be defined by ComReg.
- A signed declaration stating that the bidder will abide by the auction rules and procedures, and has submitted the requisite deposit.
- Any other information reasonably required by ComReg.

388. The bid deposit must be transferred to a bank account, as nominated by ComReg, before midnight on the same day that applications are due. The total amount of the bid deposit must be at least equal to the total of the reserve price per lot category multiplied by the number of lots in each category that the bidder has applied for. For example, if a bidder applied for two lots in both lot categories, it must submit a bid deposit of €3,800,000 (the sum of 2 multiplied by €400,000 and 2 multiplied by €1,500,000).

389. Following the completion of the application process, ComReg will not publicly announce the identity of the applicants or the number of applicants.

390. Because ComReg will not announce the identities of the applicants, it is not possible to use a self-certification scheme to identify any overlapping ownership or control amongst bidders. Self-certification has been used in many recent auctions, where ownership information provided with applications is sent to all applicants and then bidders required to certify that they have no overlaps with other bidders. Although self-certification is administratively attractive, as it reduces the burden on the regulator, it would undermine the policy of not informing applicants about who the other applicants are, which is needed to control the potential risk of tacit collusion.

9.2 Qualification Stage

391. The qualification stage determines the applicants that qualify to bid in the auction and, if required, their eligibility to bid for lots in the Main Stage.

392. In order to qualify to participate in the auction, prospective bidders must:

- have fulfilled the application and bid deposit requirements; and
- not be associated with any other applicants that have not withdrawn their application.

393. There will be a gap of at least 10 working days between the deadline for receipt of the applications and applicants being told that they have qualified. During this period, any applicant may withdraw its application by submitting a written request to ComReg. In this case, the application will be annulled and the applicant will be refunded their deposit less an administrative fee (the amount of which would be determined by ComReg).

394. The gap between application and qualification provides an opportunity for ComReg to determine whether any applicants are 'associated' with any other applicants. If any

applicants are associated, they will each be informed by ComReg and at most one of the associated applicants may participate. All other associated applicants must withdraw by a deadline specified by ComReg.

395. After the deadline for withdrawals has passed, ComReg will tell applicants whether or not they have qualified to participate in the auction. ComReg will not publicly announce the qualified bidders, or the number of qualified bidders or those applicants who failed to qualify. These will only be announced with the results of the Main Stage.

396. ComReg will publicly announce whether or not the Main Stage is required. If the Main Stage is not required, the award will progress directly to the Assignment Stage.

397. If at any point subsequent to the deadline for withdrawals and prior to the grant of licences, two or more bidders are determined by ComReg to be associates as a result of information coming to light that was not provided with their applications, then all such parties will be disqualified, will forfeit any deposit that they have submitted and may be liable for any further bids that they have submitted.

9.3 Main Stage

398. The Main Stage will consist of a single sealed-bid round. The Main Stage is only required if there is excess demand for lots in at least one lot category. Excess demand is defined as:

- aggregate demand for lots in the 2011-2015 lot category exceeding 5; or
- aggregate demand for lots in the 2015-2030 lot category exceeding 7.

9.3.1 Sealed-bid round

399. The sealed-bid round is a single round during which bidders may place multiple bids for different packages of generic lots across the two lot categories. A bid consists of a specified number of 2011-2015 lots and 2015-2030 lots and a total price for the package in whole Euros. These bids are subject to the spectrum cap of 2x10MHz per bidder in any time slice and reserve prices stated by ComReg before the start of the auction. These bids are unconstrained.

400. In the event that Meteor submits a bid for lots in the 2011-2015 category, it may be required to state its position regarding the release of its existing GSM spectrum. If Meteor bids for two lots in the 2011-2015 category, this is not necessary; such a bid would imply its relinquishing of both blocks C and D. However, if it bids for only one lot in the 2011-2015 category, it must nominate which of block C and D it surrenders. In the event that such a package bid wins, Meteor shall be entitled to a rebate on its winning price equal to the terminal value of its GSM licence which is valid until 2015. The amount of the proposed rebate for the surrender of Meteor's GSM licence from 2011 would be determined by ComReg and announced publicly prior to the auction. Where only part of Meteor's current 900MHz licence was to be relinquished, this amount would be pro rated to reflect the actual quantity of spectrum surrendered. For the avoidance of doubt, bids by Meteor including the release of existing spectrum in the 2011-2015 category are considered to be *gross* of any rebate and its winning price will first be calculated on the same basis as other bidders before any rebate is applied.

401. The sealed-bid round will be scheduled to run for a full working day. Bids would be submitted on paper in a manner specified by ComReg. Electronic copies should also be submitted (in a spreadsheet) to assist calculation of the results.

9.3.2 Calculation of winners and winning bids

402. Once the sealed-bid round closes, ComReg will determine which bids are valid. Winning bidders and the resulting winning bids are determined.

403. The set of winning bids is the combination of valid bids of greatest total value subject to the conditions that:

- At most 5+*n* lots are allocated in the 2011-2015 category, where *n* is the number of lots released in any bid by Meteor within the winning combination;
- At most 7 lots are allocated in the 2015-2030 category;
- No bidder wins more than two lots in any lot category; and
- At most one bid for a package of lots is accepted from each bidder.

404. An algorithm is used to determine the combination of bids that meets these criteria. Where there is more than one set of bids that have the same highest total value, the winning set of bids will be chosen from these combinations of bids with the highest value at random. This procedure will find the most efficient allocation of spectrum given the bids received.

405. Each winning bid has an associated base price which the winning bidder then becomes liable for. The base price of a winning bid is an overall price for the entire package of lots included in the winning bid. Therefore, a separate base price is determined for each winning bidder. (Notice that this does not involve determining a price per lot for any lot category.) There is no base price for a bidder who does not win any lots in the Main Stage.

406. Base prices are calculated using a second price rule. This is a single calculation that jointly determines a set of base prices – one for each winning bidder. One method of calculating base prices is described below.[28]

407. First, base prices are subject to the condition that the base price of a winning bid must be greater than or equal to the total reserve prices of the lots within the package associated with that winning bid.

408. Second, base prices are required to satisfy the following condition (which is described here as an algorithm for checking that the condition is satisfied):

- calculate the total amount of the winning bids (call this the "winning bid total" - W);

[28] For a description of the second-price rule and some examples of the calculation of second prices, see D. Maldoom (2007) "Winner determination and second pricing algorithms for combinatorial clock auctions", DotEcon Discussion Paper, http://www.dotecon.com/publications/dp0701.pdf

- for each winning bid, find the difference between the amount of that winning bid and the corresponding base price (call this the "price difference" for that winning bidder);
- calculate the total of the price differences for all winning bidders (call this the "total price difference" - P);
- take all of the winning bidders' Main Stage bids, and subtract the corresponding price difference for each winner from *all* bids made by that winner (call these the "modified bids");
- re-run the determination of winning bids using (a) the losing bidders' Main Stage bids without modification, and (b) the winning bidders' modified bids as reduced by the price differences (call this the "modified winner determination");
- calculate the total of the winning bids found in the modified winner determination (call this the "modified winning bid total" - MW);
- the sum of the modified winning bid total (MW) and the total price difference (P) is then required to equal the winning bid total (W).

409. There are typically many sets of base prices that satisfy these two conditions. However, all have the property that the base price of a winning bid is not more than the amount of that winning bid.

410. Amongst all these various sets of base prices, a third condition is imposed that the sum of the base prices across winning bidders is minimised. Therefore, only sets of base prices are allowed that:

- satisfy the two conditions above; and
- are such that there is no other set of base prices that also satisfies the two conditions above and where the sum of base prices across bidders is lower.

Winning prices determined by this method are in effect the lowest bids that winners could have made (instead of the bids they actually made) and still won the same packages.

411. Where there is only one set of base prices (one base price for each winner) satisfying these three conditions, this determines the base prices for the Main Stage. In the case that there are many sets of base prices satisfying these three conditions, a fourth condition is imposed that selects a unique set of base prices. This condition is expressed in terms of an algorithm for checking that it is satisfied:

- first calculate the opportunity cost for a particular winning bidder which is defined to be:
  - the amount of the winning bid of that bidder; less
  - the total of all winning bids in the winning combination; plus
  - the greatest possible total of bids subject to: (i) accepting at most one bid from each bidder; (ii) accepting no bids from that winning bidder; and (iii) allocating each lot at most once;

- second, the sum of the squares of the differences between the base price for each winner and the opportunity cost for that winner should be minimised amongst all sets of base prices satisfying the previous three conditions.

412. This procedure produces a unique base price for each winning bidder that is no more than their winning bid and is at least the reserve price for that package.[29]

9.3.3 Information available after the Main Stage

413. Once the auctioneer has determined the winning bids and the base prices, the outcome of the Main Stage will be announced to bidders. The following information will be released to all bidders:

- the identity of the winning bidders;
- the number of lots won in each lot category by each winning bidder;
- any applicants who did not qualify.

414. In addition, each winning bidder will be told the base price that applies to their winning bid. This information will not be released to other bidders at this stage or made public.

415. Losing bidders will be refunded their deposits, unless these have been forfeited for some reason.

9.4 Assignment Stage

416. By this point, the Main Stage (or Qualification Stage if no Main Stage is required) will have already determined the winners in each lot category and how many lots in these lot categories each winning bidder will receive. The purpose of the Assignment Stage is to determine how the available frequencies in the 900MHz band are distributed amongst the winning bidders from the Main Stage for each time slice (2011-2015, 2015-2030) and the final price to be paid by each winning bidder.

9.4.1 Assignment options across frequencies and across time categories

417. Winners of more than one lot will be guaranteed contiguous spectrum in a lot category; that is, only assignment options that ensure spectrum contiguity to winners of more than one lot in a given time slice will be considered. Bidders will be able to

[29] To illustrate how the second price rule works, consider the following simple example for an auction with 10 lots and one category. Suppose that there are five bidders. The winning bidders are: A (3 lots @ €30); B (3 lots at €30); and C (4 lots at €40); and the losing bidders are: D (2 lots at €15); and E (4 lots at €35). Bidders A, B and C must each pay enough that there is no alternative grouping of bidders prepared to pay more for the spectrum. Therefore, we can describe the following conditions for Prices:

- Price (Bidder A) ≥ 15; Price (B) ≥ 15; and Price (C) ≥ 35;
- Price (A + B) ≥ 15 + 35 = 50; Price (B + C) ≥ 15 + 35 = 50; and Price (A + C) ≥ 15 + 35 = 50

In this case, there is only one set of prices that meets these conditions: A and B must each pay €25; and C must pay €35.

express their valuations for being assigned the same spectrum frequencies in each time category, but this is not guaranteed – the selection of those bidders that will be awarded frequencies that meet this criterion in the final assignment outcome and those that will be required to shift frequency blocks during their licence period will be determined by bids made in the Assignment Stage.

418. The format of the Assignment Stage is the same as that of the sealed-bid round in the Main Stage – a single round with combinatorial bidding. The key difference in this round relative to the sealed-bid round in the Main Stage is that valid bids from each bidder in this round are only those that coincide with the same number of lots the bidder has already won in that category in the previous stage, or a sub-set thereof.

9.4.2 Scheduling the assignment bid round

419. For all categories where there is more than one winning bidder, an assignment bid round is required.

420. The start time and duration of the assignment bid round will be announced by the auctioneer after the completion of the Main Stage. The auctioneer has discretion over the time and duration of the round. However, it is anticipated that the round (if required) will take place a few business days after the Main Stage and last one working day.

9.4.3 Bid options for the assignment bid round

421. In this round, bidders may bid to be awarded any of the lots available in the lot category or categories in which they have been allocated spectrum:

Figure 17: Lots available in each lot category

2011-2015	2015-2030
A1	A2
B1	B2
C1	C2
D1	D2
E1	E2
F1	F2
G1	G2

Note: Lots in greyscale represent the lots available in this award

422. Consider, for example, the following sample set of results at the end of the Main Stage, where all lots in each lot category are assigned amongst four bidders as shown in Table 6:

Table 6: Sample set of winners from the Main Stage

Bidder	**Licence categories**	
	2011-2015	*2015-2030*
Bidder I	1	1
Bidder II	2	2
Bidder III	2	2
Bidder IV	0	2
Total	*5*	*7*

423. Given the spectrum allocation to bidders described above, a sample set of assignment bid round bids that could be submitted by winners of the Main Stage might correspond to the following packages:

- Where Bidder I has a value for being assigned the same spectrum frequencies in each time category, it may wish to place bids for all of the consistent frequency allocations (bids for A, B, E, F and G in both lot categories).
- Where Bidder II has a value for being assigned the same spectrum frequencies in each time category, it may wish to place a bid that expresses its value of being awarded any of the consistent frequency allocations. Further, it may also have a (higher) value for being re-assigned the block it currently holds in full plus the block it currently shares with Bidder III (that is, for F and G in both time slices).
- Where Bidder III has a value for being assigned the same spectrum frequencies in each time category, it may wish to place a bid that expresses its value of being awarded any of the consistent frequency allocations. Further, it may also have a (higher) value for being re-assigned the block it currently holds in full plus the block it currently shares with Bidder II (that is, for E and F in both time slices).
- Where Bidder IV has a value for being assigned the same spectrum frequencies as it currently holds, it may wish to place a bid that expresses its value of being awarded the C and D blocks in both lot categories.

9.4.4 Submitting assignment round bids

424. Assignment round bids must be in whole Euros. The default minimum bid for each option is zero. There is no upper bound for bids in this round.

425. If a bidder fails to submit a bid in the available time, then it will be deemed to have made a valid bid of zero for every assignment option in every lot category option in every category where it has won a generic lot in the Main Stage.

426. Only the relative bids made for different bid options will affect the final assignment outcome and the additional prices to be paid. Therefore, it is prudent (but not obligatory) for bidders to submit a bid of zero for their least favoured option in every lot category and/or their least preferred packages for which they are eligible to bid.

9.4.5 Winner determination

427. Following the close of the assignment bid round, the auctioneer will proceed to determine the winning bids. Any valid assignment options for which a bidder made no bid will be deemed to have received a bid of zero.

428. The winning bids are the combination of assignment bid round bids of greatest total value amongst all valid bids submitted, subject to the conditions that:

- exactly one bid is accepted from each bidder;
- each winner of more than one lot within a time slice receives contiguous frequencies within that time slice; and
- each bidder is assigned the same amount of spectrum in each time category as they won in the Main Stage.

429. An algorithm will be used to determine the combination of bids that meets these criteria. It is possible that there could be more than one set of bids having equal highest value. In this case, the tie will be resolved using a randomisation process. All such tied sets of bids will have an equal chance of winning.

9.4.6 Determining additional prices and the auction price

430. The additional prices to be paid by those assigned their desired frequencies are determined using a second price rule analogous to that used to determine prices in the Main Stage.

431. First, additional prices are required to be positive or zero.

432. Second, additional prices must satisfy the following condition (which is described as an algorithm for checking that the condition is satisfied):

- calculate the total amount of the winning assignment bids (call this the "winning assignment bid total" - AW);
- for each winning assignment bid, find the difference between the amount of that winning assignment bid and the corresponding additional price (call this the "price difference" for that winning bidder);
- calculate the total of the price differences for all winning bidders (call this the "total price difference" - AP);
- take all of the winning bidders' assignment bids, and subtract the corresponding price difference for each winner from *all* Assignment Stage bids made by that winner (call these the "modified assignment bids"), setting the modified assignment bids to be zero where they would otherwise be negative;
- re-run the determination of winning assignment bids using the method described in section 9.4.5, but using the winning bidders' modified

assignment bids as reduced by the price differences (call this the "modified assignment winner determination");

- calculate the total of the winning assignment bids found in the modified assignment winner determination (call this the "modified winning assignment bid total" - MAW);
- the sum of the modified winning assignment bid total (MAW) and the total price difference (AP) is then required to equal the winning assignment bid total (AW).

433. Again, there are typically many sets of additional prices that satisfy these two conditions. Amongst all these various sets of additional prices, a third condition is imposed that the sum of the additional prices across winning bidders is minimised.

434. Where there is only one set of additional prices satisfying these three conditions, this determines the additional prices for the Assignment Stage. In the case that there are many sets of additional prices satisfying these three conditions, a fourth condition is imposed that selects a unique set of additional prices. This condition is expressed in terms of an algorithm for checking that it is satisfied:

- first calculate the opportunity cost for a particular winning bidder which is defined to be:
  - the amount of the winning assignment bid of that bidder; less
  - the total of all winning assignment bids; plus
  - the sum of winning assignment bids in a modified winner determination as described in section 9.4.5 in which that winner's assignment bids are all set to zero;
- second, the sum of the squares of the differences between the additional price for each winner and the opportunity cost for that winner should be minimised amongst all sets of prices satisfying the previous three conditions.

435. This procedure produces a unique additional price for each winning bidder that is no more than the winning additional bid.

436. The auction price for each bidder will be the sum of the base price associated with the number of lots in each category allocated to them plus any additional prices associated with the specific frequency ranges assigned to them based on their assignment bid round bids.

9.4.7 Procedure for assigning lots if no assignment bid round is required

437. No assignment bid round is required in the case that there is no more than one winning bidder in any one lot category. In this event, this bidder will be assigned frequencies directly by ComReg based on the frequencies available and resulting implications for future assignment of spectrum in the 900MHz band. These frequencies will be consistent across time slices where possible.

9.4.8 End of the Assignment Stage

438. Once the auctioneer has determined the winning bids and the additional prices for the Assignment Stage, the results of the auction will be announced to all bidders. The following information will be released to all bidders:

- the identity of the winning bidders;
- the number of lots in each lot category awarded to each winning bidder;
- the frequency ranges awarded to each winning bidder for each time slice; and
- the auction price to be paid by each winning bidder, including a breakdown of the base price and any additional price applicable to that bidder.

9.5 Grant Stage

439. Following the completion of the Assignment Stage, the award process will proceed to the Grant Stage. During the Grant Stage:

- winning bidders are required to pay the total price associated with the spectrum assigned to them as part of the award, less their deposit; and
- licences are awarded to bidders.

PART C: Reserve prices and payment terms

10 Minimum prices

440. In this part of the report, we consider issues around the setting of reserve prices and payment terms for the auction. The first issue we consider is that of minimum prices – the minimum amount a bidder would need to pay for a licence even if there is little or no competition in an auction.

441. Taking the above into account along with ComReg's particular objectives for this auction we provide a recommended range for the minimum price of a 15-year licence to use a 2x5MHz lot in the 900MHz band in Section 12 and consider how this should be split between a reserve price in the auction and spectrum usage fees.

442. In order to get to these conclusions, in Section 11 we look at usage charges for spectrum set in Ireland and other countries.

10.1 Terminology: reserve prices, minimum prices and on-going charges

443. We start by defining the terms used throughout this part of the report to describe the various types of payments that spectrum licensees may need to make.

444. A **reserve price** in an auction is a price floor below which a lot will not be sold. If an auction is uncompetitive, lots may be sold at the reserve price if they are sold at all. In multi-round auctions, the reserve price usually (but not always[30]) serves as a starting price for bids in the first round of an auction. More generally, in combinatorial auctions (whether open or single-round), there is usually a requirement that any package bid must exceed the total reserve price of its component lots; reserve prices also act as a floor on winning prices.

445. Alongside any up-front payments made immediately on award of a licence, there may be other on-going payments made subsequently through the life of the licence, such as **annual payments**. A specific form of on-going payment is a **spectrum usage fee (SUF)** payable throughout the period that spectrum is available for use by the licensee. In Ireland, licence fees are generally broken down into both once-off and recurring charges. For example for the 3G licence award in 2001[31], the 3G licence fee consisted of:

- a spectrum access fee comprising an up-front payment and deferred payments in certain years.
- annual spectrum usage fees for which there might be a discounted payment structure for the early years of the licence.

[30] Some reserve price arrangements can be quite complex. For example, the US C-block auction in 1998 had a collective reserve price that needed to be achieved across a number of lots. Sometimes reserve prices are not announced to bidders in advance and so unrelated to the starting prices in an open auction.

[31] See Information Memorandum of 3G licence award in 2001, Document Number ODTR 01/96.

446. If there is little or no competition in an auction, then a licence might be won at the reserve price. However, there could additionally be on-going payments that the winner is committed to making, such as SUFs. A broader definition of the **minimum price** that the winner needs to pay should also include such on-going payments, as these will also be taken into account by bidders and would need to be paid even if prices were not raised above their starting level in an auction. Therefore, to avoid confusion, we use the term **minimum price** to refer to the combined effect of a reserve price and any other on-going fees that can be anticipated prior to the auction. For bidders, the effective minimum price is the sum of the up-front reserve price and the discounted stream of annual fees.[32]

447. On-going fees clearly affect the value of a spectrum licence to bidders. If on-going fees are increased, this decreases the expected net present value of a licence and can be expected to lower prices achieved in an auction. Therefore, for the purposes of determining what might be a sensible reserve price, we need to take account of on-going fees. This means that the most coherent approach is to first consider a possible minimum price, then consider how best this might be broken into a single up-front payment (i.e. a reserve price) and an on-going stream of payments (such as an annual SUF). In total, these various payments should implement an appropriate minimum price, allowing for discounting of the annual payments.

10.2 Key issues in setting minimum prices

448. A minimum price is the lowest price that the seller in an auction is prepared to accept. Minimum prices only affect the auction outcome if there is no excess demand at the minimum price; otherwise, the final price would be determined by bids in the auction. Therefore, the minimum price needs to be set with regard to low demand scenarios, rather than scenarios where there would be excess demand.

449. In fact, theory[33] tells us (at least in simple settings) a seller wishing to maximise revenue should set the minimum price for a single lot to be the price that the seller would set if it had to make a 'take it or leave it' offer to a single bidder. The seller would determine this 'take it or leave it' minimum price by trading off the probability of the single buyer refusing the offer versus raising higher revenues hence the seller would set the optimal minimum price that maximises expected seller revenue.

450. In practice, the criteria for a spectrum regulator such as ComReg to set minimum prices are more complicated. It is not ComReg's objective to maximise revenue in this auction. Therefore, in determining minimum prices, it would not be appropriate for it to trade off revenues against the probability of selling lots in the same way as a private seller might. Rather, its priority is to

[32] Note that the discount rate may vary between bidders.

[33] Bulow, Jeremy and John Roberts (1989) "The Simple Economics of Optimal Auctions", Journal of Political Economy, Vol. 97, No. 5. (Oct.), pp. 1060-1090.

support the efficient use of spectrum, so as to generate value for the Irish economy and society.

451. In pursuing efficient allocation and use of spectrum, there are a number of issues to be considered when setting a minimum price:

- First and foremost, minimum prices should not be set so high as to choke off demand of serious bidders;
- Minimum prices should not be set so low that there is participation by frivolous bidders[34];
- The administrative costs of running the award process should be recovered;
- Any "social option value" in awarding spectrum later need to be reflected;
- Collusion incentives need to be controlled.

452. If a minimum price were set simply to reflect administration costs and to deter frivolous applications, this would certainly also avoid any risk of choking off demand. Setting low reserve prices has become quite popular with European spectrum authorities in recent awards for this reason, as we discuss in detail below. In some cases, this might be a reasonable approach. However, for this award, the issues of the option value of delaying the award of spectrum and collusion incentives should not be ignored.

453. There may be many public policy reasons for not releasing spectrum too cheaply if there might be potentially better future options for awarding it. Competition may be weak in an auction for many reasons, including poor timing, technological or standards uncertainty or the state of capital markets. In such cases, there may be public benefit in deferring the award of spectrum until conditions are more favourable and uncertainty is reduced for bidders. This consideration is especially important in Ireland due the absence of secondary trading, as proceeding with a problematic auction that produces an outcome that cannot be modified later may be particularly unattractive. If spectrum is released in an auction where competition is weak, auction prices may not fully reflect the true, long-run opportunity cost of holding the spectrum.

454. The factors motivating the proposed timing of this award include the introduction of the Amending GSM Directive and the need to make available spectrum attached to licences due to expire in the near future. In carrying out the award of such a critical band of spectrum, greater consideration will be given to the implications of timing for the award. For example, we consider the structure of payments of licence fees in light of the current economic and financial climate in Section 13 below.

[34] Participation fees are an alternative instrument that may be more useful if this is a serious concern. In this case, the costs to a bidder of understanding the award process and preparing an application are non-trivial, so frivolous bidding is not a major concern.

455. In addition, a low minimum price is more likely to encourage collusive behaviour (whether tacit or explicit collusion). Some previous spectrum auctions with low minimum prices, such as the Swiss and Dutch 3G auctions, have been blighted by pre-auction deals between bidders attempting to fix demand at the level of supply for similar reasons[35]. Thus where collusive behaviour among bidders is a concern, setting a higher minimum price would be appropriate as this reduces the benefits from colluding or otherwise fixing demand.

456. A further consideration for ComReg is the structure of payments associated with the minimum price, and the impact this has on incentives for bidders to use or return their licences in the future. In the absence of trading, future annual SUFs are perhaps the only significant tool available to ComReg to encourage licensees to return spectrum that might not be being used efficiently. Therefore, an additional reason for setting a reasonably high minimum price is that this then allows for a correspondingly high SUF to encourage the release of any spectrum that may be inefficiently used.

10.3 Methodologies for setting minimum prices

457. There are a variety of approaches that can be used both to set minimum prices and gather useful information about an appropriate level that is unlikely to choke off efficient demand. Below, we outline four possible approaches:

- ***Modelling costs and revenues:*** This approach involves constructing high-level business cases for likely bidders. The incremental profits of the operator from these business cases will provide an indication of the buyer's willingness to pay for the spectrum, and thus an upper bound for the minimum price level. Such exercises are informative, but are relatively resource intensive to conduct – especially when there are multiple classes of bidders with very different business models. There is a large degree of uncertainty in any such valuation estimates, but nevertheless this technique should provide an indication of how increasing the minimum price may discourage certain types of bidder and affect the probability of spectrum going unsold.
- ***Benchmarking:*** This approach involves gathering data for minimum prices and licence prices for awards of comparable spectrum in other countries and adjusting these to provide benchmarks for Ireland. This is a versatile approach where different cuts or treatment of the relevant data can produce a range of benchmark values for the price of liberalised 900MHz spectrum in Ireland.
- ***Low but non trivial:*** Under this approach, the minimum price is simply set at the lowest level that could be expected to deter frivolous participation in the process, and thus ensure all winning bidders have serious business cases. This is the simplest approach to minimum price

[35] See, for example: A-Focus and DotEcon (April 2004), The Use of Auctions in Spectrum assignments, a report for PTS (Sweden), p.38.

setting and has recently been adopted or will be used by many national regulatory authorities (NRAs) around the world such as Ofcom, NPT, PTS, NITA, and regTP. Under certain circumstances, this could raise concerns about incentives for collusion amongst bidders. As discussed above, there are good reasons why this approach is inappropriate for this award.

- ***Administrative costs:*** The incremental cost of administering each licence in theory provides a lower bound on the minimum price that ComReg might set. An alternative might be to set a higher level, in which not just the incremental costs of the particular award are recovered, but also some contribution made to the common costs of running a regulator's spectrum management function (which is common across different awards). In practice, the administrative costs of running an award are likely to be small relative to the value created by users, so this method may not be much different to the 'low but non-trivial' approach.

458. These methodologies are not exclusive. In particular, the cost modelling and benchmarking exercises provide complementary information about the range of values within which a sensible minimum price may lie. In both cases, we are seeking information about how the minimum price may affect the probability of licences going unsold. In the absence of reliable information, a precautionary approach to setting minimum prices may be necessary, keeping minimum prices sufficiently low.

459. A further issue for any minimum price setting methodology is the interaction between licence conditions and the value of licences. Placing onerous conditions on licences will lower their value and this needs to be taken into account when considering minimum prices. The approach we have taken is to assume that licence conditions are not onerous and, at least as an approximation, that we can ignore this interaction. Some of our benchmarking analysis (in particular, econometric modelling of licence prices in auctions) does take account of licence conditions in a limited way. Nevertheless, the conclusions we ultimately reach are based on benchmarks and so would need to be revised if licence conditions were much more costly to comply with than those set in other jurisdictions.

10.3.1 Modelling costs and revenues

460. When setting minimum prices, the value of the spectrum to potential bidders (especially weaker bidders) provides an indication of the maximum level beyond which efficient demand may be choked off. Spectrum valuations can be estimated through an assessment of the net benefit to a potential bidder by quantifying the incremental value of the bidder's business, as a result of being able to utilise the spectrum i.e. by consideration of the value of the business with the spectrum less the value of the business without the spectrum (i.e. the next best alternative). Net benefit estimates should be made over the time period associated with the licence, and a net present value calculated.

461. Such spectrum valuation exercises typically take one of two forms:

- For a potential new market entrant, often the alternative for the business is to 'do nothing' so the maximum amount the new entrant would be willing to pay for the spectrum amounts to a proportion of the net present value of the business (revenue less costs) discounted by the required rate of return.

- Existing businesses can often derive additional revenue streams from access to additional spectrum or may make cost savings on existing services. Here, the value of the spectrum would need to factor in incremental cashflows over the period of the licence.

462. Similar valuation approaches are typically used by bidders in preparing for spectrum auctions. Obviously a spectrum authority cannot undertake such modelling to the same depth as a bidder and would not have the same quality of information available. Instead, high-level models can be developed which provide an indicative ballpark valuation of the spectrum and inevitably have to take a conservative approach.

463. The modelling of revenues and costs of potential bidders provides a potential means for ComReg to gain an estimate of the value of the spectrum to potential bidders. By considering the business cases of marginal bidders, an upper bound on a minimum price can be obtained. However, such an exercise is complex and time consuming, and may not be appropriate in all circumstances.

464. We can anticipate particularly severe problems if we were to use business case modelling to set a minimum price for the current award of liberalised 900MHz spectrum. For many bidders, the benefit of liberalised spectrum is likely to derive from having a higher quality data proposition (e.g. 3G in-building and rural coverage) and from greater flexibility in migrating from 2G to 3G. These sources of value are highly dependent on how demand for data services is expected to grow, the importance that the competitive marketplace places on certain aspects of service quality and, indeed, how incumbent operators currently configure their networks. Many of these factors are likely to be quite specific to operators and difficult to model. Potentially bidders will have private information to assist in valuing the liberalised spectrum that is not available to outside parties. Because of the importance of bidders *existing* market positions in determining what they might be prepared to pay, it is not realistic for an outside party to build a business case model in the same way that potential bidders might. For these reasons, building business cases does not seem like a reliable or useful approach for determining minimum prices for this award.

10.3.2 Benchmarking

465. Another approach to determining minimum prices is to look at both the licence fee and minimum prices of similar auctions to provide a benchmark for the value of 900MHz spectrum in Ireland. Over the last decade, a number of countries have held awards for spectrum in this or comparable frequency bands.

466. However, licences awarded in comparable spectrum auctions have either been in the 3G 2.1GHz and 2.6GHz bands **or** in the 900MHz band where the spectrum has only been used for the deployment of GSM. In theory, we know that 900MHz spectrum is more valuable than higher frequency spectrum usable for 3G (2.1GHz, 2.6 GHz, etc.) due to its superior propagation

characteristics; and we know that liberalisation should increase the value of spectrum. Therefore, inferences drawn from these awards about the value of liberalised spectrum in the 900MHz band in Ireland in our benchmarks will inevitably produce an underestimate. This does not mean that the exercise is not useful, but we must interpret the results accordingly.

467. There are a number of general issues to be considered when constructing benchmarks:

- ***Identifying sample data:*** Which awards should be included? Should the sample be restricted to the 900MHz band, or should it include similar bands, such as 850MHz (USA), 1800MHz, 2.1GHz and 2.6GHz? Should all types of award processes be considered or only those that were sold in an auction? Should all countries be included or only those with similar 'profiles' to Ireland? Does the timing of past awards matter?
- ***Treatment of data:*** The sample data identified contains spectrum awards from different countries that took place across a number of years. The licence characteristics of spectrum sold also varies across the sample data. In order to create comparable benchmarks for Ireland, the sample spectrum award data would have to be adjusted for price differences, inflation, exchange rates and licence duration differences.
- ***Benchmark metrics and controlling for differences:*** When creating benchmarks for 900MHz spectrum in Ireland, there are a variety of metrics that could be use to produce relevant benchmarks. These metrics control for factors that might affect spectrum value in award processes in different countries. These include country statistics such as population, population density, income per capita; telecommunications market metrics such as market competitiveness; as well as metrics specific to the award process such as the competitiveness of specific auctions, the type of spectrum awarded and technical conditions/restrictions on licences.

468. A further consideration is the techniques available for deriving benchmarks. A standard approach for spectrum awards is to consider a simple average of price per pop per MHz (i.e. the price divided by the population of the licensing region divided by the amount of spectrum in MHz available[36]) across a cut of the sample data. Different benchmarking metrics (as described above) can be used to create various cuts of the data that is comparable to the upcoming Irish 900MHz auction. The average licence prices achieved in auctions from these cuts of data will provide a range of benchmarks for predicted licences value of 900MHz spectrum in Ireland.

469. A more sophisticated approach is to consider larger samples but use econometric techniques to control for the differences in spectrum value that might arise across awards, countries and time. This approach considers the joint impact of various benchmark metrics on spectrum value. We use this approach in a second step. This technique has the potential to be more

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[36] Note that if the licence is for paired spectrum, then both the upper and lower blocks are counted, e.g. a 2x5MHz lot counts as 10MHz.

reliable as it controls for known difference between awards prior to making comparison, but raises issues about why one particular mathematical formulation has been used rather than another.

470. Determining the appropriate sample and benchmark metrics is a matter of judgement, not an exact science. Therefore, for the 900MHz band, we consider it appropriate to develop a number of benchmarks drawing on different samples and approaches, and compare the results qualitatively. This is elaborated further in Section 10.5.

10.3.3 Low but non-trivial minimum prices

471. Under this approach, the minimum price per lot is set at an arbitrarily low level, being an amount at which:

- no genuine bidder with a plausible business case would likely be discouraged from bidding for the spectrum; and
- only frivolous or speculative bids would be deterred.

472. Low but non-trivial minimum price setting has been adopted widely by Ofcom for recent and forthcoming UK spectrum awards. There is no particular rationale for the reserve prices chosen, other than that they are consistent across the available lots and they should all be sufficient to deter frivolous bidding.

473. This approach has three significant advantages from the perspective of a regulator. Firstly, it is very simple to implement and avoids any need for extensive justification of the reserve price setting methodology. Secondly, it should guarantee that no spectrum will go unsold inefficiently. Put differently, with minimum prices at these levels, if there is spectrum that is unsold, it will be due to deficient demand, not because demand has been choked off by an excessive reserve price. Thirdly, it prevents the regulator from being exposed to any accusations that it is revenue raising.

474. However, this approach also has a number of potential downsides and it should not be assumed that simply because the approach is now quite widely used it is appropriate for all awards:

- In the event of deficient demand, revenues will likely be very low. This may be unsatisfactory if this represents a failure to achieve maximum economic benefit from the spectrum because the timing of the award was inappropriate.
- There may be incentives for bidders to collude before an auction or in the early rounds to fix demand so that all parties can benefit from low prices at the expense of the seller. This risk can be eased (but not eliminated) through auction rules that make collusion (tacit or otherwise) more difficult (such a limiting transparency), but nevertheless if the risk is significant it is prudent to use all available tools to reduce it.

475. In conclusion, given potential concerns about incentives for collusion, we are concerned that a minimum price set too low for this auction may be inappropriate.

10.3.4 Administrative costs

476. The incremental cost of administering each licence (including the costs of the award process) in theory provides a lower bound on the minimum price that ComReg might set. If a bidder could not at least afford to pay these costs, then it would probably be more efficient for ComReg to hold on to the spectrum until such time that a more valuable use emerged.

477. It is quite common for regulators to set upfront payments and annual fees which are at least in principle linked to spectrum management overheads, though often these might be additional to other charges. For example, the Danish government typically charges both a one-off amount to cover the costs of an award and an annual fee as contribution to spectrum management costs. However, by itself, charging administrative costs alone may result in a low minimum price that has similar drawbacks to the low but non-trivial approach.

478. While information on costs is clearly useful in considering the minimum price, this kind of data is typically difficult to obtain. In particular, there are large common costs across multiple bands in spectrum management, making it difficult to allocate costs to any specific band. This also means that it may be difficult to determine administrative costs for one band without a much larger review, which would be resource intensive.

479. In conclusion, administrative costs provide an important justification for a non-zero minimum price. However, for this award, we doubt it would be practical to undertake a formal evaluation of such costs as a justification for setting the minimum price. Other considerations suggest setting a minimum price much above this level, in which case administrative costs would become a negligible aspect of the minimum price.

10.4 Reserve price trends in recent awards

480. The recent trend among European spectrum regulators seems to be towards setting low reserve prices. This is evident in the low but non-trivial reserve prices set for 2.6GHz spectrum auctions in Norway, Sweden, Denmark, Germany and the Netherlands (which are detailed below). This trend is also exemplified in the low reserve prices Arcep set for an upcoming auction for the fourth French 3G licence of €240 million (approximately €0.10 per MHz per head of population)[37]. This seems to have led the Bouygues Group to consider submitting a complaint to the European Commission on concerns that the fourth 3G licence would be awarded at a much lower price than it paid for its 3G licence in 2002[38].

481. For the 2.6GHz auctions held to date, the low but non-trivial approach has been the most common approach for setting reserve prices. This was explicitly adopted in the Netherlands and Denmark and also appears to have been the approach in the completed award of spectrum in the 2.6GHz band in Norway

[37] http://www.cellular-news.com/story/39366.php?s=h

[38] Bouygues Group paid 619 million Euro (in 2002 prices) for its 3G licence in 2002 in a Beauty Contest.

and Sweden. In the United Kingdom, Ofcom has adopted this approach for awards in various bands such as for the cancelled award of spectrum in the 2.6GHz band. We also expect that Ofcom will use this approach in the future.

482. In Norway, bidders were obliged to submit a bank guarantee for the amount of their bids in the first round. NPT remarked that, "the overall objective of the guarantee is to ensure that those registering for the auction have a genuine interest in the available frequency resource."[39] NPT adopted this approach notwithstanding potential concerns about low participation given that Norway has only two main mobile operators.

483. In Sweden, PTS did not provide a justification for its reserve prices, however it remarked that "minimum bids should not be interpreted as PTS's appraisal of the licences,"[40] which implies that the reserve prices were not in any way related to marginal valuations. Further, PTS imposes additional annual administrative fees of SEK25,000 per MHz, so administrative costs were presumably not a consideration either. In summary, it appears that PTS also adopted a low but non-trivial approach, but decided to adopt somewhat higher prices than the three other countries – possibly to speed up the auction.

484. FICORA, the Finish regulator did not provide a justification for its reserve prices in the upcoming award of spectrum in the 2.6GHz band. Yet, the reserve price for the Finish auction is similar to that in other 2.6GHz auctions, implying that FICORA are implicitly implementing low, but non-trivial, reserve prices.

485. Bundesnetzagentur, the German telecommunications regulator, has decided to award spectrum in the 2.6GHz band together with spectrum in the 800MHz digital dividend band. Interestingly, they have set the same reserve price for spectrum in both frequency bands despite the bands being likely to have different values, suggesting the approach is not related to underlying estimates of licence value.

486. The following table summarises the reserve prices set in these countries on a per MHz per population basis. We have calculated an implied reserve price for a 2x5MHz licence in Ireland on the basis of the minimum price per MHz per population figures.

[39] See http://www.npt.no/portal/page/portal/PG_NPT_NO_EN/PAG_NPT_EN_HOME/PAG_RESOURCE_TEXT?p_d_i=-121&p_d_c=&p_d_v=106026

[40] PTS, 2008, Open invitation to apply for licence for use of radio transmitters in 2500-2690MHz band, page 17.

Table 7: Reserve prices in other upcoming awards

Country	Band	Reserve price for 2x5MHz paired (local currency)	Price per MHz per population (Euro)	Implied reserve price for 2x5MHz in Ireland (Euro)
Norway	2.6GHz	NOK 1,000,000	0.00240	101,000
Sweden	2.6GHz	SEK 2,750,000	0.00279	117,000
Netherlands	2.6GHz	€ 100,000	0.000598	25,000
UK	2.6GHz	£ 100,000	0.000191	8,000
Denmark	2.6GHz	DKK 1,000,000	0.00244	103,000
Finland	2.6GHz	€ 150,000	0.00286	120,000
Germany	2.6GHz	€ 2,500,000	0.00304	128,000
	800MHz	€ 2,500,000	0.00304	128,000

Source: Population figures from the CIA World Factbook 2009: Norway 4,660,539, Sweden 9,059,651, Netherlands 16,715,999, United Kingdom 61,113,205, Denmark 5,500,510, Finland 5,250,275, Germany 82,329,758 ; Average exchange rates for June 2009 taken from OANDA: 0.13431 Euro/DKK, 0.11185 Euro/NOK 1.16719 Euro/Pound, and 0.09195 Euro/SEK.

487. Except for the upcoming award of 2.6GHz spectrum in the Netherlands and the cancelled award of spectrum in the same band in the United Kingdom, there seems to be a certain consistency across the benchmarks calculated from reserve prices used in the various auctions. They imply a low but nontrivial reserve price of between €100,000 and €130,000 for a 2x5MHz lot in Ireland. As discussed above in Section 10.2 there are good reasons why a low but non-trivial approach is inappropriate for this award.

10.5 Benchmarking using auction data

488. In this subsection we describe the benchmarking exercise we have conducted, drawing on price data from spectrum awards worldwide. This is a key input into our recommendation on the minimum price for the 2x5MHz lots available in the Irish 900MHz band. We only consider awards of similar frequencies where similar types of uses are likely to be deployed; specifically, we only use data from awards of frequencies available for 2G and 3G use. We also only consider data from auctions where price is the only winning determinant and thus is comparable across awards.

489. Our full auction data sample consists of 114 award processes across 28 countries worldwide, covering 5,969 licences. Price data is taken from DotEcon's Spectrum Awards Database and has been augmented with information from the CIA World Factbook on population estimates, purchasing-power parity exchange rates and GDP per capita figures for 2007,

2008 and 2009[41]. Geographical, demographic and economic data before 2007 is from the World Bank's *World Development Indicators* database.

490. We have taken two different approaches to benchmarking based on actual prices achieved in auctions. The first approach is simply to take the average of price per MHz per head of population of auctions from various subsets of data. The second approach involves using econometric analysis to identify a set of statistically significant metrics that influence the value of spectrum and, using these metrics, to predict a licence value for a 900MHz licence in Ireland.

491. Creating benchmarks of minimum prices (as opposed to achieved auction prices) would not be particularly helpful as national regulators clearly have different objectives and considerations when setting minimum prices. National regulators also use different techniques (as discussed in the previous sub-section) to arrive at minimum prices. Hence minimum prices will not necessarily bear any correlation to the benchmark metrics (population, GDP per capita, auction competitiveness, etc.) unlike auction prices, which ultimately reflect the valuations of losing bidders.

492. If we look at the ratio of the reserve prices to minimum prices achieved in spectrum auctions in our data set, we find that the average value is a little over 50%. However, this must be interpreted very cautiously and does not mean that reserve prices are typically set at about half of licence value. There are many uncompetitive auctions in which outturn prices simply reflect reserve prices and the ratio is necessarily 100%. Conversely, there are many other auctions in which low reserve prices are used and the ratio is close to zero. Practice in setting reserve prices is so varied that one should not treat *average* behaviour by regulators as indicating *typical* behaviour.

10.5.1 The auction data set

493. From our full data set, we only considered data from auctions of spectrum that could be use for mobile services (2G or 3G).

494. Licence price data included annual fees where applicable, that is, licence price is calculated as the aggregate sum of upfront payments and the discounted stream of annualised fees over the term of the licence. Annualised fees are calculated by taking the difference between the aggregate sum of all payments over the term of the licence, subtracting any upfront payments and then dividing the net amount by the duration of the licence[42].

495. The awards in our dataset have taken place in different countries at different points in time. Therefore, the price data from these awards have been brought in a common currency and corrected for inflation through the following steps:

[41] CIA World Factbook, available online at: https://www.cia.gov/library/publications/the-world-factbook/.

[42] This method will produce Annualised Fees that are different from actual annual fees when the stream of actual annual fees set is not uniform. In general, this method of calculating discounted licence price will give rise to discrepancies to the actual discounted licence price a bidder will face when the stream of annual payments is not uniform, for example when the licence price is paid in instalments that do not span the entire term of the licence but only for a specified period during the licence term.

- first, prices are converted from local currencies into a common currency (USD) using a Purchasing Price Parity (PPP) exchange rate to account for price differences between countries (this expresses prices in nominal USD terms);
- prices in nominal US dollars are adjusted for USD inflation[43] (converting prices at different times into real USD terms in the present);
- corrections are made for differing licence duration[44] (converting prices into equivalent values for a 15-year licence term);
- finally, all prices have then been converted into Euros using a PPP rate for the first half of 2009[45].

GDP data was also adjusted for inflation in the same way. Hence all monetary value variables are expressed in terms of June 2009 Euros for a 15-year licence.

496. All prices are then converted into per MHz per head of population figures for ease of comparison across different countries and licences.

10.5.2 Average-based benchmarks

497. Our first approach to benchmarking the value of 900MHz spectrum in Ireland is to consider the *average* auction prices achieved in comparable auctions. We look at this average across different sets of comparators.

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[43] Inflation has been adjusted using monthly USD Consumer Price Index (CPI) data from the US Bureau of Labour.

[44] Our adjustment for licence duration is based on the NPV calculation of the licence value assuming an equal flow of benefit from the licence for each year. Under this assumption, the annual stream of benefits from the licence would be equal to the total licence value divided by $\sum_{t=0}^{D-1}\left(\frac{1}{1+10.21\%}\right)^{t}$, where D is the duration of the licence. We have converted all licence prices to an equivalent 15-year licence price by finding the NPV of this annual benefit of the licence over a 15 year term. Therefore, a licence of duration D years will have an equivalent 15-year term licence value calculated as follows:

$$\text{LicenceFee}_{15\text{yearterm}} = \text{LicenceFee}_{D} \times \sum_{t=0}^{14}\left(\frac{1}{1+10.21\%}\right)^{t} \Big/ \sum_{t=0}^{D-1}\left(\frac{1}{1+10.21\%}\right)^{t}$$

The interest rate (10.21%) used in the discount rate is the weighted average cost of capital for Eircom as determined by ComReg in 2008 (see ComReg, 2008, Media Release – 22 May 2008, available online at: http://www.comreg.ie/_fileupload/publications/PR220508.pdf).

[45] The official PPP rate for 2009 is not yet available so to we used a derived a PPP rate. In the last 3 years, PPP rates between the Euro and USD were 8%- 30% higher than official exchange rates. In particular in 2008, this percentage was around 23%. However inflation in Ireland in 2008 was 4.1% and in the first half of 2009 US inflation was about 2.3% whilst prices in Ireland deflated about 2% during this period. Therefore following this trend, the mark up of the PPP rate over the official exchange rate should be less than 3%-18%. A conservative value for this mark up would be around the mid point of this range at about 10%. Therefore applying a 10% mark up to the first half of 2009 average exchange rate between the USD and Euro in 2009 from OANDA of 0.75011 Euro/Dollar would give a H12009 PPP rate of 0.8251.

498. The data set used consists of both auctions where only national licences are sold (for example, most European countries usually award national licences) and auctions of regional licences (for example in the USA or Canada). The approach taken has been first to calculate a price per MHz per head of population for each licence. In cases where there has been a regional award, regional prices have been collapsed into a single population-weighted national auction average price. The resulting prices were then combined with other auction average prices to create a simple average of prices across awards (i.e. each award receives equal weight). In particular, we have used the following formula to construct the benchmark:

Equation 1: Weighted average price formula

$$\bar{p} = \sum_{k=1}^{K} \frac{1}{K} \left(\sum_{i=1}^{I_k} w_{k,i} p_{k,i} \right)$$

where

- $\bar{p}$ is the average price per MHz per population (our benchmark price);
- K is the number of awards in the data set;
- $w_{k,i}$ is the adjusted[46], licence-specific weight of licence i, where each licence is weighted by its population coverage in relation to the population in country of award k;
- I_k is the number of licences in award k; and
- $p_{k,i}$ is the price of licence i in award k.

499. Various average-based benchmarks can be created depending on which awards we include or exclude. The following sets of awards were considered:

- All mobile (2G and 3G) licences sold in an auction;
- All licences awarded in European countries;
- All licences awarded in countries with GDP similar to Ireland;[47]
- All GSM900 and GSM1800 licences in the dataset; and
- All 3G licences in the dataset.

In section 17.1, we provide a list of the awards used to construct each of these five benchmarks.

[46] We use adjusted weights. These take into account that population coverage stated in regional licences do not always add up to the population figure by which they are divided. We therefore adjust these weights by dividing them by the sum of all weights of the country as shown in the following equation:

$$w_{k,i} = w^{*}_{k,i} \Big/ \sum_{i=1}^{I_k} w^{*}_{k,i}$$ where $w^{*}_{k,i}$ are the unadjusted weights.

[47] We consider all licences awarded in countries with GDP above €20,000.

500. The following table (Table 8) gives an overview of the average licence price per MHz per population for these various groups of awards. The implied value of a licence for a 2x5MHz lot in Ireland is calculated by multiplying the price per MHz per population by 10 (the size of a licence in MHz) and the population of Ireland[48] (taken as 4,203,200).

Table 8: Benchmarks using averaging method

Benchmark group	Average price per MHz per population	Implied value of 2x5MHz in Ireland
All mobile licences sold in an auction	€0.691	€29.1m
All licences sold in an auction in a Europe	€0.546	€22.9m
All licences sold in countries with similar GDP per capita	€0.625	€26.3m
All GSM licences	€0. 790	€33.2m
3G licences	€0.800	€33.6m

501. The various average-based benchmarks imply that the value of a 2x5MHz 900MHz lot in Ireland might lie between €22 million and €34 million. When interpreting this, we must remember that the benchmark data does not include any cases of 900MHz liberalised spectrum, so this is likely to be an underestimate.

502. Including all mobile licences sold in an auction produces a benchmark for the average price of mobile spectrum since 2000 (i.e. €0.691/MHz/pop). The lowest benchmark (€0.546/MHz/pop) is based on the mobile licences sold in an auction in European countries only. This is because spectrum generally yields lower prices on a per head of population basis in European countries relative to other regions such as the USA and the Middle East.

503. Over the last decade or so, the majority of spectrum auctions have been for 3G licences. The bulk of GSM frequencies have traditionally been administratively awarded to operators, and the GSM auctions that we have witnessed during this period are often for returned spectrum or additional GSM frequencies (for example the E-GSM band[49]). Thus there lacks sufficient data on the actual market value of GSM licences auctioned. The data shows that on average GSM

[48] We have used the estimate for July 2009 provided by the CIA World Factbook available online at https://www.cia.gov/library/publications/the-world-factbook/geos/ei.html.

[49] The E-GSM band is 880-890 MHz paired with 925-935 MHz, which is immediately below the GSM900 band.

licences are worth roughly the same as 3G licences. However, the relative value of GSM versus 3G spectrum is probably not fully reflected in this observed data due to the lack of availability of GSM licence price auction data; a much greater proportion of 3G licences have been auctioned than GSM licences during the period considered. Further we know from the superior propagation characteristics of GSM spectrum compared to 3G spectrum that GSM licences should have a higher relative value than 3G licences.

504. This is supported by various studies[50] that suggest that implementing UMTS technologies (such as UMTS and, in the future, LTE) at 900MHz as opposed to the current use of 3G technologies at 2.1GHz is likely to provide net present value improvements of between 39% to 105% in Western Europe and Asia Pacific if cost savings are reinvested to increase coverage. Hence there is both empirical and theoretical evidence to suggest that within a country, a liberalised GSM licence should be worth significantly more than a 2.1GHz 3G licence.

10.5.3 Regression-based benchmarks

505. In the second benchmarking exercise, we use econometric analysis to predict a licence price for 900MHz spectrum in Ireland. In particular, we regress the price per MHz per head of population on various explanatory factors that might affect the price of spectrum in an auction, such as:

- Country characteristics such as the income level of the country, its demography and geography;
- The level of competitiveness in an auction;
- Licence characteristics such as whether the licences sold were national or regional and the potential licence use;
- The competitiveness in the telecommunications market; and
- Time trend of prices.

506. The regression analysis allows us to consider the joint influence of the various factors that might have an impact on spectrum value. However, we assume that the effects of these various metrics on spectrum value are all additive in nature and that there are no interaction effects between them.

507. We run the regression analysis on the following three data sets:

- All mobile licences sold in an auction;
- All mobile licences sold in Europe; and
- All GSM licences.

[50] See the recent report by Ovum consulting on the potential value of UMTS900 in particular with respect to capital expenditure savings compared to UMTS2100. Ovum Consulting, 2007, Market Study for UMTS900 – A report to GSMA, available online at: http://www.gsmworld.com/documents/umts900_full_report.pdf.

508. In addition to a simple model with additive effects, we have also estimated functional forms in which we explicitly allowed for interaction effects between the various explanatory variables. This, however, did not lead to improved predictions for Ireland.

509. Our first regression data set consists of all mobile licences sold in an auction. We have identified the following model as providing a good fit for this dataset:

Equation 2: Regression equation for all mobile licences sold in an auction

$$PMHzPop = \beta_0 + \beta_{GDPpc} \bullet GDPpc + \beta_{ApPop} \bullet ApPop + \beta_{WtB} \bullet WtB + \ldots.$$
$$\ldots + \beta_{invNmnos} \bullet invNmnos + \beta_{national} \bullet national + \beta_{AFME} \bullet AFME + \beta_{preIt} \bullet preIT + \ldots$$
$$\ldots + \beta_{year01} \bullet year01 + + \beta_{year0203} \bullet year0203 + \beta_{year0405} \bullet year0405\ldots.$$
$$\ldots + \beta_{year0607} \bullet year0607 + \beta_{year0809} \bullet year0809$$

where:

- $PMHzPop$ is price per MHz per population (our dependent variable);
- β_0 is a constant;
- $GDPpc$ is GDP per capita;
- $ApPop$ is area per capita, a measure of population density;
- WtB is the ratio of winners to bidders in the auction, a measure of the level of competition in the auction;
- $invNmnos$ is the inverse of the number of MNOs in the end, a measure of competitiveness in the telecommunications market;
- $national$ is a dummy variable which is 1 if it is a national licence and 0 if not;
- $AFME$ is a dummy variable which is 1 if it is an African or Middle-Eastern country and 0 if not; and
- $preIT$ is a dummy which is 1 if the licence was sold before the Italian 3G auction (the last auction before the spectrum bubble burst) or 0 if the licence was sold afterwards;
- $Year$ is a dummy which is 1 if the licence was sold in these years and 0 if not. Years are grouped biannually. For example $Year0607$ is one if licence was sold in 2006 or 2007 and 0 otherwise.

510. We use a weighted least squares estimator (using the same weights for each individual licence as for the calculation of weighted average price per MHz per population for each auction as used in the average-based benchmark approach) to estimate the coefficients of the model.[51] The results are summarised in the following table.

[51] For more information on this estimator, see Greene, W, 2003, Econometric Analysis Fifth Edition, pp.225-227.

Table 9: Regression analysis using all mobile licences sold in an auction

Coefficient for:	Estimated coefficient	Standard error
GDPpc	0.0000255**	0.000002
ApPop	-1.083**	0.234
WtB	-1.90**	0.0695
invNmnos	2.95**	0.259
national	-0.000890	0.0507
AFME	0.802**	0.0585
preIT	0.804**	0.0989
yearD_01	-1.02**	0.0830
yearD_0203	-1.80**	0.0952
yearD_0405	-1.51**	0.0876
yearD_0607	-1.43**	0.0868
yearD_0809	-1.30**	0.0873
Constant	1.83**	0.128

Note: Coefficients which are significant at the 5% and 1% level are marked with one and two stars, respectively[52].

511. As can be seen from Table 9, the income level in a country has a positive effect on the price of spectrum (controlling for all other factors in the regression equation). In addition, the larger the area per head of population, the lower is the price at which the spectrum would sell. This is because the more dispersed the population in a country is, the higher the cost to roll out a network would be.

512. The negative coefficient of the winners-to-bidders ratio confirms the expectation that the higher the level of competition in the auction, the higher would be the licence price in the auction. Further, we would expect that the price of the spectrum achieved is higher if competition in the end market is weaker (which translates into a higher value of coefficient of invNmnos, the inverse of the number of network operators). Our estimation

[52] This means that the probability of those coefficients being equal to zero is smaller than 5% or 1%, respectively.

shows that, controlling for other factors, increasing the number of mobile network operators in the market lowers licence values.

513. The overall time trend of spectrum licence prices is represented by the negative coefficients on the dummy variables for years. These indicate the decline of spectrum prices from a peak that was achieved during the telecoms equity market bubble in 2000.

514. We can use the estimated coefficients in Table 9 to predict the value of the spectrum to be sold in Ireland. The following table lists the assumptions used for the relevant explanatory variables for Ireland (where applicable).

515. From Table 9 above, we note that a 10% reduction in WtB will on average lead to a rise in predicted price of about €0.19, so our results are fairly sensitive to the assumptions made about the competitiveness of auction (as one would expect). It would be inappropriate to assume that the auction was uncompetitive (a winners-to-bidders ratio of 1) as we are trying to determine a reserve price here. Therefore, our forecasts are based on an assumed competition scenario in the auction as represented by the winners-to-bidders ratio of 0.86; this value is the sample average of the winners-to-bidders ratio across the whole sample for national awards (there tend to be many more bidders in regional awards so these are not representative). This value is close to a likely auction outcome scenario for the upcoming 900MHz auction of 4 winners from 5 bidders, which would give winners-to-bidders coefficient of 0.8.

Table 10: Inputs used for predictions

Independent variable	Value
Population	4,203,200
GDP per capita (in Euros)	43,300
Number of mobile network operators	4
Number of participating bidders	5
Winners to bidders	0.86
Area (in square kilometres)	70,280

516. These assumptions produce a predicted price per MHz per head of population for Ireland of €0.58, which gives an implied licence value for a 2x5MHz lot of about €24.3 million based on the data set including all mobile licences.

517. The same regression exercise was then applied to the two smaller data sets of all European mobile auctions (the Africa-Middle East dummy here is redundant hence dropped) and all GSM auctions. Considering only European auctions would eliminate any impact on spectrum value that was not fully accounted for by the Africa-Middle East dummy variable within the first model when estimating the licence price for a European country. Further, the predictive power of the Europe-only model may be higher as European countries are more similar in geography and demographics to Ireland. Any effects that

European legislation might have on spectrum value within Europe should also be captured to a certain degree.

518. Looking only at GSM auctions on the other hand would have better predictive power for the 900MHz frequency band. However, as discussed earlier, the benchmark value may be biased downwards as a result of the lack of 900MHz auctions in Europe. Also, the value of liberalising 900MHz licences and allowing 3G is not included.

519. The regression results are presented in Section 17.2 and the predicted prices presented in Table 11, which also shows the results from an estimation using all mobile licences. Overall the regression analysis on the three different data sets used produce fairly consistent results of an implied licence value of a 2x5MHz block of between €16 million and €26 million. This is broadly consistent with our simple averaged benchmarks discussed in the previous subsection from the previous section (€22-€34 million). The findings of the two different benchmarking approaches (averaging and econometric forecasting) are summarised in Table 12.

Table 11: Predicted value of the Irish spectrum based on regression analysis

Data set	Price per MHz per population	Implied value of a 2x5MHz block
All mobile licences	€0.578	€24.3m
Auctions in Europe	€0.397	€16.7m
All GSM auctions	€0.622	€26.1m

10.5.4 Interpretation of benchmarking results

520. In addition to these benchmarks, we also show a figure for the value of the spectrum based on the average price of the four 3G licences already awarded in Ireland in the 2.1GHz band. This figure (€22.3 million for a 2x5MHz licence) is lower than the international benchmarks, though the benchmarks are of licence prices from auctions where Ireland awarded its 3G licences via beauty contests. Given that there are likely to be significant cost savings from operating 3G at 900MHz rather than 2.1GHz, the average 3G licence price paid in Ireland can be seen as a lower bound for the value of liberalised 900MHz spectrum. Therefore, an assumption that a reasonable lower bound on the value of a 2x5MHz block of 900MHz spectrum could be €25-€30 million or higher is broadly consistent with the observed 3G licence prices paid in the

beauty contests in which Vodafone, O2, Hutchison (in 2002), and Eircom (in 2007) won their 3G licences[53].

Table 12: Summary of benchmarks

Benchmark group	Technique	Implied value of a 2x5MHz lot
All mobile	Average benchmark	€29.1m
	Regression analysis	€26.1m
Europe	Average benchmark	€22.9m
	Regression analysis	€16.7m
GDP	Average benchmark	€26.3m
GSM only	Average benchmark	€33.2m
	Regression analysis	€24.3m
3G only	Average benchmark	€33.6m
	Ireland average	€22.3m[54]

521. As already mentioned, there are no available benchmarks for 3G spectrum at 900MHz. Therefore, we have had to rely on existing GSM900 and GSM1800 data, which does not take into account the likely significant increase in value of liberalised licences. In addition, due to the general lack of auction data in the GSM bands, we use larger data sets containing licences in other bands as well. Hence the implied value of a 2x5MHz lot from our regression benchmarking results is most likely to be **lower** than the actual expected licence value of liberalised 900MHz spectrum in Ireland. This needs to be taken into account in interpreting these results for the purposes of setting a minimum price.

[53] Using the discounted licence price calculation method described in footnote 42 will result in discounted licence prices of €25.3m for Vodafone and O2, €13.3m for H13G and €25.1m for Eircom (an average of €22.3m). Using the actual payment structure as prescribed in section 4.3 of the 3G Information, Vodafone and O2's actual discounted licence price for their 3G licences is about €28.4m (2009 prices) whilst Hi3G paid approximately €14.7m and Eircom €26.9m (producing an average of €24.6m).

[54] This is the average of the discounted licence prices from the 2002 and 2007 Irish 3G awards calculated in June 2009 Euro terms with the methodology described in section 10.5.1. However as explained in footnote 42, this methodology applies an Annualised Fee across the term of the licence that will not be reflective of actual annual fees if their annual fee payments are not uniform as is the case with the Irish 3G licences. If one were to calculate the average discounted licence price of the Irish 3G licence in 2002 and 2007 using the payment schedule of fees as listed in the section 4.3 of the Irish 3G Information Memorandum, the four Irish 3G licences would produce an average price of €24.6m for a 2x5MHz licence in 2009. See footnote 53 for individual licence prices.

522. Interpreting our benchmarking analysis as providing a lower bound, yet being cautious about the uncertainty of these estimates, it seems reasonably safe to conclude from the data that the value of a 2x5MHz lot at 900MHz is likely to be in the upper half or possibly even above our range of estimates of €16million to €34 million. Further support is provided by the average 3G licence price achieved in Ireland of about €22.3m (see footnote 54 and footnote 53 for individual licence prices), which is again a lower bound as this does not take into account the better propagation of 900MHz spectrum nor was competitively determined. Overall, we recommend that a reasonable range for a minimum price for 2x5MHz 900MHz licence in Ireland is €25-30 million. Setting a minimum price at such levels should be low enough to prevent choking off efficient demand. It may well be that a higher minimum price could be set, but we lack evidence above this range that this would not cause demand to be choked off.

11 Benchmarking of spectrum fees

523. In the previous section, we investigated a minimum price for licences in the 900MHz band in Ireland. In this section, we benchmark spectrum usage fees and consider any potential precedent for establishing a suitable breakdown of this minimum price between the upfront fee to be paid upon completion of the auction, and spectrum usage fees, to be paid on an annual basis for the duration of the licence period.

524. To do this, we first examine the level of spectrum usage fees currently in place for similar licences in Ireland relative to the overall value of licence fees. We then examine spectrum usage fees in other EU countries, and assess trends across these countries in setting spectrum usage fees. These insights then feed into our recommendation regarding the breakdown of our recommended minimum price into an upfront payment and annual spectrum usage fees for licences awarded for use of liberalised 900MHz spectrum.

11.1 Current spectrum fees in Ireland

525. The Spectrum Access Fees for GSM and 3G licences in Ireland were:

- Vodafone (previously Eircell) and O2 paid £10m (€12.73m) and £15m (€19.08m) respectively for 2x7.2MHz of GSM900 spectrum and approximately £5.6m (€7.12m) for 2x14.4MHz of GSM1800 spectrum. Meteor paid £10m (€12.73m) for 2x4.8MHz of GSM900 and 2x14.4MHz of GSM1800 spectrum and £1.25m (€1.59m) for 2x2.4MHz of GSM900 spectrum.
- €50.7m for a 3G "A" licence, and €114.3m for a 3G "B" licence. The 3G licences were issued to Vodafone, O2 and Hutchison 3G Ireland (H3GI) in 2002 and to eircom/Meteor in 2007.

526. The current spectrum usage fees for GSM and 3G in Ireland are summarised in the following table:

Table 13: Current GSM and 3G annual Spectrum Usage Fees in Ireland

	Meteor, O2, Vodafone	H3GI	Per MHz spectrum
GSM 900 (2 x 7.2MHz)	€ 914,220		€ 63,487.50
GSM 1800 (2 x 14.4MHz)	€ 1,371,312		€ 47,615.00
3G (2 x 15MHz +1 x 5MHz)	€ 2,222,045		€ 63,487.00
3G (2 x 15MHz)		€ 1,904,610	€ 63,487.00

527. For easier comparison with benchmarks in the following subsections, the final column in Table 13 normalises the annual spectrum usage fees on a per total MHz basis (i.e. 2x1MHz of paired spectrum is equivalent to 2MHz of unpaired). In order to obtain the annual spectrum usage fee for 2x5MHz, for example, the price per MHz of unpaired spectrum must, therefore be multiplied by 10.

11.2 Spectrum usage fees in other EU countries

528. The benchmarks presented in the following tables relate to spectrum usage fees for 900MHz, 1800MHz and 2.1GHz frequency bands. We have not included spectrum access fees within our benchmarking exercise as these will be determined in Ireland by the results of the auction process.

Table 14: Spectrum Usage Fees in 900MHz for selected EU countries

	Usage fee per year per MHz (EUR)	Comment	Population (million)	Eurocent/ MHz/ pop /year
Ireland	63,488		4.4	**1.44**
Spain	774,245	2008 figure.	45.2	**1.71**
France	534,000 (est.)	Basis: 1% of revenues generated from spectrum usage. For spectrum awarded/renewed after 2005.	62	**2.42 (est.)**
Belgium	77,250	2007 figure.	10.7	**0.72**
Portugal	120,000	Twice as much for spectrum exceeding 35MHz.	10.7	**1.12**
Netherlands	None	All fees upfront	16.7	**0.0**
Cyprus	None	All fees upfront	0.8	**0.0**
Denmark	7,575	2010 figure	5.5	**0.14**
Sweden	5,563	2010 figure, subject to NRA board approval	9.2	**0.06**
Italy	1,443,234	The first 15MHz are not charged for. Fee per MHz exceeding 15MHz.	58.9	**1.23**
Finland	18,241		5.3	**0.34**

529. A review of the benchmarks for 900MHz spectrum reveals that most countries have either low or no annual spectrum usage fees. In the countries where no or very low usage fees are recorded the value of the spectrum captured by the award process, be it an auction or "beauty parade" with a defined payment level, is captured upfront and in a single payment.

530. It is common that low spectrum usage fees are set among the countries that were sampled. In particular, spectrum usage fees in Ireland are the third highest behind Spain and France. The Spanish figure partly reflects the relative failure of the Spanish 3G spectrum auction, which took place in the aftermath of the Dot Com crash. In order to capture a reasonable share of the value of the spectrum the regulatory authority set a high level of spectrum usage fees to compensate for the low valuations achieved in the auction process. France represents a special case, as it is the only country that bases the spectrum usage fees on a proportion of revenue. Our benchmark is an estimate based on reported revenues in the operators' company accounts. Italy also provides a high benchmark but it is important to note that no charge is made for the first 15MHz of spectrum.

Table 15: Spectrum Usage Fees in 1800MHz for selected EU countries

	Usage fee per year per MHz (EUR)	Comment	Population (million)	Eurocent/ MHz/ pop /year
Ireland	47,615		4.4	**1.08**
Spain	619,648	2008 figure.	45.2	**1.37**
France	285,500 (est.)	Basis: 1% of revenues generated from spectrum usage. For spectrum awarded/renewed after 2005.	62	**2.05 (est.)**
Belgium	77,250	2007 figure.	10.7	**0.72**
Portugal	120,000	Twice as much for spectrum exceeding 35MHz.	10.7	**1.12**
Netherlands	None	All fees upfront	16.7	**0.0**
Cyprus	None	All fees upfront	0.8	**0.0**
Denmark	7,575	2010 figure	5.5	**0.14**
Sweden	5,563	2010 figure, subject to NRA board approval	9.2	**0.06**
Italy	1,443,234	The first 15MHz are not charged for. Fee per MHz exceeding 15MHz.	58.9	**1.23**
Finland	13,680		5.3	**0.26**

531. A review of the benchmarks for 1800MHz spectrum reveals a similar pattern in terms of levels. It is also relevant to note that there is not a significant difference between the spectrum usage fees for 900MHz and 1800MHz bands.

532. The observations drawn from 900MHz and 1800MHz benchmarks are reinforced by the benchmarks from 2.1GHz.

Table 16: Spectrum Usage Fees in 2.1GHz (UMTS spectrum) for selected EU countries

	Usage fee per year per MHz (EUR)	Comment	Population (million)	Eurocent/ MHz/ pop /year
Ireland	63,487		**4.4**	**1.44**
Spain	774,135	2008 figure.	**45.2**	**1.71**
France	1% of revenue generated by spectrum use.	Basis: 1% of revenues generated from spectrum usage. Upfront fee: 24 million EUR per MHz for 20 years licence term	**62**	***1.61 (est.)***
Belgium	72,200	2007 figure.	**10.7**	**0.67**
Portugal	120,000	Twice as much for spectrum exceeding 35MHz.	**10.7**	**1.12**
Netherlands	None	All fees upfront	**16.7**	**0.0**
Cyprus	None	All fees upfront	**0.8**	**0.0**
Denmark	7,575	2010 figure	**5.5**	**0.14**
Sweden	2,596	2010 figure, subject to NRA board approval	**9.2**	**0.03**
Italy	1,443,234	The first 15MHz are not charged for. Fee per MHz exceeding 15MHz.	**58.9**	**1.23**
Finland	13,680		**5.3**	**0.26**

11.3 Main observations

533. Below we summarise the main inferences that can be made based on this benchmarking:

- The greatest proportion of total spectrum fees is set by an auction mechanism or, previously, by "beauty contest". These are paid upfront as a spectrum access fee.
- Most benchmarked countries have relatively low or no annual spectrum usage fees although Spain, France and Portugal do provide precedents for higher spectrum usage fees (SUFs).
- Most countries have only a small or no difference in the level of annual SUFs across different spectrum bands. However, spectrum access fees generated by auctions reveal a much higher degree of variation.
- None of the countries out of those considered in this section had requirements for performance bonds and penalties for non-usage or inefficient usage of spectrum or the failure to meet licence conditions other than Ireland.
- With the exception of Finland, no countries had implemented any phasing or discounting of fees. In the case of Finland annual SUFs are phased in over a 5-year period in 20% increments of the total final annual fee.

12 Recommendations on reserve prices and spectrum usage fees

534. Section 10 has developed a set of benchmarks for minimum prices to help in assessing at what level a minimum price could lead to demand for spectrum being choked off. In this section, we make a recommendation on a minimum price. We then consider in the following section how this might be broken into a reserve price and a spectrum usage fee.

12.1 Level of minimum price

535. Several European national regulators have taken to setting low but non-trivial minimum prices in recent or upcoming mobile spectrum auctions. Such a reserve price might be in the order of €100,000. However, such a low reserve price would significantly increase collusion incentives, which is a concern given the small number of bidders that might participate in this auction. To alleviate such collusion concerns, we recommend a higher minimum price should be set.

536. In addition, we should consider the implications of spectrum usage fees for efficient usage of spectrum after an auction. Spectrum is not tradable in Ireland and so there is no financial incentive for licensees to release spectrum to others who might be able to create greater value. A possible way to provide such an incentive (at least in part) would be to charge annual spectrum usage fees (SUFs) that are sufficiently high to encourage return to ComReg where spectrum was not being used to create sufficient value for the current licensee; ComReg could then reallocate the spectrum. For SUFs to be effective in encouraging licensees to return any unused or underperforming spectrum, they have to be set at a meaningful level that reflects the opportunity cost of holding the spectrum. This is difficult to achieve given that the latter is unknown prior to the auction. Nevertheless, this consideration provides an additional argument for reasonably high minimum prices, especially the component due to spectrum usage fees.

537. Against these two arguments for relatively high minimum prices, we need to balance of the risk of inefficiently choking off demand by setting minimum prices too high. This means finding some level of minimum price such that we can be reasonably certain that the true liberalised value of the spectrum exceeds this level.

538. In Section 10, we saw a range of benchmarks for the value of a 2x5MHz licence in Ireland of €16-34million for a 15-year licence. Benchmarks created using a simple averaging method suggest the upper end of the range, whereas benchmarks based on econometric methods suggest the middle to lower end of the range.

539. This range is likely to underestimate the true value of liberalised 900MHz spectrum. These benchmarks are based on datasets made up either in majority by 3G spectrum auction price data or un-liberalised GSM (both 900MHz and 1800MHz) spectrum auction price data, both of which provide a lower bound to the likely value of 900MHz spectrum in Ireland. We do not have data yet on the value of 900MHz 3G spectrum, but we are only seeking a conservative lower bound on the likely value of such spectrum.

540. For these reasons, we recommend that the minimum price be set in the upper regions of our predicted licence value range, say €25m-30m.

541. We note that a type B 3G licence that Vodafone and O2 won in 2002 had an effective discounted licence price for 2x5MHz of 3G spectrum for a 15-year duration in June 2009 Euros of €25.3million[55]. Hence given that the value of liberalised 900MHz spectrum should exceed that of 2.1GHz spectrum, the risk of choking off demand with a minimum price of €25m-30m should be limited. However, determining an appropriate level of minimum price is not an exact science and there can be no absolute certainty about this.

542. We have no reliable evidence to make a realistic assessment of the potential effects of setting a minimum price above this level. Benchmarking analysis is fundamentally limited by the lack of comparator data for liberalised 900MHz spectrum. It is certainly possible to undertake business case modelling (at least in a generic manner) to investigate the possible value of this spectrum further. However, for reasons already discussed in Section 10.3.1, it seems unlikely that this would provide much insight.

12.2 Structure of reserves prices and SUFs

543. The minimum price of a licence is made up of an upfront component that is the reserve price for the auction and the sum of annual spectrum usage fees (SUFs) across the licence term. Therefore, we have a choice how to split any particular level of overall minimum price between a reserve price and SUFs.

544. In order for the SUFs levels to reflect the opportunity cost of spectrum with minimum prices set close to estimated licence value, there is a good case that the upfront reserve price component should be a relatively small proportion of the minimum price and the annual SUFs the remaining majority. However, against this we need to balance the risks of deferring too much of the

[55] Vodafone had to pay a Spectrum Access Fee of €114.3m in 2002 for its B type licence of 2x15MHz plus 5MHz unpaired of UMTS spectrum. Including the annual Spectrum Usage Fee of €2.22m per year, the total discounted licence fee calculated as per the methodology in section 10.5.1 (see footnote 42) was about €97.9m for the 20 year 3G licence (using Eircom's WACC in 2008 of 10.21%). If however the payment schedule of fees were as described in section 4.3 of the Irish 3G Information Memorandum then the discounted licence value for Vodafone licence is €93.0m. As the difference in licence value between these two calculation methods is only about 5%, for consistency, we will use the former.

Adjusting this nominal discounted licence fee to a 15-year term (using Eircom's WACC in 2008 of 10.21%, see footnote 44) would result in an effective licence fee of about €87.6m for a 15-year licence. This price is then converted into USD using a PPP exchange rate of €1 to USD1.02437 so that a common rate of inflation can be applied to all licences considered in the benchmarking exercise. The inflation rate used is that of USD inflation. Thus applying an USD inflation adjustment term of 1.17393 to adjust prices to June 2009 terms (between 2002 and 2009 the price of a standard consumer basket of goods increased by about 17.393%) then converting this back into Euros using the Euro to USD PPP rate in the first half of 2009 of I USD to €0. 8251 (see footnote 45) will give a licence fee of about €82.9m in June 2009 Euros. Finally scaling the licence to 2x5MHz and adjusting for population differences between 2002 and 2009 will give an effective discounted licence fee of Vodafone's 3G licence of about €25.3m in June 2009 terms.

For more information about how currencies were converted in the analysis see Section 17.3 and on discounted licence fees footnote 42 and 53.

minimum payment. Without sufficient up-front payment, bids may not be credible and give rise to subsequent default risks.

545. Having determined what proportion of the minimum price should be implemented through an up-front reserve price, the remainder needs to be annualised using a discount factor that reflects the cost of capital of an operator to give an annual SUF level. Therefore, the factors that would affect the level of annual SUFs are:

- the minimum price level;
- the proportion accrued to the upfront reserve price component and consequently that accrued to the annual SUFs; and
- the discount factor used for annualising.

546. In Table 17 below, we consider the annual SUF level for the minimum price levels of €25m and of €30m for a 15-year licence. We take a range of proportions of minimum fees accrued to the annual SUFs components (from 0% to 100%) and two discount factors – 10.21% which is the weighted average cost of capital of Eircom set by ComReg in 2008[56] and a higher discount rate of 15%.

547. For each of these scenarios, we need to calculate corresponding reserve prices for 2x5MHz lots in each of the two time slices: the four years 2011-2015 and the 15 years from 2015-2030. We have simply assumed that the cashflows generated from a licence are flat over time and used the appropriate discount rate assumption to convert the value of 15-year licence into that for a 4-year licence given this assumption.[57] This procedure may somewhat overstate the value of the earlier time slot if cashflows are in fact growing over time, but it is a reasonable first approximation. Furthermore, there is a greater risk of muted competition for the earlier time slice, so it not unreasonable to err in the direction of setting the reserve price for the earlier time slice high relative to the later time slice rather than the converse.

548. The overall results for the SUF and the reserve prices for lots in each time slice are shown in Table 17. These figures relate to a single 2x5MHz block. We suggest that at least 50% of the minimum price be implemented through the

[56] See ComReg, 2008, Media Release – 22 May 2008, available online at: http://www.comreg.ie/_fileupload/publications/PR220508.pdf

[57] Our adjustment for licence duration is based on the NPV calculation of the licence value assuming an equal value of the licence for each year. Under this assumption, the value of the licence for one year would be equal to the total licence value divided by $\sum_{t=SD}^{t=ED-1}\left(\frac{1}{1+10.21\%}\right)^{t}$ which is the effective discount rate, where SD is the first year of the licence and ED is the last year of the licence (see footnote 44 for further details). For our licences in the two time slices 2011-2015 and 2015 to 2030, a discount factor for the first 4 years and for the last 15 years is applied respectively. The interest rate (10.21%) used in the discount rate is the weighted average cost of capital for Eircom as determined by ComReg in 2008 (see ComReg, 2008, Media Release – 22 May 2008, available online at: http://www.comreg.ie/_fileupload/publications/PR220508.pdf).

SUF to provide some spectrum release incentives, but this proportion is not critical to any of the proposals.

549. Our suggested minimum price range of €25m-€30m is broadly consistent with the amount that was paid for the type B 3G licences in 2002 (about €25.3m or €28.4m depending on calculation method described in footnote 53) for an equivalent amount of spectrum for a 15-year term. The spectrum utilisation fee set for a 3G licence in the 2002 award was €2.2m. In the most plausible lower discount rate scenarios, this is broadly consistent with an SUF recovering 75% of the overall minimum price.

Table 17: Parameters for determining reserve price and SUFs for a 2x5MHz block

Minimum price	Proportion of minimum price in SUF	Discount factor	Annual SUF	Reserve price for 2011-2015 licence	Reserve price for 2015-2030 licence
€25m	90%	10.2%	€2.7m	€1.1m	€1.7m
	75%		**€2.3m**	**€2.6m**	**€4.3m**
	50%		€1.5m	€5.3m	€8.5m
	0%		€0	€10.5m	€17.0m
	90%	15%	€3.4m	€1.2m	€1.4m
	75%		€2.8m	€3.1m	€3.6m
	50%		€1.9m	€6.1m	€7.2m
	0%		€0	€12.2m	€14.3m
€30m	90%	10.2%	€3.3m	€1.3m	€2.0m
	75%		**€2.7m**	**€3.2m**	**€5.08m**
	50%		€1.8m	€6.3m	€10.2m
	0%		€0	€12.6m	€20.3m
	90%	15%	€4.0m	€1.5m	€1.7m
	75%		€3.4m	€3.7m	€4.3m
	50%		€2.2m	€7.3m	€8.6m
	0%		€0	€14.7m	€17.2m

13 Structuring payments

550. In this section we turn to the question of how payments from successful bidders for spectrum might be structured. We consider whether there are benefits to providing payment deferrals and how these might be organised.

13.1 Deferral options

551. In the current financial and economic climate, it is prudent to have measures to safeguard against financing constraints upsetting the auction. For instance, capital market upheaval shortly before an auction could adversely affect some bidders and greatly diminish competition, potentially to the benefit of other bidders. Once a timetable is in place for an auction, it may be difficult to defer it. A safeguard against such problems is to provide options for deferral of payments whose attractiveness is linked implicitly to the level of auction prices.

552. If a larger proportion of the minimum price were apportioned to SUFs and consequently a small proportion to the upfront reserve, financing constraints would tend to come into play only when licence prices exceeded the reserve price by a large enough amount. Therefore, we can achieve the desired effect by allowing bidders to defer only some proportion of the *excess* they need to pay above the reserve price. With such a scheme, if prices are close to the reserve, there is little ability to defer payments, but the deferral options increase as prices increases.

553. For example, licensees could be allowed to defer the payment of up to 50% of their licence price above the reserve price to the start of the licence period, spreading the payment of the outstanding amount across three to five years. A minimum of 50% of the licence price above the reserve price (and the entirety of the reserve price) would have to be paid upfront to ensure that the bid is credible.

554. There is always some risk of payment default whenever deferred payment schemes are offered. Therefore, an interest rate should be applied to deferred payments that at least reflects this risk. The deferral option should not be misused by bidders as a convenient low-cost credit facility and is only intended to provide a safeguard against unforeseen funding difficulties. Therefore, the interest rate to be applied should exceed the cost of usual commercial funding.

13.2 An example payment schedule

555. For the sake of illustration, suppose that the auction were to be held in 2010 and the reserve price of a 2x5MHz 15-year licence was €4.3m with an annual fee of €2.3m. Suppose that a bidder wins the 2x5MHz licence starting from 2015 at a price of, say, €10m.

556. In this example, the payments that this bidder will be required to make would be as follows:

- an immediate minimum payment after the auction of €7.15m (equal to the reserve price of €4.3m plus 50% of excess over reserve);

- an SUF of €2.3m each year from 2015; and
- up to €2.85m can be optionally deferred into equal payments of €1.7m in 2015, 2016, 2017 (at say, 12% interest rate).

13.3 Indexation

557. A particular feature of this award of 900MHz spectrum is that it may set both SUFs and deferred payments that could stretch out into the future for some time. For instance, if a 15-year licence were issued starting 2015, SUF payments would be taken until 2030.

558. Given this long time scale, it might be prudent to build in some indexation of SUFs against inflation. Furthermore, the interest rate used for calculating the interest costs of any deferred payments should be a nominal one that includes reasonable expectations about inflation. Indexation should not create additional risks for bidders as a mobile network operator's revenues and costs would in any case be affected by inflation.

PART D: Licence conditions

14 Key issues for licence conditions

559. In this part of the report, we consider the potential licence conditions that could be applied to spectrum in the 900MHz band. The remit of the report in this regard is to provide economic analysis of 'the costs, benefits, advantages and disadvantages regarding other potential licence conditions in light of the Commission's statutory functions and objectives' (*Section 2.2.2, ComReg document 09/40)*. To this end, in this section, we first describe the general issues that will have an effect on the design of licence conditions for liberalised 900MHz spectrum. We then evaluate the alternative options for a number of potential licence conditions given these issues in Section 15. Finally, we present our recommendation on conditions to be linked to licences for spectrum in the 900MHz band.

14.1 Particularities of Ireland

560. When formulating licence conditions, it is important to consider the particular national conditions faced by mobile network operators and the effects these might have on operating conditions. Ireland has a population of 4.4 million and low population density. Compared with other European countries, Ireland has a low level of urbanisation. The percentage of population living in cities is 61%, which is significantly less than other European countries, for which the corresponding proportion ranges between 75% and 90%. This creates two differences relative to more typical EU Member States:

- mobile communications, both voice and mobile broadband data services, may be of greater importance to those living in more remote areas of Ireland;
- network deployment costs may be higher for a given level of population coverage, as a greater proportion of consumers live in rural areas, and as a result it may be more difficult to incentivise rural roll-out.

561. In considering the arguments for and against particular licence conditions, we have been mindful that the legal and policy framework within which ComReg operates is somewhat different to that of many other European regulators. The most significant difference is that spectrum trading is not permitted in Ireland, unlike many other EU member states. As a result, we cannot rely on any commercial incentives from spectrum trading to encourage efficient use of spectrum throughout the entire life of a licence. In particular, the main mechanism available for re-allocating spectrum during the life of a licence is for it to be returned to ComReg and then re-awarded. This suggests the adoption of a cautious approach to ensuring that spectrum is used effectively and value is created for society. Licence conditions should be set such that if the current licensee fails to make reasonable use of its spectrum, then it will violate those conditions.

562. The absence of spectrum trading means that we do not need to be overly concerned about ensuring that obligations on licensees can be linked clearly with the specific spectrum being used (rather than imposing conditions more generally on the operations of a licensee holding a number of spectrum licences at different frequencies). Indeed, there may be a case for linking the provision of certain services with obligations falling on a licensee as a result of

it being licensed frequencies in a specific band, but then allowing the licensee to meet these obligations using any of the spectrum licensed to it. In effect, although there would be an obligation associated with specific spectrum, there could be flexibility offered in how the obligation is dispatched. This issue is considered further in subsequent sub-sections.

14.2 Lessons from international experience

563. We do not believe that international practice with regard to the setting of licence conditions in general provides much useful guidance with regard to the specific task at hand, that is, setting licence conditions for new licences in the 900MHz band. The market conditions in Ireland are also quite distinctive, as discussed above. In particular, conditions set for licences in other EU countries or in countries further afield are typically not relevant for the following reasons:

- The mobile market is developing and changing very rapidly. Market conditions and technology have evolved in ways that were not envisaged when awarding 3G spectrum (even relatively recently). Conditions applied to UMTS licences issued in 2000 and 2001 may be irrelevant given current understanding of 3G deployment costs and demand for data services.
- With the exception of auctioning guard bands, the most recent licensing has been in higher bands i.e. 2.1GHz and 2.6GHz. The potential licensing issues in the 900MHz band are not the same as in higher bands (1800MHz, 1900MHz, 2.1GHz and 2.6GHz), especially in regard of geographic coverage obligations in rural areas.
- 700MHz was auctioned in the USA during 2008, but this was a band not previously used for mobile services and is not subject to the same widespread *de facto* harmonisation as the 900MHz band.
- Licences recently issued in other countries in previously unused bands do not have to take account of existing technology and service migration. The greenfield nature of such licences makes it easier to apply service- and technology-neutral concepts as there is no need to consider legacy uses.
- Very few countries have already re-farmed 900MHz spectrum and, in the few cases where this has occurred, the circumstances and regulatory framework in which this occurred were different. Some EU countries have already allowed the deployment of UMTS in 900MHz prior to the finalisation of the Amending Directive.
- Mobile data in the form of HSPA only started to take off during 2007 and did not take off in most markets until 2008. This knowledge was not available to regulators that issued licences prior to the explosive growth of HSPA services.

564. For these reasons, we believe that the most relevant benchmarks are those that can be derived from recent 900MHz liberalisation and re-farming initiatives. However, there have been relatively few re-farming processes and in many of the cases to date, these have been based on a negotiation between the regulator and operator, rather than holding an open and competitively

neutral award of licences. Also, re-farming processes have yet to occur with the Amending Directive now in force.

565. Nevertheless, we have examined the following proposed award processes to determine whether there are useful analogies to the current Irish 900MHz award:

- 900MHz award in Sweden (March 2009);
- 900MHz award in Singapore;
- 900MHz award in Hong Kong;
- 900MHz award in New Zealand;
- 900MHz award in Australia;
- 900MHz award in Germany;
- consultation documents for forthcoming 900MHz awards issued in Italy, Belgium and Spain; and
- German consultation document on proposed 800MHz award.

566. In addition, we have also reviewed the licence conditions set in various auctions in the EU and America. We have focused on more recent awards of spectrum as these will have taken the greatest account of recent market developments, especially for mobile data. The most relevant awards are:

- 2008 Canada AWS spectrum auction;
- 2007 Norway 2.6 GHz auction;
- 2008 Sweden 2.6 GHz auction;
- 2008 Hong Kong 2.6 GHz auction and
- 2008 USA 700MHz auction;

567. In conclusion, the particular demographic and geographic conditions in Ireland and the lack of completed award processes for liberalised 900MHz spectrum licences mean that practice from previous award processes may not be appropriate to carry over without a forward-looking view of how mobile markets may develop. This should help to ensure that licence conditions imposed have the maximum potential to remain robust to developments over the course of the licence period.

14.3 Regulatory and policy framework

568. ComReg's duties, functions and objectives in relation to Ireland's radio spectrum are set out clearly in its initial consultation document.

569. Potential licence conditions need to be considered in light of these objectives, bearing in mind that there may be tension between some objectives. For example, if LTE were to be deployed in 900MHz, this would bring greater efficiency in terms of burst rates and data throughput in wider spectrum blocks i.e. above 2x10MHz. (This is in line with ComReg's objective to ensure efficient use of spectrum, as outlined in the Communications Regulation Act 2002.) However, smaller spectrum blocks would allow more operators (current and potential) to offer services at 900MHz and competition might increase (in accordance with ComReg's objective to promote competition as set out in the Communications Regulation Act 2002).

570. As noted in Section 3.1, the Authorisation Regulations (giving effect to Directive 2002/20/EC) require that any licence condition "shall be objectively justified in relation to the electronic communications network or service concerned and shall be non-discriminatory, proportionate and transparent." The Authorisation Regulations also limit the broad types of conditions that may be applied to a licence to use radio spectrum. In particular, Part B lists seven general categories into which spectrum licence conditions should fall:

1. Designation of service or type of network or technology for which the licence has been granted, including, where applicable, the exclusive use of a frequency for the transmission of specific content or specific audiovisual services.
2. Effective and efficient use of frequencies in conformity with Regulation 23 of the Framework Regulations, including, where appropriate, coverage requirements.
3. Technical and operational conditions necessary for the avoidance of harmful interference and for the limitation of exposure of the general public to electromagnetic fields, where such conditions are different from those included in the general authorisation.
4. Maximum duration in conformity with Article 5 of the Authorisation Directive, subject to any changes in the national frequency plan. (The relevant part of Article 5 says "Where Member States grant rights of use for a limited period of time, the duration shall be appropriate for the service concerned.").
5. Usage fees in accordance with Regulation 20.
6. Any commitments which the undertaking obtaining the usage right has made in the course of a competitive or comparative selection procedure.
7. Obligations under relevant international agreements relating to the use of frequencies.[58]

571. Of these seven categories of potential licence conditions, the first and second are the most relevant for our considerations. In particular, the second category is key as it potentially includes various measures aimed at ensuring that spectrum is used efficiently and effectively. We do not consider technical conditions related to interference management (other than in the broad terms already considered in Part B of this report).

572. In its previous 3G licence award, ComReg made extensive use of licence conditions that reflected commitments made by the successful bidders in the comparative evaluation process. These conditions would fall into the sixth category in terms of Annex B of the Authorisation Directive. The situation for the award of 900MHz licences is somewhat different, as our proposal outlined

[58] Note that amendments to the EU regulatory framework for electronic communications were adopted by the Parliament and the Council in late November 2009. Amendments to this framework will need to be transposed into national laws before 19 June 2011.

in Part B is for an auction in which the value of bids forms the basis for determining the winning bidders, rather than a beauty parade in which other qualitative commitments might be made. Therefore, where previously ComReg's 3G award process in effect got licensees to set many of their own licence terms (such as the value of performance bonds), in this case it is necessary for ComReg to set a number of these terms, define licence rights and obligations clearly and then allow competition on price through the auction process.

14.4 Other issues

573. In this sub-section, we briefly discuss some additional issues that should influence the design of licence conditions for licences in the 900MHz band in Ireland.

574. Apart from the freedom to deploy technologies other than GSM in the 900MHz band, the question arises as to whether some of the other licence conditions originally imposed on the holders of 900MHz spectrum are still relevant or should be relaxed or discarded in any new licences awarded.

14.4.1 Role of other bands in meeting obligations

575. When 900MHz licences were originally awarded, they provided the first and (at the time) the only opportunity to deploy mobile networks. New liberalised licences are likely to be used in a different way, with operators holding spectrum at a variety of frequencies and using a portfolio of spectrum to deploy networks in the most efficient manner (for example with lower frequencies used to provide wide-area coverage and higher frequencies to provide localised capacity). The link between spectrum holdings at one particular frequency and deployment of a particular service is becoming tenuous, and will likely become even more so over the coming years.

576. In considering how licence obligations might be imposed upon spectrum licence holders more broadly, it would appear at first that there is some tension between the potential objectives of, firstly, the imposing of licence obligations linked to specific frequencies and, secondly, allowing licensees the flexibility to decide how to meet their obligations resulting from the acquisition of a spectrum licence relating to particular frequencies. However, as aforementioned, it appears possible to impose licence obligations on specific spectrum holdings and yet allow licensees a degree of flexibility to meet these obligations by:

- conferring upon a licensee certain obligations as a result of holding a licence relating to certain frequencies (in this case, frequencies in the 900MHz band); and simultaneously
- allowing the licensee to meet the obligations deriving from its 900MHz licence with the spectrum assigned to it in the 900MHz band and/or spectrum assigned to it in any other band.

We return to the question of what conditions this approach might be relevant for in the following section.

14.4.2 The characteristics of 900MHz spectrum

577. Special consideration needs to be given to the licensing of spectrum below 1GHz generally due to its different propagation characteristics compared with higher frequency bands. Sub-1GHz spectrum is ideally suited for providing geographic coverage in rural areas in a cost-effective manner and for providing better in-building penetration.

578. Digital dividend spectrum may be an alternative source of sub-1GHz spectrum in the future, but the timescale for release of this spectrum and the potential availability of equipment is currently uncertain. Therefore, for the time being anyway, the 900MHz band is the only available sub-1GHz band to shortly become available for deploying broadband mobile services in Ireland.

14.4.3 Mobile data market and uncertainty

579. In 2007, mobile data services finally started to take off, despite many years where expectations of demand were not realised. The introduction of HSPA technology has played a major role, with HSPA built into many handsets and the rapid take-up of mobile data dongles for laptops. An increasing amount of web browsing is occurring through mobile devices. The “Internet of Things”, with on-line connectivity of a wide-range of equipment is another source of potentially massive growth in demand for mobile data that we have yet to see. At present, mobile data demand is growing exponentially in all European markets. For example, Cisco has forecasted that mobile data will grow at a compound annual growth rate of 131% from 2008 to 2013[59].

580. To support possible demand of this magnitude, regulators will need to release available spectrum efficiently, rapidly and where possible on a technology- and service-neutral basis. This development underscores the need to facilitate the use of spectrum across many different bands operating in conjunction with one another to provide enough capacity to support services. Further, operators will need to deploy new technologies and be commercially innovative to meet these challenges.

581. Licence conditions should not attempt to second-guess these future developments, as the path is so uncertain. Licence conditions should, however, be robust to unpredictable changes in technology, services and potential legislation. Where such conditions do not meet the requirements of such a rapidly developing market, competition and indeed innovation may be dampened. In contrast, if a licence condition introduces a principle and allows for the specifics to be ruled upon as and when the need arises, this allows much greater flexibility for operators in meeting unpredictable levels of demand for different mobile services.

[59] See Cisco’s VNI Forecast available at: http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html

14.4.4 Technology neutrality

582. For example, in existing Irish GSM licences, coverage is defined by reference to average field strength for the base-to-handset radio transmissions. A certain field strength threshold must be met for outdoor coverage to be considered present and a higher threshold for indoor coverage. The use of a field strength criterion is possible in this case because the radio technology is known.

583. Moving to technology -neutral licensing may create problems for this approach. Because the radio technology is not fixed, it may make less sense to define coverage in terms of field strength. For example, the field strength criteria are significantly different amongst 3G and GSM licences, partly because of the different propagation characteristics of different bands, but also because of the use of fundamentally different radio technologies. Clearly a field strength requirement is rather arbitrary if the technology is not known in advance. Furthermore, some services may be inherently more fault tolerant than others.

14.4.5 Meeting of social objectives

584. There are two social benefits generated as a result of the *current* licensing regime in the 900MHz band in Ireland that need to be considered:

- National coverage for voice calls: Current licences held by existing operators in the 900MHz band have high coverage requirements.
- Emergency service calls: A further aspect of voice coverage relates to public safety, in that GSM licensees are required to provide free emergency service calls which, by virtue of current coverage levels, is widely available.

These issues need to be considered in the context of alternative licence conditions considered for new 900MHz licences. In particular, there could be a worry that existing voice coverage levels might not be maintained if existing obligations are dropped; this would have a knock-on effect for the geographic availability of emergency calls.

585. However, against this worrisome possibility we must balance the fact that competition between mobile operators has led to existing coverage levels in excess of the requirements of current 900MHz licences. Therefore, if competition is a sufficient spur to providing coverage, it may be possible to set weaker coverage obligations without risk to the availability of voice calls (and emergency calls). Indeed, it seems unlikely that any operator would unilaterally reduce geographical coverage when migrating from GSM to 3G, as this would create an opportunity for its competitors.

586. Given sites and backhaul are already in place to support existing GSM coverage levels, the cost savings for an operator of reducing coverage from existing levels may in practice be quite limited. Although it is possible that existing operators might rapidly switch 900MHz spectrum from GSM to 3G use in urban areas to provide more capacity, in rural areas the economics are likely to be different. Incumbent operators (at least those that win 2x10MHz of liberalised spectrum) would be more likely to initially switch some, but not all, of their 900MHz spectrum from GSM to 3G use, retaining at least some spectrum to

run a legacy GSM network in rural areas. The economics of turning off GSM networks in rural areas is likely not to be driven so much by pressing need for spectrum for 3G, but rather by the fact that it would become unprofitable at some point to maintain and run a legacy GSM network with few users.

587. We discuss subsequently the difficulties that might arise from trying to carry over obligations from existing 900MHz licences to new liberalised licences. Given these difficulties, it may well be that simply rolling over obligations on any incumbents who win new licences will be impractical. In this case, the question is whether the social objective for voice coverage, and associated objective for emergency call coverage, can be met in other ways, for example through greater reliance on competition amongst operators to secure acceptable levels of coverage.

14.4.6 Issues for coverage

588. A coverage obligation could be used as a tool to ensure the coverage of rural areas, in that licensees are obliged to cross-subsidise services in less profitable geographical areas from those in more profitable areas. In such a case, there is a strong argument for applying a coverage obligation homogeneously to all licensees so as not to distort service market competition. All operators would face similar constraints on the pricing of services created by the same coverage obligation and would compete to dispatch the obligation at least cost.

589. Whilst coverage obligations are a key tool in achieving rural provision, there are two distinct ways in which the obligation might be formulated. The first is a simple compulsion: provision of a particular service over a certain geographical area is required as a licence condition. This is the way coverage obligations are typically implemented. A second alternative approach is prohibition of cherry-picking behaviour. We would want to prevent an operator serving just low-cost areas at a lower price than competitors with greater coverage; this ensures that cross-subsidisation between high- and low-cost areas is not undermined by competition. This can be achieved with the weaker obligation that, if an operator provides a particular service, then it must meet a coverage obligation. However, this second alternative is a weaker condition than the first, as it does not compel provision of a particular service, but rather only prohibits cherry-picking in the event that the service is offered.

590. Specifically in Ireland, given that there is no provision for spectrum trading, coverage obligations could also be used as a safe-guard against spectrum being hoarded either anti-competitively or inefficiently, as holding spectrum entails some commitment to build network infrastructure. In either case, where coverage obligations are being used as such a safeguard, these would not need to be set at a high level to achieve the desired effect.

14.4.7 Homogeneity of new licences

591. Where it is possible to have concurrent licences, there are potential benefits from concurrent licences in a band being homogeneous, i.e. all licences in force at the same time having the same conditions. This should allow for neutral competition in service markets across licensees. Even if asymmetric conditions are well-intentioned, there is a risk of unexpected consequences

that might later create competitive distortions as future market developments cannot be foreseen.

592. Homogeneity also has significant practical benefits, as it would make administration and oversight of licences by ComReg easier through a common compliance regime for all licensees. Design of the award process may also be simpler if it is possible to treat licences as a single homogenous group and all bidders are subject to similar obligations if they win licences.

593. Given the benefits envisaged as a result of homogenous licence conditions, and the difficulties in justifying differences in licence conditions that would sustain over a reasonably long period, it is unsurprising that most spectrum awards to date have offered homogeneous licences. Of the countries with recent 2.6GHz or 900MHz awards (listed in Section 14.2 above), all of these involved homogenous licences with one exception: Hong Kong, which places a universal service obligation on the largest player. The first wave of 3G awards across Europe in 2000/2001 in some cases involved reservation of licences for new entrants or variation in the amount of spectrum made available in each lot, but otherwise licence conditions were typically homogeneous. Therefore, heterogeneity in licence conditions is rather uncommon in practice.

594. Despite the prevalence of homogeneous licensing, it is still worth considering critically whether this principle should apply to the award of 900MHz spectrum in Ireland, specifically those concerning coverage and roll-out obligations, given the asymmetry between existing operators in the 900MHz and other potential operators in this band:

- Bidders are in asymmetric situations in that existing licence holders in the 900MHz band might continue using this spectrum for legacy GSM operations for some time and currently meet high coverage obligations as mandated in their current licences. However, mandating similar high coverage levels for new 900MHz licences may make the business cases of potential entrants infeasible.
- Any potential new entrant to the 900MHz band may not be in a position to provide the same type of level of services as an existing operator in this band, as it may not have a comparable level of access to spectrum at other frequencies to use alongside 900MHz spectrum.
- Owing to the conditions of existing 900MHz licences, existing operators in this band are best placed to continue to meet the social objectives in previous sub-sections.

595. In this context, in our assessment of whether new 900MHz licences should be homogenous or not, we have considered coverage and roll-out in the context of three alternative licensing principles:

- *Homogeneity of all new 900MHz licences:* this would involve exactly the same conditions for all new licences and would require coverage (and similar) obligations to be set in a manner where it is feasible for an entrant to compete;
- *Tailoring of licences to the historic position of operators:* Where new licences were to be awarded to operators currently holding 900MHz licences, coverage obligations would be set equal to those currently mandated. This would provide protection against any reduction in

voice coverage (and consequent impact on emergency call availability). Where new licences were to be awarded to operators new to the 900MHz band, coverage obligations would be set at a lower level, the same level for all new entrants to the band.

- *Coverage clause specific to GSM use:* In this case, licence conditions would not be triggered by historical use of GSM *prior* to award of the current licence, but rather by any use of the liberalised licence for GSM. In this sense, licences would be homogeneous for all licensees, though certain additional obligations would fall on any licensee using all or part of its 900MHz spectrum for GSM. There could be a modest coverage requirement for 3G services but, where an operator opts to provide GSM services, a higher coverage requirement for voice services could apply.

596. A possible risk with the second of these approaches is that setting different licence conditions for licensees according to the previous coverage obligations set under a now expired licence might be resisted by the existing incumbents. It might be argued, for example, that if the rights accorded by existing 900MHz licences expire, then so should the obligations associated with those licences. This is not, in our view, a compelling argument, as there are objective differences in the positions of licensees according to the network assets they already have in place, access to radio sites and so on which might justify differing treatment. There are clear precedents for treating incumbents and entrants differently in award processes, such as through reserving licences for entrants (as in the 2000 UK 3G award) and differing treatment of licensees is provided for under the Authorisation Regulations.

597. The third approach attempts to overcome any potential objections by only conditioning licence conditions on how the spectrum is *currently* used and not taking into account in any way licensees historic positions. Given that existing GSM operators who won spectrum would be likely to run a legacy GSM service, this is effectively quite similar to the second approach in terms of likely outcomes achieved, but is arguably less open to arguments of discrimination as the additional obligations for GSM would potentially apply to any person offering GSM. However, this approach is too blunt to allow us to take into account any difference between operators in the coverage of existing GSM networks or differences between the coverage obligations of existing 900MHz licences. Therefore, even this approach does not provide an effective means to roll over existing GSM coverage obligations, as there would be no means to differentiate between the different positions of the existing GSM operators.

598. On balance, we believe that the first approach is preferable provided that there is reasonable confidence that relaxing coverage obligations would not compromise social objectives for voice coverage and associated emergency call coverage.

14.4.8 Scope of licence conditions

599. Given ComReg's objectives in relation to licensing of spectrum in Ireland, it may be appropriate to attach some non-technical conditions (i.e. conditions other than those needed for interference management) to licences. Indeed, it is very common across all jurisdictions to impose such conditions.

Nevertheless, there are good arguments for keeping such licence conditions to a minimum:

- Licences are more likely to be future proof with respect to technology, services and changes in legislation; and
- Licences with fewer associated licence conditions are more likely to attract new entrants, especially those with unconventional business cases.

600. Further, it is important not to use licence conditions as a means of achieving specific policy goals where these may not be the most economically efficient mechanism for achieving such goals. The argument against excessive use of spectrum licensing as a policy tool was well argued by Ofcom, the UK telecommunications regulator[60]:

> *"1.26 The key message is that while the use of spectrum to achieve policy goals is seductive in that it appears to allow worthy objectives to be achieved at no cost, this is far from the truth. It is likely to be more costly than intervention at the output stage and it results in less clarity as to the cost of achieving the objective. It should generally be avoided."*

This should be kept in mind when assessing the alternative licence conditions in the following section.

[60] Ofcom, "Progress on key spectrum initiatives", 3 April 2008. See http://www.ofcom.org.uk/radiocomms/sfr/sfrprogress/

15 Discussion of key licence conditions

601. Existing GSM 900MHz licences impose conditions in the following broad areas:

- Definition of the licensed mobile services to be provided;
- Quality of service, performance standards and obligations, e.g. maximum rates for dropped and blocked calls, billing requirements, etc.;
- Provision of free voice calls to the emergency services;
- Roaming;
- Coverage and roll-out obligations;
- Charges to customers; and
- Performance guarantees.

602. Many of these conditions relate specifically to named services where provision of these services is a licence requirement. For new 900MHz licences, the more liberalised environment would require making licence conditions less linked to the provision of specific services. Nevertheless, some conditions such as billing requirements or minimum standards for voice calls could be carried over quite naturally to a more liberalised environment with a little reinterpretation.

603. However, by far the most significant issue for new licences is the extent to which existing coverage obligations could be carried over to new licences and, even if feasible, whether it is desirable to do so. This issue is intertwined with that of whether licences should be same for all licences (homogeneous licences) or else differentiated according to some objective differences across licensees (such as whether they previously held a GSM 900MHz licence).

15.1 Coverage and roll-out obligations

15.1.1 International practice

604. There is much variation amongst the few available examples of international practice in setting of coverage obligations for recent spectrum awards in comparable spectrum bands:

Table 18: International practice in setting coverage obligations

International Country	Coverage Requirement
900MHz award in Sweden (March 2009)	Maintain percentage area coverage per county for a mobile telephony service that is currently being maintained until 31/12/15 Coverage may be provided by using one's own or another licence holder's infrastructure in the 900MHz, 1800MHz and 2.1GHz bands
900MHz award in Singapore	Nationwide coverage of Public Cellular Mobile Telecommunication Services within 2 years

900MHz award in Hong Kong	50% of population* – 5 years *Coverage refers to network and service coverage, band currently used for GSM and is designated for public mobile services. The TA is also inclined to require the successful bidder to lodge a performance bond to ensure its compliance with the rollout obligations.
900MHz award in New Zealand	Within five years of purchase: • The licensee must provide a cellular service that is available for use by, and is being offered for use on a commercial basis to, at least 65% of New Zealand's resident population without relying on infrastructure (including networks) provided by persons other than the licensee • The cellular service provided must operate 24 hours per day, seven days per week (excluding reasonable outages including those for maintenance and construction
900MHz award in Australia	There is no coverage obligations in the original PCS 800MHz licences described in the auction documentation Not clear what the licence conditions on coverage will be for re-farmed spectrum and for digital dividend spectrum

800MHz award in Germany (for the 790-862MHz spectrum in upcoming German Big Auction and not the existing 900MHz licences)	(1) Minimum total coverage* by 01/01/2016: 50% (2) Four roll-out categories in each Federal state with a requirement that the roll out obligation has to be completed in ascending categories (roll our to rural areas first). The categories are defined as follows: • Category 1: underserved rural areas (pop<5001, but Federal States can determine whether other areas are underserved as well), minimum 90% coverage** • Category 2: 5000<pop<20,001, min. 90% coverage** • Category 3: 20000<pop<50,001, min. 90% coverage** • Category 4: 50000<pop, min. 90% coverage** *The coverage requirement does not refer to any particular service but this frequency band was designated for mobile services with a preference for services providing high-speed internet to rural areas **If, in the period up to 1 January 2016, towns and districts are served by other providers/technologies using equivalent or advanced broadband solutions, this coverage will count towards the 90% target rollout obligation.
2008 Canada AWS spectrum auction	Between 10% and 50% of the regional population (licences were regional) within 5 years. Roll out obligation was with reference to Advanced Wireless Services and was roughly proportional to population density of the region[61]
2007 Norway 2.6GHz auction	No coverage or roll-out requirements apply
2008 Sweden 2.6GHz auction	No coverage or roll-out requirements apply

[61] See Annex 2 of Industry Canada's *Policy Framework for the Auction for Spectrum Licences for Advanced Wireless Services and other Spectrum in the 2 GHz Range* for the regional breakdown of roll out targets.

2008 Hong Kong 2.6GHz auction	Roll out obligation was service dependent: (a) where the scope of the service authorised under the Licence includes a fixed service, coverage of the network and the service shall be provided within 5 years from the issue of the Licence and maintained thereafter, to a minimum of 200 commercial and/or residential buildings in Hong Kong; AND (b) where the scope of the service authorised under the Licence includes a mobile service, coverage of the network and the service shall be provided within 5 years from the issue of the Licence and maintained thereafter, to an area where at least 50% of the population of Hong Kong live from time to time.
2008 USA 700MHz auction	Licensees must provide signal coverage and offer service* to (1) at least 35% of the geographic areas of their licences within four years of the end of the DTV transition, and (2) at least 70% of the geographic areas of their licences at the end of the licence term * The 700 MHz Band licenses may be used for flexible fixed, mobile, and broadcast uses, including fixed and mobile wireless commercial services (including FDD- and TDD-based services); fixed and mobile wireless uses for private, internal radio needs; and mobile and other digital new broadcast operations. These uses may include two-way interactive, cellular, and mobile television broadcasting services.

605. Consequently, this does not by itself provide any clear lessons in considering potential coverage obligations for new licences in the 900MHz band in Ireland. Nevertheless, the coverage obligations being imposed in recently awarded licences (which are likely to be used incrementally alongside other spectrum by existing operators) are typically less onerous that those imposed when GSM or 2.1GHz spectrum was initially awarded for the creation of new networks.

15.1.2 Carrying over existing coverage obligations

606. What case might there be for carrying over similar coverage obligations currently in existing GSM licences, either to voice services or to even data services? Existing Irish GSM 900MHz licences impose somewhat different coverage obligations on the three existing operators. The most onerous conditions are on Vodafone, who have a 99% population coverage obligation and a 92% geographical coverage obligation. O2 has a similar (though slightly weaker) obligation to Vodafone, but Meteor has a less onerous 80% population coverage obligation. These would be considered as “high” coverage obligations in the context of international examples presented in Table 18 above, the large majority of which impose significantly less onerous requirements.

607. Regardless of the service affected, if all new licensees were faced with coverage obligations which were similarly high to coverage levels under the existing licences, this could be disadvantageous to entrants in terms of their ability to meet those obligations. If existing 900MHz operators were to win new liberalised licences, they would be able to meet almost any voice coverage obligations imposed immediately and would have a very large advantage in meeting any data coverage obligation. Conversely, a new entrant to this band may require substantial resources to provide such high coverage levels. Coverage obligations that are set too high may render many potential new entrant strategies infeasible. Therefore, it is likely that high coverage obligations on all operators winning new liberalised licences in the 900MHz band would dampen competition within the auction and discourage participation by potential new entrants.

608. For these reasons, regardless of the affected service, we would not recommend setting high coverage obligations homogenously for all licensees due to the adverse impact on entrants.

15.1.3 Heterogeneity of coverage obligations

609. What about the alternative approach of differentiating coverage requirements according to whether licensees had previous 900MHz licences? We focus first on whether there would be a material social benefit from such variation, regardless of how exactly we might implement these heterogeneous licence conditions.

610. The case for varying the new licences for liberalised 900MHz spectrum and imposing tighter conditions on incumbents hinges on the view taken of the benefits of the high levels of GSM coverage in Ireland at present. If there is social value to high coverage, the question is how effective competition can be in delivering sufficient coverage if such external benefits are not fully taken into account by operators when building out their networks. Would these benefits be reduced or maintained if it was left entirely at the discretion of existing and potential operators in the 900MHz band to decide their level of coverage?

611. We note that the roll-out and coverage obligations required for GSM networks in the 900MHz band have already been achieved and indeed have exceeded the minimum levels mandated in all three GSM900 operators' respective licences. Even though there may be social benefits of building out networks that operators do not necessarily take into account, the mode of competition between operators nevertheless gives strong incentives to provide coverage as an aspect of service quality differentiation. Therefore, the probability that these levels of coverage would reduce significantly as a result of migrating to 3G technologies seems likely to be low.

612. Nevertheless, before concluding on this point we must consider that relaxing a coverage obligation at the same time as liberalising licences is a somewhat different situation to hypothetically relaxing the coverage obligation on *non-liberalised* GSM licences. Clearly operators are likely to use liberalised spectrum for 3G services (as this provides capacity at lower unit cost as well as new services), which will over time progressively squeeze out GSM services. This process will probably happen first in urban areas where 3G's advantages in delivering capacity are most valuable. Nevertheless, despite there being

competing demands on an operator's spectrum for provision of 3G and legacy GSM services, it is difficult to see how opening up the option to provide 3G services could reduce rural GSM coverage in the short term. Over time, as GSM equipment is swapped out even in rural areas, there is no obvious incentive for incumbents to reduce coverage if they have already found it desirable commercially to offer that level of coverage already. Indeed, it might even be that the cost advantages of 3G networks over GSM networks might even encourage further roll-out in the long term as more marginal areas may become economic to serve.

613. A somewhat different issue is whether differentiated licence conditions might raise concerns about those licensees with less onerous coverage conditions cherry-picking. Could such an approach to licence conditions facilitate a strategy for new entrants to offer only the more profitable services – that is, services only in relatively high density, urban areas? Were these services to cannibalise existing 900MHz operators' customer bases, might this erode those operators' ability to cross-subsidise lower margin, rural based customers? If so, this would tend to undermine, rather than enhance, rural coverage.

614. This cherry-picking scenario does not seem likely. An entrant would be at a natural, significant disadvantage to incumbents in terms of access to sites and existing backhaul networks. It might be able to compete for certain types of customers and in certain geographical areas, but would not have the initial coverage of an incumbent (whether for voice or data services) and might find it difficult to compete for high-margin customers. Furthermore, placing even a moderate coverage obligation on an entrant would significantly constrain its ability to behave in this manner.

615. In summary, there does not seem much benefit to be gained from using heterogeneous coverage conditions. Although it might be argued that imposing a high coverage obligation on incumbents could be a safeguard to protect existing GSM coverage levels, such an approach would only remove what is, in our view, a small risk. Further, as noted above, there is always the possibility that, whether warranted or not, the imposition of heterogeneous coverage obligations could give rise to arguments about discrimination.

616. ComReg's current policy regarding new liberalised licences in the 900MHz band is that existing operators will not get to access these benefits simply by retaining existing 900MHz licences; rather, they would have to compete for new licences in open competition on the same basis as other operators that have not previously held licences in this band. Given this approach, it might seem inconsistent to require that these operators take on obligations from expired licences where their corresponding rights from those licences have clearly lapsed. However, given the differences in the respective positions of licensees, such differing treatment may be justified if the grounds for doing so are sufficient to meet ComReg's requirement for its actions in such instances to be proportionate.

617. A further possible approach might be to create different classes of licences, say some with higher coverage obligations and others with lower coverage obligations. These different classes of licence could then be offered alongside one another at auction. This might neutralise any potential objection about discrimination between different operators on the basis of their historic

position, as all bidders would have exactly the same opportunities to select between different types of licence with different obligations within an open competition. Whilst this might seem superficially attractive, there are significant problems. It would make any award process much more complex. Most importantly, licences with high coverage obligations would very probably not attract competition other than from incumbents. Therefore, it would be difficult to sustain any significant competition for such licences within an auction and incumbents might be able to win licences at a fraction of their true opportunity cost. Entrants might argue that they were being treated unfairly, as they would be constrained in the licences they could compete for.

618. In summary, setting different coverage obligations for different licensees seems to offer little advantage that might outweigh the potential risks. There may be little benefit in trying to carry over existing coverage obligations of GSM licences for incumbents as competition is in any case likely to deliver a reasonable outcome given the GSM coverage levels from which we are starting. Against this we need to balance the fact that any such approach with heterogeneous conditions would run some risks of complaint that the differentiation of licence conditions was not justified (whether or not this argument is ultimately viable). Therefore, we would recommend that any coverage obligations apply homogeneously to all licences. This would require coverage and roll out obligations appropriate for new entrants, otherwise competition within the auction may be impeded and entrant unfairly penalised.

619. Therefore, in the following sub-sections, we consider the level of potential coverage obligations in light of specific services with a view to providing a recommendation that is suitable for all new 900MHz licences and in light of the issues surrounding those specific services.

15.1.4 Potential coverage obligations for mobile broadband

620. First, we consider the specific question of whether there might be any rationale for imposing a homogeneous coverage obligation for mobile broadband services.

621. ComReg is required to ensure the extensive rollout of broadband services in Ireland:

> *"The Commission shall, in the exercise of its functions, take into account the national objective regarding broadband rollout, viz, the Government wishes to ensure the widespread availability of open-access, affordable, always on broadband infrastructure and services for businesses and citizens on a balanced regional basis within three years, on the basis of utilisation of a range of existing and emerging technologies and broadband speeds appropriate to specific categories of service and customers."*
>
> *Direction 3, as published in the Official Journal on 28 February 2003*
>
> *"ComReg shall use regulatory and enforcement tools, where necessary and subject to relevant requirements under European and National law, to support initiatives to develop broadband and remove regulatory barriers, if any exist, to such initiatives. In encouraging the further rollout of broadband ComReg shall have a particular focus on:*

- *the residential and SME sectors;*
- *balanced regional development and;*
- *potential for broadband provision on alternative platforms."*

Direction 2(i)(b), as published in the Official Journal on 2 April 2004

622. There appear to be two approaches that could be adopted in implementing coverage obligations to promote mobile broadband in rural areas. The first approach would require operators in the 900MHz band to offer a mobile broadband service with a defined minimum data rate (burst and/or average) and a minimum coverage level (most likely based on population).

623. This first approach might be rather inflexible, as it requires a particular type of service to be offered. Whilst it may be possible to second-guess how spectrum is likely to be used in the near-term, such an obligation to provide a particular type of service might not be future-proof. Moreover, if the coverage level required was too onerous it might even constrain the possibilities for existing 900MHz operators that win new liberalised licences to provide legacy GSM services. Any incumbent GSM operator winning spectrum would need to make part of its spectrum available for mobile broadband and would be constrained by the amount of remaining spectrum available for providing legacy GSM. Indeed, it may be impossible to then provide legacy GSM at all under such an obligation if an operator only won a single 2x5MHz block. Therefore, at the very least any such obligation would need to be set conservatively to avoid the risk of impeding provision of legacy GSM services.

624. The second approach would require that operators be subject to a coverage obligation in regard to mobile broadband in the event that it offered such a service satisfying the definition, but there would be no obligation to provide such a service. This is effectively a prohibition on cherry-picking, rather than a compulsion to offer the service. To implement this second approach it is particularly important to have an appropriate definition of what "mobile broadband" is, which would probably involve:

- provision of general access to the public Internet; and
- a minimum download speed to distinguish the service from narrowband data.

Any service that satisfied these criteria would then need to meet the coverage obligation.

625. This second approach is quite attractive, as it does not force any particular choice of technology or service on the operator. If an operator chose to compete for mobile broadband consumers, it would be subject to the coverage obligation and, therefore, be required to deploy mobile broadband services to a significant portion of the country. In effect, the coverage obligation would act as a restriction on cherry picking behaviour, but otherwise leave operators free to continue with legacy GSM services as they saw fit.

626. Providing the coverage obligations were not set uneconomically high, this approach seems a reasonable means to encourage at least one operator (and possibly a number of operators) to provide mobile broadband services with the desired coverage level without the risk of cherry-picking. Consider the

alternative that no licensee offered such services. This would create an opportunity for one operator to be the sole provider of such services, particularly where the coverage obligation was very onerous. Typically one would expect multiple providers (indeed, probably all licensees) to provide such services given the expected growth of the mobile broadband market. More generally, there might be a trade-off between the coverage obligation set and the economically viable number of providers choosing to provide such services.

627. For such a coverage obligation to work effectively, it is very important that the definition of "mobile broadband" is sufficiently broad. In particular, if the definition were too narrow, it might be possible to construct a service that fell outside of the definition and so was not subject to the coverage obligation, but which still competed to some extent with other mobile broadband services that were subject to coverage obligations. This would allow for cherry-picking of high-margin urban areas by inventing a service that fell outside the coverage obligation. For example, if a requirement for "mobile broadband" was a minimum upload speed, then someone might try to cherry pick by offering a service with fast download, but slow upload that was suitable only for web browsing but nothing else. This would undermine the profitability of those services subject to the coverage obligation and the original objective of allowing geographical cross-subsidisation.

628. Regarding the assessment of what level at which this obligation should be set, a level must be set that incorporates two separate issues. One issue is stopping cherry-picking (discussed above), which requires that the coverage area at least covers the most profitable customers. A key consideration in considering what level of coverage might be mandated is the proportion of the Irish population that live in areas that would be regarded as relatively desirable to serve. We consider that the level of the Irish population living in urban areas is a possible indicator of this. In 2008, 61% of the population of Ireland were living in urban areas[62]. The extent of urbanisation should be a central consideration in setting any coverage obligation on new licensees. Specifically, we consider that a requirement much less than this would allow new entrants to focus only on a sub-set of high-margin, urban customers. This would erode the feasibility of existing operators in the 900MHz band that were to aiming to offer higher coverage services. Conversely, prescribing a coverage level much beyond this level might call into question the feasibility of a new entrant.

629. The other issue that would need to be taken into account is the National Broadband Scheme. Under this scheme, H3GI has been granted support for providing broadband in a number of specified rural areas within Ireland. The aim of this scheme is to provide broadband services to the final 10% of the population, which requires the coverage of an additional 33% of the area of the country. This scheme has a number of implications for broadband coverage obligations for 900MHz licences:

[62] CIA World Factbook

- First, the Scheme ensures national coverage for these services, removing this motivation from the assessment of broadband obligations on 900MHz licensees as a means to ensure this level of coverage.
- Second, given that H3GI is required to provide wholesale access to any other operator that wishes to serve premises in the area covered by the National Broadband Scheme, the conditions are favourable for future operators in this band to roll out to as much of the country as is feasible given the services they intend to provide and their assessment of demand for these services and to use wholesale access (if appropriate) to extend coverage where roll-out would otherwise be uneconomic.

Considering these factors, we recommend only a medium level of coverage obligation be set for future broadband operators in the 900MHz operators in this band. This would allow a data-centric entrant to cover major urban centres without providing incentives for existing 900MHz operators that win new licences to roll back services when transitioning to 3G technologies.

15.1.5 Potential coverage obligations for voice

630. Similar options exist for structuring coverage requirements for voice services. The simple approach is to compel voice services to be supplied with a minimum coverage. A possibly better approach might be to have a coverage obligation without a compulsion to offer a particular service. If an operator were to use the licensed spectrum to provide voice services, then it could subject to a coverage obligation. If the operator chose not provide a voice service, it would not be not subject to such an obligation.

631. The case for setting a voice coverage obligations has a variety of potential costs and benefits, the nature of which will inevitably change with the extent of the coverage obligation. The principle benefits are:

- *Protection of existing GSM voice coverage levels.* With a sufficiently strenuous coverage obligation, any risk of rollback of existing voice coverage levels can be eliminated. However, to achieve this, it is necessary for tight obligations to apply to existing operators immediately on take-up of new licences. In particular, this benefit would not be present if all licences had phased roll-out obligations that only required levels of voice coverage comparable with existing GSM levels to be achieved several years after the start of new licences. A further issue is that for this benefit to be present, there must be an underlying assumption that competition between MNOs will not by itself deliver an acceptable level of coverage.
- *Knock-on benefits for emergency call coverage.* Although this benefit might be collapsed in with the previous category, a high level of voice coverage also ensures that the provision of emergency calls in rural areas is protected. Again, this benefit is only relevant if a coverage obligation is set at a sufficiently high level (i.e. comparable with existing GSM coverage levels) for at least one licensee.

- *Prevention of cherry-picking that might undermine competitive provision of reasonable coverage levels.* Setting coverage obligations at even a moderate level may prevent strategies aimed at picking off the most profitable urban areas with low prices. This may be sufficient to ensure that competition amongst operators delivers wide coverage, as it is possible to use higher margins earned in low cost urban areas to cross-subsidise higher cost rural areas. It is not necessary to set a high coverage obligation to achieve this effect, but merely a sufficiently onerous obligation to prevent such a cherry-picking strategy.

632. On the cost side, we need to consider the following issues:

- *Discouragement of entrants and reduced auction participation.* If voice coverage obligations are set too high or if roll-out obligations do not allow sufficient time for coverage obligations to be met, this is likely to make licences highly unattractive for new entrants. At the same time, there could be little diminution in the value of licences to GSM incumbents, who could meet high voice coverage requirements easily. This could reduce competition in the auction and lead to spectrum being awarded at far below its true opportunity cost. It would be unfair and discriminate against entrants.

- *Inadvertent creation of a data coverage obligation.* Depending on how a voice coverage obligation is framed, there is a danger that data services not directly aimed at provided voice service could come within the scope of the obligation. In particular, any data service with sufficient bandwidth and sufficiently low latency has the potential to carry voice service over a data carrier. Current VOIP services are a good example. If a voice coverage obligation is framed in a service and technology neutral manner, it is difficult to see how services such as VOIP could be excluded from the obligation. Therefore, the situation could arise that an operator intending primarily to offer data services finds its coverage strategy effectively constrained by a voice coverage obligations. Even if voice coverage obligations are framed more tightly to avoid this problem, it may be difficult to eliminate the perception that there is some risk for a data-centric entrant focussing primarily on urban areas.

633. Overall, we believe that the case for voice coverage obligations is much weaker than that for mobile broadband. This is because existing GSM coverage is already high and, as we have already discussed, it seems unlikely that existing operators who secure liberalised licences will use this as an opportunity to wind back voice coverage. Further, depending on how these obligations are set, such an obligation on voice may act as a deterrent to potential entrants considering only the provision of broadband services.

15.1.6 Costs of meeting coverage obligations

634. Although we have identified some risks above from setting high coverage obligations (both for data and voice services), equally it must be recognised that the costs to operators, especially incumbent operators, of meeting even quite strenuous coverage obligations are not necessarily prohibitive given the propagation characteristics of 900MHz spectrum.

635. The move from 3G at 2.1GHz to 3G at 900MHz should drastically reduce the cell sites required to meet coverage requirements. Indeed, in it report for ComReg on this issue commissioned in 2008, Vilicom estimated that the cost savings from deploying 3G infrastructure at 900MHz relative to 2.1GHz was as much as 35%. As evidenced below, this saving relates to the dramatic reduction in the number of base stations required to reach a high proportion of the Irish population:

> *"A design exercise was carried out in order to assess the deployment cost of national UMTS networks in the 900 MHz, 1800 MHz and 2100 MHz bands. The design was carried out to provide voice & data coverage to 95% of the population and 80% of the geographic area of the Republic of Ireland. The number of base-station sites required for a 900 MHz network was found to be 533, 1013 for an 1800 MHz network and 1243 for a 2100MHz network."*[63]

636. As a further illustration of this saving on infrastructure, consider the case of Sweden (for which there is publicly available data and models). The publicly available cost model assumes the following base station radius for rural areas and the corresponding maximum cell coverage in each case:

Table 19: Typical cell radii

Spectrum band	Base station radius for rural areas	Maximum cell coverage
900MHz	10km	260km^2
1800MHz	6km	93.4 km^2
2.1GHz	4km	41.6 km^2

637. It is immediately apparent that there are large advantages from using 900MHz spectrum to provide mobile services in low population density, rural areas. This is particularly important in the case of Ireland given the large proportion of the country that has a relatively low population density. The landmass of Ireland covers approximately 70,000 square kilometres. Therefore, if one were to provide coverage throughout the country around 270 cells would be required (before taking account of topographical features that might require a small upward adjustment to this figure). This number is relatively small in relation to the total number of cells used by operators at present.

638. Considering further the case of Sweden, extending rural coverage from around 1/3 to all of the rural areas increased costs in that model by around 10%. However, Sweden has a surface area of around 6.5 times that of Ireland while its population is only 2.25 times that of Ireland. This suggests that the *incremental* impact of changing coverage requirements may be rather small

[63] ComReg 09/14a, "Redacted Vilicom Report on UMTS Network Design and Cost".

once coverage requirements are already reasonably high due to the large size of 900MHz cells.

639. These models suggest that the cost implications of setting coverage obligations at the levels considered in the Vilicom report might be modest, at least for an incumbent. However, we have not investigated this issue systematically as this would require technical modelling beyond the scope of this study.

15.1.7 Assessment

640. There are various advantages and disadvantages for setting high coverage requirements. Although the costs of meeting coverage requirements may be not be prohibitive for incumbents, there are concerns about the relative effects on entrants and incumbents. Differentiating coverage obligations across entrants and incumbents is not without risks, as this is open to arguments about objective justification and compatibility with a neutral competitive process for all liberalised licences.

641. Overall, the idea of carrying over existing voice coverage obligations in some way as a safeguard for existing coverage levels is not compelling. We believe that given the cost characteristics of 3G networks at 900MHz, high coverage levels for 3G services will be met anyway (at least by incumbents winning liberalised licences) without requiring this through licence obligations, and that mandating of high coverage has the potential to restrict and in the extreme case discourage new entrants.

642. Given that both voice and mobile broadband will, into the future, be provided using the same technologies, we do not consider that setting high coverage obligations for voice is appropriate if there is a risk that this has unintended consequences for data-centric entrants. These downside risks may not be large, but there is significant uncertainty about the future effects of high coverage obligations.

643. If coverage obligations are used, there is a good case for setting these at a medium level and in line with those appropriate for mobile broadband. Given the various issues discussed above in relation to coverage obligations for mobile broadband, we recommend that where a coverage obligation is linked to the assignment of a new 900MHz licence, this coverage level be set at the level of area coverage sufficient to serve 50-70% of the population. This range seems likely to be sufficient to inhibit cherry-picking, but low enough not to destroy the viability of potential new entrants. Such an obligation could apply to voice calls and to mobile broadband where an operator offers such services.

15.1.8 Measurement of coverage obligations

644. At present, coverage is defined by reference to transmitter field strength. The required field strength for coverage to be present is different for GSM and 3G services. Whilst it might be possible to continue using such an approach, a natural question is whether this is future-proof given likely changes in radio technologies. For example, what if future receiver improvements allowed a service to be deployed successfully with lower field strength? In this case, the coverage requirement would lead to an inefficient network topology.

645. A simple solution to this issue is to define coverage area for a particular service by reference to the probability of the service being available being sufficiently large. For example, for a particular 1km square to be included as part of the coverage area for a particular service, that service must be available at a random time and at a random outdoor location within the square at 1.5m from the ground with at least a specified probability. The requirement could additionally contain a requirement that this probability of availability is achieved with a certain level of network loading (e.g. a certain percentage of people in the area simultaneously using the service). This approach could define an outdoor coverage area without specifying any particular radio technology.

646. Defining an indoor coverage area is more difficult, as there is no fixed notion of what "indoor" might mean. However, going back to the field strength approach taken in GSM licences, it may be possible to define "indoor coverage" as being achieved if "outdoor coverage" would still have been achieved if the radio signal present were attenuated by a certain amount.[64] We do not make any specific recommendation for a licence obligation on this, but identify it as an area for further consideration in setting licence conditions.

647. The methodological and practical problems in defining indoor coverage are clearly more severe than those of outdoor coverage. This raises the question of whether there is any point in imposing an indoor coverage obligation in addition to an outdoor coverage obligation.

648. There are good reasons to expect market forces to be reasonably effective in providing incentives for good indoor data coverage at least in urban areas. 900MHz spectrum has superior propagation characteristics to 2.1GHz spectrum and could be used to provide mobile broadband more deeply into buildings. There may be valuable market segments (e.g. mobile workers with laptops) that would value such a service and operators would be likely to compete strongly for such consumers.

649. In addition, the issue of indoor coverage may become less important as new technological solutions become available. For example, H3GI is already deploying "smart repeaters" to provide indoor 3G coverage as part of the Irish National Broadband Strategy. These effectively extend the range of the existing radio network. Also, 3G femtocells are coming onto the market, which do not even need a radio connection to the public 3G network to provide localised 3G coverage. There are already commercial offers from some operators (e.g. Vodafone in the UK) where a domestic customer can install a small low-power base station on the end of an ADSL connection to provide in-building coverage for all 3G services normally provided over a public network. This may provide a more cost-effective route to patching indoor coverage holes than building more public network. We have yet to see how these disruptive technologies might play out, but the situation with regard to indoor coverage is clearly quite different to that with outdoor

[64] For example, current GSM 900MHz licences require a field strength of 56dBuV/m for indoor coverage or 46dBuV/m for outdoor coverage, which implies a 10db attenuation.

coverage; there is no compelling need for cross-subsidisation between high- and low-margin locations to drive indoor coverage. Given this difference, we believe that there might be a good case for limiting any mobile broadband coverage requirements simply to an outdoor requirement if relevant services are offered using the band.

15.1.9 Roll-out requirements

Specification of requirements

650. Where a coverage obligation is linked to a licence for spectrum, there are two main alternatives how this obligation may be specified: either a percentage of the population to be served or a percentage of the area that the licence covers to be served. Both of these measures are commonly used in practice.

651. Where an operator rolls out its network with a strict priority given to higher population density areas, both approaches are effectively equivalent. If build-out starts with areas with high population density and expanding first to areas of medium and then to areas of low population density, then it would be possible to map the percentages of population that might be specified to percentages of geographic coverage. Setting a coverage obligation using either a coverage or a population coverage obligation would achieve the same result in terms of the area served.

652. Nevertheless, despite the similarities of the two methods, there are good reasons to favour a geographic, rather than population based objective. First, population density measures where people live, rather than where they are likely to be. Operators typically provide mobile phone coverage along major road and transport links even if population density is low. A large proportion of the population is working in the major urban centres – Dublin, Cork, Galway and Limerick – while a significant number of these customers are not living in these centres but are commuting from a range of different places. Specifying a coverage obligation in terms of geography, rather than population, leaves it up to network operators to decide where subscribers are most likely to be and to provide coverage at locations most likely to meet customers' needs effectively. In contrast, a population-based coverage obligation provides a further incentive to prioritise areas with high population density.

653. Second, a clear disadvantage of population-based coverage requirements is that it requires detailed data on the location of population in order to determine whether or not the obligation has been met. Measuring geographical coverage is much simpler, as population-density data is not needed.

Level of requirements

654. Roll-out requirements are in effect a phasing in of coverage requirements for operators setting up new networks. They set milestones for required coverage at certain points over the duration of the licence. In the case of a green field network, roll-out requirements have a timetable set relative to the start date of the licence.

655. If ComReg were to implement either a voice or a mobile broadband coverage obligation in the way discussed above, there would be a need for phasing in of this obligation, otherwise it would create a large asymmetry between entrants and incumbents in their ability to meet the obligation. However, any

phasing of this obligation should not create too much delay, as otherwise this negates the benefit of the coverage obligation in achieving rural roll-out. In particular, it should not be possible for a latecomer to cherry pick by being subject to lesser coverage obligation than existing operators.

656. Despite the fact that if existing 900MHz operators were to win new liberalised 900MHz licence they would in practice likely exceed coverage requirements without much effort, this is not a compelling reason for varying roll-out requirements (as opposed to long-run coverage requirements) depending on whether or not a licensee had a previous 900MHz GSM licence. We have already discussed in detail the risks of complaint that heterogeneous licences might create.

657. In order to fulfil coverage obligations, operators should ideally have flexibility to use different spectrum bands to meet these obligations. Without such flexibility, it is difficult to see how in the future spectrum in different bands can be used together efficiently as portfolio. Our suggestion is that the coverage obligations would fall upon operators in the 900MHz band upon the assignment to them of a new liberalised licence. However, operators would have the discretion to optimise the use of their different spectrum assignments to meet this obligation.

658. In determining the required pace of a roll-out requirement, we need primarily to consider the requirements it is reasonable to apply to a data-centric entrant. Given the level of coverage obligation recommended, we would suggest a relatively long time horizon over which to meet such obligations:

- Operators must have coverage of 25-35% of the country within 3 years of the date of assignment of a liberalised licence for spectrum in the 900MHz band;
- Operators must have coverage of 50-70% of the country within 5 years of the date of assignment of a liberalised licence for spectrum in the 900MHz band.

659. Despite the recommendation to apply the same rates to mobile broadband and voice services, if these obligations are set at different levels, this obligation could be applied in a contingent manner, so that if a service of the relevant type is offered at all during the licence period, it is subject to these coverage conditions. However, it might be possible to stop short of compelling an operator to provide any particular service. Note that if this approach is adopted, it is very important that the coverage and roll-out conditions have a timetable that it set relative to the start of the licence, not when the service is first offered, otherwise delay incentives could be created.

660. This said, it may be possible to take more generic approach to coverage obligations, but, in this regard, our conclusions are more speculative. Provided that coverage obligations are moderate, there could be an obligation that each service delivered using the licensed spectrum is offered with coverage exceeding the required level. If a probabilistic definition of service availability is used, the coverage condition can be expressed quite generically. In practice, this would be a radically different way of implementing coverage obligations, so further consideration would be needed.

15.2 "Use it or lose it" condition

661. In several European countries, "use it or lose it" conditions have been attached to spectrum usage rights at various points, but the practice is not prevalent. In the German UMTS auction of 2000, interested parties had to deliver a frequency usage concept explaining how they would use the spectrum. However, in the current consultation for the German "Große Auktion" of 2.6GHz, 900MHz and 800MHz, no "use it or lose it" conditions have been attached to licences. The New Zealand 2.6GHz licence has a specific use it or lose it clause. Hong Kong manages this through the mechanism of a performance bond.

662. "Use it or lose it" conditions have some severe drawbacks:

- They are difficult to implement in a technology- and service-neutral world, as it is not easy to define generally what making reasonable use of spectrum entails. Nationwide frequency assignment might make any assessment of reasonable use difficult. There are examples in Germany where assignees with a nationwide frequency assignment have been using the spectrum only in a few big cities.
- There might be reasonable commercial reasons for holding spectrum unused temporarily, either as a part of a process of migrating legacy services or as an option for future capacity expansion. One would not wish to inhibit such behaviour.
- A "use it or lose it" condition may be very easy to circumvent through operating "phantom" services.

663. A "use it or lose it" obligation represents a weak form of coverage obligation that is primarily intended to ensure that spectrum is made reasonable use of, or otherwise returned to ComReg for re-award. Given that as part of our recommendations we propose a medium level of coverage and roll-out obligations, the case for a "use it or lose it" licence condition is much diminished. In addition, the 2x10MHz spectrum cap provides a protection for competition in mobile service markets and largely removes possibilities for speculative hoarding. We therefore recommend that a "use it or lose it" clause is not included in the licence conditions of new liberalised licences for spectrum in the 900MHz band in Ireland.

15.3 Service quality and performance standards

664. Traditionally, licences issued by ComReg have contained a variety of conditions about supplying specific services and maintaining quality standards. However, the previous approach would need to be revisited in the context of a move towards service- and technological-neutral licensing. In particular, it may be inappropriate to impose conditions requiring specific, defined services to be offered.

665. At present, existing GSM licences contain wide discretion for ComReg to both monitor service quality and to specify performance standards. This condition is not currently linked to any specific service. In particular, all three existing GSM 900MHz licensees have the following condition in their licences:

"The Director may, by direction in writing given to the Licensee, specify performance standards and obligations with respect to service quality or modify existing performance standards and obligations and the Licensee shall comply with any such directions."

666. Such a licence condition would seem to give ComReg powers to intervene to ensure that any service offered through the licence (whether through the use of other spectrum bands or not) can have reasonable quality standards imposed. This approach is consistent with a service- and technology-neutral approach and seems able to adapt to any new services that might evolve.

667. We do not believe that the condition above is sufficient by itself to provide certainty to operators about ComReg's approach to service quality. It may provide weak incentives to operators, as the condition appears intended to operate *ex post* if there are service quality problems, rather than to provide *ex ante* clarity on what quality levels licensees should expect to implement right from the start of their licences. Therefore, it would be helpful to augment this general catch-all condition with some more specific obligations.

668. It seems perfectly possible to impose some general obligations on licensees along the lines of those required by previous ComReg licences without defining specific services. For example, measures aimed at prompting transparency (so that quality can be assessed by consumers) may be valuable regardless of what service is offered.

669. It may also be sensible to safeguard the current quality standards for voice calls, but to homogenise the various different thresholds for dropped and blocked calls that different existing licences require. It seems natural to homogenise these at the tightest existing thresholds in GSM and 3G licences. Imposing such a condition is compatible with a broadly service-neutral and technology-neutral approach provided there is no compulsion to offer a particular service or to use a particular technology. This can be achieved by requiring quality standards for voice calls are meet in the event they are offered. The concepts of blocked and dropped calls are quite generic and would not seem to be linked to any particular technology.

670. Given the preceding general comments, we believe that the following service quality conditions might be useful for ComReg to consider imposing:

- The licensee maintains a coverage map for services provided in part or entirely through the licensed spectrum and makes this available to ComReg and consumers on a regular basis. The definition of coverage is described in Section 15.1.8 above. Licensees would be responsible for collecting data themselves and making it available to ComReg upon its request to verify any claims they made about their coverage area.
- If voice calls are offered using the licensed spectrum, the quality standards for outdoor calls within the coverage area of the service should be at least as good as those required by the tightest requirements of existing 900MHz and 2.1GHz licences in terms of blocked and dropped calls;
- A log of system availability for any network using the licensed spectrum in whole or in part is maintained and that annually this achieves a specified average availability;

- Billing obligations are difficult to define generally if services are not known, but there could be a general obligation to provide transparent and disaggregated bills that allow consumers to determine the costs of individual services used. In cases where services are billed by usage (as opposed to at a flat rate) the usage metric must be clear and transparent to consumers. If voice calls are billed by use, billing obligations could be the same as existing GSM and 3G licences (to provide start time, end time, duration and call cost). These billing obligations would apply to any service delivered in part or in its entirety using the licensed spectrum.

671. Such an approach as that outlined above would ensure that current quality standards for voice calls would be maintained, but also that there is transparency about the coverage areas for delivery of other services. In particular, there could be an obligation to make such data public, which might assist consumers in making informed choices about which operator provides the best price and quality combination.

672. At present, existing licensees are under an obligation to provide paper bills unless by express agreement with customers. Given the increasing use of electronic billing by many utilities and the significant cost savings and environmental benefits that result, ComReg may want to consider relaxing this condition to allow more widespread e-billing as an alternative.

15.4 Emergency services

673. The existing 900MHz licences contain a requirement to provide free voice calls to emergency services. Existing licences contain a range of conditions about the provision and handling of emergency calls in the "Access to the Emergency Services" schedule. There is also wide discretion for ComReg to direct a licensee in how it handles emergency calls.

674. Given that the 900MHz band provides the widest population coverage and the most extensive geographic coverage, it may be appropriate to attach conditions to the 900MHz band that ensure free access to emergency service numbers continues. These obligations could be triggered whenever the licensee offers voice calls. We see no obvious reason that this should not be applied in a technologically neutral manner, so that any means of providing voice calls (whether GSM, 3G or VOIP) would be subject to similar obligations. This would be a change to ComReg's current approach, as non-traditional methods of delivering voice calls would fall into the emergency services provisions. Clearly this raises broader questions about the costs of providing emergency services calls on all networks, not just mobile, that go far beyond the scope of this report.

675. We understand that ComReg is concerned that existing emergency service provisions within GSM licences should be augmented to include an obligation to provide data on the location of a mobile caller to the emergency services. Given that many network operators across Europe are already offering location-based services (e.g. cell-site triangulation on Google Maps) commercially, this does not seem like an onerous requirement. However, the provision of location data for emergency services use would need to be accurate and timely. ComReg would need to investigate the requirements of the emergency services in this regard and the cost implications for operators.

However, we note that the conditions in existing GSM licences already allow ComReg to issue a direction in regard to the handling of emergency calls that might allow a requirement for caller location data to be imposed.

676. One problematic scenario would be where legacy GSM networks are all turned off at some future date, but the geographical coverage of 3G networks is less than that of the original GSM network, undermining emergency call availability in rural areas. As discussed however, we consider that the probability of existing 900MHz operators winning new liberalised licences in the 900MHz band and subsequently reducing their coverage below their currently high levels is low. Therefore, we do not believe that ComReg would need to mandate a high level of voice coverage in order to ensure that services deployed using spectrum in the 900MHz band will be sufficiently widespread to ensure that emergency calls will be carried over the duration of new licences. Rather, a high level of coverage is likely anyway.

677. Given the long period for which these licences will be active, there may be unexpected technological developments. Therefore, we recommend that the requirement to carry emergency calls be redefined as necessary in consultation with operators. The powers in existing GSM licences provide a good model.

15.5 Penalties and performance bonds

678. If ComReg is to police licence conditions, then it needs an appropriate range of penalties that are credible. In particular, ComReg needs a variety of penalties of different sizes so that the penalty used can be matched to the infraction rather than having only a limited range of very severe penalties. If a proportionate penalty is not available, this may create an opportunity for a licensee to appeal the penalty, ultimately undermining the credibility of the penalty regime itself and reducing incentives to comply with licence conditions.

679. ComReg has a number of powers bestowed upon it through legislative provisions in order to enforce licence conditions. Together, Statutory Instrument No.s 468/1997, 422/1999 and 339/2003 provide ComReg with the power to:

- Refuse to grant a licence;
- Revoke or suspend a licence; or
- Amend a provision of a licence.

680. In addition, existing GSM licences specify financial penalties that operators are liable to pay in the event of failing to meet coverage and/or exceed maximum permitted call blocking and dropping rates. The magnitude of the penalties varies across licences, but it is in the order of €1-3 million.

681. In some cases, it may be possible to take direct action to require compliant behaviour. Such cases do not need a penalty regime, so for the purposes of the current discussion we can ignore them.

682. A reduction of the licence term represents a material penalty and also a credible threat for dealing with a range of moderate to serious violations of licence conditions. The business case for a major network investment relies on the free cash flows in the later period of the licence to generate the majority

of the overall value. Indeed, in the case of a new entrant the benefit of investing often lies almost entirely in the terminal value. Any reduction in the licence term would represent a material penalty. The reduction of the licence term is also a credible threat (at least provided the reduction is not too large relative to the remaining term) as it does not create any immediate disruption to the operation of the business, which would impose an unacceptable cost on the public.

683. The opportunities for credible reduction of the licence term clearly diminish later in the life of the licence. At some point in the licence's life, the reduction of the term is effectively a termination of the licence. This suggests that it may be valuable to have alternative penalties, such as performance bonds, that can be used later in the licence's life when curtailment is no longer credible.

684. A further problem is that any reduction in the term of one operator's licence would result in all licences no longer terminating at the same date. A common termination date for licences in the same band is desirable to facilitate a subsequent spectrum award. This issue could be resolved by offering the operator the opportunity to re-purchase the remaining years of the licence. Provided the cost of re-purchasing the lost years is less than the present value of the anticipated free cash flows generated in those years then it would be rational for the operator to re-acquire them which would resolve the issue of co-terminous licence terms. This clearly reduces the effective penalty to the extent that the re-purchase cost is less than the value of the lost cashflows.

685. To avoid diluting the penalty, it is important that the re-purchase price is not too cheap. Ideally one would want to estimate the value of the lost cashflows to set this price. In practice, this is likely to be difficult and the best available guide may often be the original purchase price adjusted for the length of the original licence term. However, such an adjustment requires assumptions about the distribution of free cash flows through the licence's life and the licensee's cost of capital. Given uncertainty, it is likely that a re-purchase price would inevitably be set conservatively and so some dilution of the original penalty would occur.

686. In order to create an immediate consequence and penalty for the business from breaching the condition the operator could be required to re-purchase the lost years within 24 months (provided they have rectified their breach) or they would lose the right to re-acquire those years at the proposed fee. The operator could still acquire the lost years at a later date but the fee would increase annually at a penal rate of interest. The period of 24 months has been suggested to allow sufficient time for coverage to be increased as planning permission issues can be time consuming; two years should provide sufficient time to rectify what should only be a relatively small increase in coverage to become compliant with licence conditions.

687. Such a curtailment measure was provided for in licences awarded in the 700MHz band in the US. In this case, different licences had different roll-out requirements. Despite differences across licences holders as regards these obligations, the over-arching principle regarding the enforcement of roll-out obligations was as follows:

> "Any licensee that fails to meet the interim requirement within their license areas will have their license terms reduced by two years, from ten to eight years, thus requiring the licensee to meet the end-of-term benchmark at an accelerated schedule. For those licenses in which the end-of-term performance requirements have not been met, the unused portion of the license will terminate automatically without Commission action and will become available for reassignment by the Commission subject to the "keep-what-you-use" rule."[65]

688. While this rule is not directly transferable given the regional nature of licences and the corresponding ease of taking curtailing some but not all of a licensees regional licences in response to falling short of requirements on it with regard to rollout, this does not preclude the imposition of a larger area rollout condition (that is, national in the case of Ireland) and relating curtailment of the licence to the whole area.

689. Licence curtailment clearly provides a useful range of penalties depending on the duration of the curtailment. However, short curtailments may not be very credible, as the licensee might judge that ComReg would be unwilling to impose a relatively small penalty through a curtailment of the licence, as this would create the problem of different termination dates for licences. Also, close to the end of the life of a licence, curtailment becomes less credible. For these reasons, it would be useful for ComReg to have an alternative mechanism that could be used to impose smaller penalties.

690. As a rough rule of thumb, we suppose that a curtailment of less than 2 or 3 years would probably not be worth imposing and that it would be better to have an alternative mechanism, such as a performance bond, to deal with such situations. We can form an order of magnitude assessment of how large such a performance bond would need to be by looking at the likely impact on licence value of such a short curtailment.

691. We have taken an upper end estimate of the value of 2x5MHz licence from our benchmarking exercise (say €25-30million) and assumed that the licensee's cost of capital is the same as Eircom's current Weighted Average Cost of Capital (WACC) of 10.21%. The result of curtailing the licence is quite sensitive to the assumptions that we make about the growth of free cashflows (FCF); the more these are loaded to the back of the licence, the greater the impact of curtailment. A 2% free cashflow growth would be in line with long-run economic growth, but the back-loading of cashflows would probably be much more marked than that, so we also include 10% and 20% growth scenarios. This suggests that an impact of €2-15million (depending on the assumptions made) might be plausible. Therefore, for breaches requiring a smaller penalty that this, it would seem more appropriate to forfeit a performance bond, rather than make a short curtailment.

[65] http://wireless.fcc.gov/auctions/default.htm?job=auction_factsheet&id=73

Table 20: Value impact of short licence curtailments

Assume WACC of 10.21% and licence duration of 15 years		Flat FCFs	FCFs grow at 2% pa	FCFs grow at 10% pa	FCFs grow at 20% pa
Licence value of €25m	Terminal value of last 3 years of licence	€1.74m	€2.15m	€4.90m	€12.76m
	Terminal value of last 2 years of licence	€1.10m	€1.38m	€3.26m	€8.93m
Licence value of €30m	Terminal value of last 3 years of licence	€2.09m	€2.58m	€5.88m	€15.31m
	Terminal value of last 2 years of licence	€1.32m	€1.65m	€3.91m	€10.72m

692. In Hong Kong a performance bond was required at the level of HK$50million (€4.4 million) per 5MHz of 2.6GHz spectrum. However, in November 2008 the regulatory authority reduced the requirement to HK$25million (€2.2 million) following presentations from the operators highlighting the financial climate and the challenges of raising suitable finance. The performance bond would become payable if operators failed to cover 50% of the country. In light of the current financial climate ComReg should be careful to avoid stipulating a performance bond that damages the ability of the operators to raise the capital required to finance the roll-out of the network.

693. We examined the fees and penalties of operators in Europe. The countries examined were Spain, France, Belgium, Portugal, Netherlands, Cyprus, Denmark, Sweden, Italy and Finland. Of the countries examined we found no evidence of the use of performance bonds.

694. Operators should face appropriate consequences if they fail to meet licence conditions. The consequences should be proportionate to the degree and impact of the breach. Retaining the existing enforcement and amendment measures provide a range of flexible remedies for dealing with breaches. The existing measures could be supplemented with a specified maximum level of term curtailment and an immediate and identified financial cost for re-acquiring the lost years to maintain co-terminus terms. In light of the current financial climate we believe that a significant performance bond could be harmful to the raising of finance and investment and a token level of bond,

which does not impair operator's ability to raise finance, would provide limited coercive properties.

695. Overall, a reasonable approach might be to require a performance bond of around €2-3 million. Minor breaches would result in loss of some or all of this bond. More major breaches could be dealt with through curtailment of licences. Pre-specifying penalties for breach of licence conditions (e.g. failure to meet coverage obligations) is unlikely to be compatible with the principle of penalties being proportionate to the severity of the breach.

15.6 Reporting and compliance

696. The current authorisation conditions linked to GSM900 licences are that "The Authorised Person shall provide such information requested from time to time by the Commission, in the form and at the times specified by the Commission, for the purpose of the objectives set out in Regulations 17(1) and 18(1) of the Authorisation Regulations and in Regulation 17(1) of the Framework Regulations; and in accordance with the provisions of Regulation 18(3) of the Authorisation Regulations and Regulation 17(2) of the Framework Regulations."[66]

697. These current conditions are similar in nature to those in other European territories. Many jurisdictions also require information to be submitted annually on the use of the frequencies and the rollout of the network.

698. In the UK, licensees have to provide on request general information on equipment and use of frequencies or the roll out of their network. Similar terms exist in the Netherlands, Germany and Norway. In Germany, licensees are required to provide information annually on spectrum usage, network structure and expansion of the network. In Norway the licensee is also required to notify the regulator on technology or technologies that are being deployed in order to utilise the spectrum.

699. Reporting and monitoring is required to ensure compliance with licence conditions and assists ComReg in discharging its obligation to ensure efficient spectrum management. The current conditions do not place an onerous cost burden on operators whilst providing ComReg with the tools to ensure compliance with the licence conditions. We would recommend retaining the current condition, and that the type of information to be reviewed by ComReg is revised at intervals deemed appropriate by ComReg in light of technological developments and the use of these technologies in the 900MHz band.

[66] http://www.comreg.ie/_fileupload/publications/ComReg0381r1.pdf

16 Recommendations and conclusions

700. In this section, we present our recommendations regarding the inclusion (or not) of licence conditions in new licences in the 900MHz band in a number of key areas:

- Coverage
- Roll-out requirements
- 'Use it or lose it' obligation
- Service quality and performance standards
- Emergency services
- Penalties and performance bonds
- Reporting and compliance with licence conditions

16.1 Coverage

701. We recommend that:

- All operators awarded liberalised 900MHz licences should have the same coverage obligations regardless of whether they previous held 900MHz GSM licences;
- ComReg define the coverage area for a particular service by reference to the probability of the service being available as this is future-proof;
- Coverage obligations focus on outdoor coverage given likely technological developments with regard to indoor coverage.

702. Whilst coverage obligations could be applied to voice services or to mobile data, we recommend that the focus is on mobile data, as it is unlikely voice coverage will fall significantly from current levels delivered with GSM networks. Coverage obligations should be implemented contingently, so that an obligation bites if a service is offered, but detailed compulsions to offer particular services are avoided.

703. As spectrum in different bands is likely to be used together as a portfolio, we recommend that ComReg consider linking coverage and roll-out *obligations* to a specific band, but providing flexibility in how the obligation is *dispatched*, for example by providing a service using spectrum in other bands alongside the 900MHz band.

16.2 Roll-out requirements

704. Further to our recommendation that this coverage obligation be set at a medium level, we suggest that this obligation be phased in as follows:

- Operators must have area coverage sufficient to serve 25-35% of the population within 3 years of the date of assignment of a liberalised licence for spectrum in the 900MHz band; and
- Operators must have area coverage sufficient to serve 50-70% of the population within 5 years of the date of assignment of a liberalised licence for spectrum in the 900MHz band.

16.3 "Use it or lose it" obligation

705. We recommend that a 'use it or lose it" clause is not included in the licence conditions of new liberalised licences for spectrum in the 900MHz band in Ireland.

16.4 Service quality and performance standards

706. We believe that the following service quality conditions might be useful for ComReg to consider imposing:

- The licensee maintains a coverage map for services provided in part or entirely through the licensed spectrum and makes this available to ComReg and consumers on a regular basis. Licensees would be responsible for collecting data themselves and making it available to ComReg upon its request to verify any claims they made about their coverage area.
- If voice calls are offered using the licensed spectrum, the quality standards for outdoor calls within the coverage area of the service should be at least as good as those required by the tightest requirements of existing 900MHz and 2.1GHz licences in terms of blocked and dropped calls;
- A log of system availability for any network using the licensed spectrum in whole or in part is maintained and that annually this achieves a specified average availability;
- Billing obligations are imposed by way of general principles of transparency, disaggregation and clarity of any usage metrics.

16.5 Emergency services

707. We do not believe that ComReg would need to mandate a high level of voice coverage in order to ensure that voice services will be sufficiently widespread to ensure that emergency calls are available. Rather, an obligation to provide free emergency calls where voice calls are provided should be sufficient.

708. In terms of the form of any requirement that operators comply with this obligation, we recommend that the requirement to carry emergency calls be redefined as necessary in consultation with operators. This could include provision of location data and implementation of the obligation in a technological neutral manner on all operators who provide voice calls.

16.6 Penalties and performance bonds

709. A range of penalties need to be available that can provide a credible response to breaches of licence conditions. A combination of curtailment of licence term for serious breaches and forfeit of a performance bond of around €2-3 million for more minor breaches should provide the necessary range and be credible.

16.7 Reporting and compliance

710. ComReg should retain broad obligations for reporting data to ensure compliance with licence conditions present in existing licences. It may be difficult to anticipate in advance what data may be needed to monitor compliance and general powers to request data are needed. We recommend that the current condition be maintained, and that the type of information to be reviewed by ComReg is revised at intervals deemed appropriate by ComReg in light of technological developments and the use of these technologies in the 900MHz band.

17 Benchmarking analysis

17.1 List of awards included in benchmark groups

Entire dataset

711. The following table lists the awards used in this benchmarking exercise.

Table 21: List of awards in entire dataset

Country	Auction	Year
Australia	PCS 2000 auction	2000
United Kingdom	3G Auction	2000
Netherlands	3G Auction	2000
Germany	3G Auction	2000
Italy	3G Auction	2000
Austria	3G Auction	2000
Switzerland	3G Auction	2000
Bulgaria	2nd GSM Licence Auction	2000
New Zealand	Auction 3: 1710 - 2300 MHz	2001
Nigeria	GSM Auction	2001
United States	Auction 35 - C and F Block Broadband PCS	2001
Canada	Additional PCS Auction	2001
Belgium	3G Auction	2001
Australia	3G Auction	2001
Singapore	3G Auction	2001
Austria	GSM 1800 Auction	2001
Greece	3G Auction	2001
Greece	2G and 3G	2001
Singapore	2G Auction	2001
Denmark	3G Auction	2001
Hong Kong China	3G Auction	2001
United States	Auction 41 Narrowband PCS	2001
Norway	E-GSM Auction	2001
Norway	GSM 1800 Auction	2001
Czech Republic	3G Auction	2001

Country	Auction	Year
Israel	2G/3G Auction	2001
Nigeria	SNO (Digital Mobile License)	2002
United States	Auction 44 - Lower 700 MHz Band	2002
Austria	GSM 2002 Auction	2002
United States	Auction 49 - Lower 700 MHz Band	2003
Norway	3G Auction 2	2003
United States	Auction 51 Regional Narrowband PCS	2003
United States	Auction 50 Narrowband PCS	2003
Norway	450 MHz Auction	2004
Austria	GSM 2004 Auction	2004
United States	Auction 58 - Broadband PCS	2005
Sweden	450 MHz Auction	2005
Bulgaria	3G Auction	2005
Latvia	2G/3G Auction	2005
Trinidad and Tobago	GSM Auction	2005
United States	Auction 60 - Lower 700 MHz Band Auction	2005
Denmark	3G Auction 2	2005
Ireland	WDM Auction	2005
Indonesia	3G auction	2006
Austria	450 MHz Auction	2006
United Kingdom	DECT Auction	2006
Georgia	3G Auction	2006
Egypt	2G/3G Auction	2006
United States	Auction 66 - Advanced Wireless Services	2006

Country	Auction	Year
Georgia	GSM 1800 MHz	2006
Denmark	450 MHz	2006
Estonia	3G Tender	2007
Macedonia FYR	Third GSM licence	2007
Denmark	870 MHz	2007
Nigeria	3G Auction	2007
Ireland	1785-1805 MHz	2007
United Kingdom	1785-1805 MHz	2007
Saudi Arabia	Saudi 3rd GSM license and 3rd 3G license	2007
Hong Kong China	Hong Kong CDMA	2007
Norway	2.6 GHz	2007
Norway	3G 4th licence	2007
Norway	Residual 2.6GHz	2008
United States	Auction 73-700MHz	2008
Sweden	1900-1905MHz	2008
Sweden	2.6GHz	2008
Canada	AWS auction	2008
Bulgaria	Bulgaria 4th GSM License	2008
Qatar	Qatar second mobile licence	2008
Austria	900 MHz Auction	2008
Turkey	3G	2008
Poland	E-GSM	2008
Norway	1790-1800MHz	2008
Hong Kong China	BWA Auction	2009
Hong Kong China	1800MHz auction (expansion)	2009

Europe-only dataset

712. The following table lists the awards in the Europe-only dataset used to obtain the benchmarks based on licences sold in Europe. The dataset contains 41 awards.

Table 22: List of awards used for Europe-only benchmarks

Country	Award	Year
United Kingdom	3G Auction	2000
Netherlands	3G Auction	2000
Germany	3G Auction	2000
Italy	3G Auction	2000
Austria	3G Auction	2000
Switzerland	3G Auction	2000
Bulgaria	2nd GSM Licence Auction	2000
Belgium	3G Auction	2001
Austria	GSM 1800 Auction	2001
Greece	3G Auction	2001
Greece	2G and 3G	2001
Denmark	3G Auction	2001
Norway	E-GSM Auction	2001
Norway	GSM 1800 Auction	2001
Czech Republic	3G Auction	2001
Austria	GSM 2002 Auction	2002
Norway	3G Auction 2	2003
Norway	450 MHz Auction	2004
Austria	GSM 2004 Auction	2004
Sweden	450 MHz Auction	2005
Bulgaria	3G Auction	2005
Latvia	2G/3G Auction	2005
Denmark	3G Auction 2	2005
Ireland	WDM Auction	2005
Austria	450 MHz Auction	2006
United Kingdom	DECT Auction	2006
Denmark	450 MHz	2006
Estonia	3G Tender	2007
Macedonia FYR	Third GSM licence	2007
Denmark	870 MHz	2007
Ireland	1785-1805 MHz	2007
United Kingdom	1785-1805 MHz	2007
Norway	2.6 GHz	2007
Norway	3G 4th licence	2007
Norway	Residual 2.6GHz	2008
Sweden	1900-1905MHz	2008
Sweden	2.6GHz	2008
Bulgaria	Bulgaria 4th GSM License	2008
Austria	900 MHz Auction	2008
Turkey	3G	2008
Poland	E-GSM	2008
Norway	1790-1800MHz	2008

GDP dataset

713. The GDP dataset consists of licences sold in countries with GDP per capita similar to Ireland. The following table summarises the awards included in this dataset. There are 54 awards included in this dataset.

Table 23: List of awards in GDP dataset

Country	Award	Year
Australia	PCS 2000 auction	2000
United Kingdom	3G Auction	2000
Netherlands	3G Auction	2000
Germany	3G Auction	2000
Italy	3G Auction	2000
Austria	3G Auction	2000
Switzerland	3G Auction	2000
United States	Auction 35 - C and F Block Broadband PCS	2001
Canada	Additional PCS Auction	2001
Belgium	3G Auction	2001
Australia	3G Auction	2001
Singapore	3G Auction	2001
Austria	GSM 1800 Auction	2001
Singapore	2G Auction	2001
Denmark	3G Auction	2001
Hong Kong China	3G Auction	2001
United States	Auction 41 Narrowband PCS	2001
Norway	E-GSM Auction	2001
Norway	GSM 1800 Auction	2001
United States	Auction 44 - Lower 700 MHz Band	2002
Austria	GSM 2002 Auction	2002
United States	Auction 49 - Lower 700 MHz Band	2003
Norway	3G Auction 2	2003
United States	Auction 51 Regional Narrowband PCS	2003
United States	Auction 50 Narrowband PCS	2003
Norway	450 MHz Auction	2004
Austria	GSM 2004 Auction	2004
United States	Auction 58 - Broadband PCS	2005
Sweden	450 MHz Auction	2005
United States	Auction 60 - Lower 700 MHz Band Auction	2005
Denmark	3G Auction 2	2005
Ireland	WDM Auction	2005
Austria	450 MHz Auction	2006
United Kingdom	DECT Auction	2006
United States	Auction 66 - Advanced Wireless Services	2006
Denmark	450 MHz	2006
Estonia	3G Tender	2007
Denmark	870 MHz	2007
Ireland	1785-1805 MHz	2007
United Kingdom	1785-1805 MHz	2007
Saudi Arabia	Saudi 3rd GSM license and 3rd 3G license	2007
Hong Kong China	Hong Kong CDMA	2007
Norway	2.6 GHz	2007
Norway	3G 4th licence	2007
Norway	Residual 2.6GHz	2008
Sweden	1900-1905MHz	2008

Country	Award	Year
United States	Auction 73- 700MHz	2008
Sweden	2.6GHz	2008
Canada	AWS auction	2008
Qatar	Qatar second mobile licence	2008
Austria	900 MHz Auction	2008
Norway	1790-1800MHz	2008
Hong Kong China	BWA Auction	2009
Hong Kong China	1800MHz auction (expansion)	2009

GSM-only dataset

714. The following table summarises the awards dataset used to determine the GSM only benchmarks. A total of 41 awards is included in this dataset.

Table 24: List of awards used for GSM-only benchmarks

Country	Award	Year
Australia	PCS 2000 auction	2000
United States	Auction 33 - Upper 700 MHz Guard Bands	2000
Bulgaria	2nd GSM Licence Auction	2000
Nigeria	GSM Auction	2001
United States	Auction 35 - C and F Block Broadband PCS	2001
Canada	Additional PCS Auction	2001
United States	Auction 38 - Upper Guard Bands	2001
Austria	GSM 1800 Auction	2001
Greece	2G and 3G	2001
Singapore	2G Auction	2001
United States	Auction 41 Narrowband PCS	2001
Norway	E-GSM Auction	2001
Norway	GSM 1800 Auction	2001
Israel	2G/3G Auction	2001
Nigeria	SNO (Digital Mobile License)	2002
United States	Auction 44 - Lower 700 MHz Band	2002
Austria	GSM 2002 Auction	2002
United States	Auction 49 - Lower 700 MHz Band	2003
United States	Auction 51 Regional Narrowband PCS	2003
United States	Auction 50 Narrowband PCS	2003
Austria	GSM 2004 Auction	2004
United States	Auction 58 - Broadband PCS	2005
Latvia	2G/3G Auction	2005
Trinidad and Tobago	GSM Auction	2005
United States	Auction 60 - Lower 700 MHz Band Auction	2005
United Kingdom	DECT Auction	2006
Egypt	2G/3G Auction	2006
Georgia	GSM 1800 MHz	2006
Macedonia FYR	Third GSM licence	2007
Ireland	1785-1805 MHz	2007
United Kingdom	1785-1805 MHz	2007
Saudi Arabia	Saudi 3rd GSM license and 3rd 3G license	2007
United States	Auction 73- 700MHz	2008
Sweden	1900-1905MHz	2008
Bulgaria	Bulgaria 4th GSM License	2008
Qatar	Qatar second mobile licence	2008
Austria	900 MHz Auction	2008
Poland	E-GSM	2008
Norway	1790-1800MHz	2008
Canada	Auction of spectrum for air-ground services	2009
Hong Kong China	1800MHz auction (expansion)	2009

3G-only dataset

715. The following table summarises the awards dataset used to determine the 3G-only benchmarks. A total of 27 awards is included in this dataset.

Table 25: List of awards used for 3G-only benchmarks

Country	Award	Year
United Kingdom	3G Auction	2000
Netherlands	3G Auction	2000
Germany	3G Auction	2000
Italy	3G Auction	2000
Austria	3G Auction	2000
Switzerland	3G Auction	2000
New Zealand	Auction 3: 1710 - 2300 MHz	2001
Belgium	3G Auction	2001
Australia	3G Auction	2001
Singapore	3G Auction	2001
Greece	3G Auction	2001
Denmark	3G Auction	2001
Hong Kong China	3G Auction	2001
Czech Republic	3G Auction	2001
Norway	3G Auction 2	2003
Bulgaria	3G Auction	2005
Latvia	2G/3G Auction	2005
Denmark	3G Auction 2	2005
Indonesia	3G auction	2006
Georgia	3G Auction	2006
Egypt	2G/3G Auction	2006
United States	Auction 66 - Advanced Wireless Services	2006
Estonia	3G Tender	2007
Nigeria	3G Auction	2007
Norway	3G 4th licence	2007
Canada	AWS auction	2008
Turkey	3G	2008

17.2 Regression analysis

Auctions in Europe

716. In this subsection, we estimate a similar equation to the one in section 10.5.3 for the dataset comprising mobile licences sold in Europe. The specification which we used this dataset is shown in the following equation.

Equation 3: Regression equation for all mobile licences sold in Europe

$$PMHzPop = \beta_0 + \beta_{GDPpc} \bullet GDPpc + \beta_{ApPop} \bullet ApPop + \beta_{WtB} \bullet WtB + ...$$
$$... + \beta_{invNmnos} \bullet invNmnos + \beta_{national} \bullet national + \beta_{preIT} \bullet preIT + ...$$
$$... + \beta_{year01} \bullet year01 + \beta_{year0203} \bullet year0203 + \beta_{year0405} \bullet year0405 + ...$$
$$... + \beta_{year0607} \bullet year0607 + \beta_{year0809} \bullet year0809$$

where:

- $PMHzPop$ is price per MHz per population (our dependent variable);
- β_0 is a constant;
- $GDPpc$ is GDP per capita;
- $ApPop$ is area per capita, a measure of population density;
- WtB is the ratio of winners to bidders in the auction, a measure of the level of competition in the auction;
- $invNmnos$ is the inverse of the number of MNOs in the end, a measure of competitiveness in the telecommunications market;
- $national$ is a dummy variable which is 1 if it is a national licence and 0 if not;
- $preIT$ is a dummy which is 1 if the licence was sold before the Italian 3G auction (the last auction before the spectrum bubble burst) or 0 if the licence was sold afterwards;
- $Year$ is a dummy which is 1 if the licence was sold in these years and 0 if not. Years are grouped biannually. For example $Year0607$ is one if licence was sold in 2006 or 2007 and 0 otherwise.

717. The estimated coefficients for this equation are summarised in the following table.

Table 26: Regression analysis using licences sold in Europe

Coefficient for:	Estimated coefficient	Standard error
GDPpc	0.0000117	.0000101
ApPop	-9.23*	4.19
WtB	-0.458	0.249
invNmnos	9.26**	1.45
national	0.0172	0.204
preIT	1.75**	0.265
yearD_01	-0.995**	0.220
yearD_0203	-0.794*	0.309
yearD_0405	-0.827**	0.255
yearD_0607	-0.952**	0.251
yearD_0809	-0.677*	0.281
Constant	-0.751	0.674

Note: Coefficients which are significant at the 5% and 1% level are marked with one and two stars, respectively[67].

718. The predicted value of a 2x5MHz lot based on this estimation is shown in the following table.

Table 27: Predicted value of the Irish spectrum based on all mobile licences sold in an auction in Europe

Price per MHz per population	Implied value of a 2x5MHz block
€ 0. 397	€ 16,700,000

GSM auctions only

719. Finally, we estimate a similar equation based on a dataset consisting of all GSM licences sold in an auction. The specification which we used this dataset is shown in the following equation.

[67] This means that the probability of those coefficients being equal to zero is smaller than 5% or 1%, respectively.

Equation 4: Regression equation for GSM only

$$PMHzPop = \beta_0 + \beta_{GDPpc} \bullet GDPpc + \beta_{ApPop} \bullet PopDens + \beta_{WtB} \bullet WtB + ...$$
$$... + \beta_{invNmnos} \bullet invNmnos + \beta_{national} \bullet national + \beta_{AFME} \bullet AFME + \beta_{preIt} \bullet preIT + ...$$
$$... + \beta_{year01} \bullet year01 + \beta_{year0203} \bullet year0203 + \beta_{year0405} \bullet year0405 + ...$$
$$... + \beta_{year0607} \bullet year0607 + \beta_{year0809} \bullet year0809$$

where:

- $PMHzPop$ is price per MHz per population (our dependent variable);
- β_0 is a constant;
- $GDPpc$ is GDP per capita;
- $PopDens$ is population density and hence a measure of set up costs;
- WtB is the ratio of winners to bidders in the auction, a measure of the level of competition in the auction;
- $invNmnos$ is the inverse of the number of MNOs in the end, a measure of competitiveness in the telecommunications market;
- $national$ is a dummy variable which is 1 if it is a national licence and 0 if not;
- $preIT$ is a dummy which is 1 if the licence was sold before the Italian 3G auction (the last auction before the spectrum bubble burst) or 0 if the licence was sold afterwards;
- $Year$ is a dummy which is 1 if the licence was sold in these years and 0 if not. Years are grouped biannually. For example $Year0607$ is one if licence was sold in 2006 or 2007 and 0 otherwise.

The estimated coefficients for this equation are summarised in the following table.

Table 28: Regression analysis using GSM licences only

Coefficient for:	Estimated coefficient	Standard error
GDPpc	0.000047**	0.000002
PopDens	0.000005	0.0000176
WtB	-1.92**	0.121
invNmnos	1.04**	0.348
national	-0.104	0.0738
AFME	1.45**	0.0852
preIT	-3.59**	0.214
yearD_01	-3.97**	0.176
yearD_0203	-4.84**	0.188
yearD_0405	-4.33**	0.174
yearD_0607	-4.05**	0.181
yearD_0809	-4.35**	0.180
Constant	4.49**	0.211

Note: Coefficients which are significant at the 5% and 1% level are marked with one and two stars, respectively68.

720. The predicted value of 2x5MHz lot based on this dataset is shown in the following table.

Table 29: Predicted value of the Irish spectrum based on GSM licences

Price per MHz per population	Implied value of a 2x5MHz block
€ 0.622	€26,100,000

[68] This means that the probability of those coefficients being equal to zero is smaller than 5% or 1%, respectively.

17.3 Note on currency conversions

721. The benchmark process deals with different currencies and exchange rates using Euros as the common currency. Conversions from respective local currencies are dealt with as follows:

$$Price_{local\ currency\ year\ of\ award} \xrightarrow{PPP_{annualrate}} Price_{USD\ year\ of\ award}$$

$$Price_{USD\ year\ of\ award} \xrightarrow{USD\ Deflator} Price_{June\ 2009\ USD}$$

$$Price_{June\ 2009\ USD} \xrightarrow{PPP_{H12009}} Price_{June\ 2009\ EURO}$$

722. Nominal prices in local currency from various countries are first converted from local currency to US dollars using an annual Purchasing Price Parity (PPP) rate. The PPP rate accounts for price differences between the country in which the licences were auctioned and the US. This price in US dollars at the year of award is then adjusted for US dollar inflation using CPI data from the US Bureau of Labour and all prices are expressed in common June 2009 US dollar terms. Finally prices are converted back into Euros using a PPP rate for the first half of 2009 (see footnote 45). This process will convert all prices to June 2009 Euros of which all benchmarking analysis is carried out and results presented in.

723. The process of using a PPP rate and then adjusting for inflation using a common deflator (i.e. the USD deflator) should account for differing inflation rates between countries; this is because PPP exchange rates should reflect the price differentials between the country of the award and the US created by differential inflation. This should in effect be largely equivalent to running the benchmarking analysis by first adjusting all prices in local currency by local inflation rates then converting to US dollars with an official exchange rate. The former method has been implemented because the DotEcon Spectrum Award Database contains PPP rates[69] for US dollars and US CPI data only. It would be impractical to do a similar analysis in local currencies and to collect deflator time series for all local currencies in the sample as inflation rates differ across countries. Bringing all the data to a common currency using PPP rates and then deflating avoids the need to gather data about local inflation rates, as these are effectively encapsulated within the PPP rate. These two approaches should be closely similar in the absence of large capital and financial market imperfections.

[69] From the World Bank's World Development Indicators database.

724. The process of converting prices from June 2009 US dollar prices to June 2009 Euro has been done using a derived PPP rate for the first half of 2009 (as the official PPP rate for 2009 will not be available until inflation figures are published) as described in footnote 45.

725. The above described conversion process is explained in the following example, consider the conversion of prices of the Irish 3G licences awarded in 2002 into June 2009 terms. The following rates have been applied:

$PPP_{USD/EURO2002}$	0.9762 (1€ to 1.02437)
Derived PPP rate for H12009	0.82512
Compounded USD inflation between June 2002 and June 2009	Approximately 17.4%

726. Although there have been significant movements in nominal exchange rates between 2002 and 2009, this is mainly accounted for by differential inflation and should not have a strong effect on the outcome of the analysis as PPP rates were used for currency conversions that take into account price differentials between countries. In particular, the change in the US dollar/Euro PPP rate in 2002 and 2009 is approximately 15.5%. In this period, the compounded US dollar inflation rate is approximately 17%, thus the inflation rate between 2002 and 2009 had virtually accounted for all the exchange rate movements in the period.