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Auction design proposals for the award of frequencies in the 700, 1500 and 2100 MHz bands

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Contents

1 Introduction

This note sets out two auction design proposals for the forthcoming award of frequencies in the 700, 1500 and 2100 MHz bands in Austria for further consideration.

These proposals are based on our understanding of the objectives for this award, the nature of underlying demand and the general environment within which the assignment will be conducted. We take account of feedback received in the first consultation on product and auction design for the forthcoming award.

We begin by setting out the key parameters for the auction design, reflecting the objectives and the market conditions (Section 2). One of the specific challenges in this award is the objective of assigning ambitious coverage obligations (specific details of which will need to be determined) alongside the available spectrum. In broad terms, this can be done by either linking these obligations to specific spectrum blocks, or assigning obligations separate from, but alongside the frequencies. We describe possible auction formats for each of these approaches (Sections 3 and 4) and summarise our conclusions (Section 5).

2 Key parameters for auction design

2.1 Objectives

The objectives for this award are – in order of priority:

- legal certainty, i.e. robustness to legal challenges to ensure the timely utilisation of the second tranche of digital dividend spectrum;
- efficient frequency utilisation, i.e. the assignment of spectrum to those users who can create the greatest value for customers and the economy;
- promoting or safeguarding competition, i.e. assigning spectrum in a way that supports effective competition in the downstream markets, avoiding outcomes where spectrum holdings become too asymmetric or concentrated;
- promoting coverage, i.e. using the award to extend coverage of mobile services and ensuring that 5G services will be available in line with the objectives set out in various 5G strategy plans; and
- promoting innovation, which is predominantly linked to making available spectrum without delay and offering the opportunity for innovators to obtain frequencies.

Meeting these objectives requires an auction design that:

- minimises complexity and reduces uncertainty for bidders, offering them the greatest possible control over outcomes (avoiding the risk of leaving the auction empty-handed without explicitly accepting such an outcome);
- allows bidders to express their demand for different spectrum portfolios on a level playing field without being exposed to substitution and aggregation risks and limits incentives and scope for strategic bidding;
- works well with the competition safeguards that need to be put in place to ensure that the award will not result in spectrum assignments that could threaten effective downstream competition;
- potentially includes the assignment of obligations that promote downstream competition (such as an obligation on winners of spectrum to provide capacity to MVNOs); and
- supports the assignment of (potentially quite ambitious) coverage obligations together with the spectrum on offer, in line with the objective of using the award substantially to improve coverage with 5G and broadband services whilst minimising the risk of spectrum remaining unsold.

2.2 Available spectrum and nature of demand

The spectrum available for the award comprises 2x30 MHz in the 700 MHz band, up to 90 MHz in the 1500 MHz band and 2x60 MHz in the 2100 MHz band.

The latter is currently used by MNOs for the provision of 3G and 4G services and assigning this spectrum in a timely manner and in a way that ensures business continuity is crucial for efficiency. Operators have claimed that there is a need for ensuring that they can retain a critical amount of spectrum in this band (with references having been made to 2x15 MHz or 2x10 MHz).

Although the 700 MHz band has not been fully cleared at present, it is expected that all frequencies will be usable without restrictions by the time the auction is completed.

The 1500 MHz band – made up of the core band (40 MHz in the centre) and the extension bands (25 MHz on either side) – is harmonised for SDL use and fully available. However, there are significant usage restrictions on the two blocks at the lower edge of the band.

In order to provide maximum flexibility to operators assembling their spectrum portfolios and support competition for incremental spectrum, the intention is to offer spectrum in small blocks (ideally in the form of 2x5 MHz blocks in the 700 and 2100 MHz bands, and 5 or 10 MHz blocks in the 1500 MHz band), unless there are strong reasons to believe that this could result in unacceptable aggregation risks.

All the blocks in the 2100 MHz band are of similar value and can therefore be offered initially in the form of frequency-generic lots, leaving the assignment of specific frequencies to winners of bandwidth to a separate assignment stage. This ensures that frequency assignments will be contiguous, and bidders need not be concerned about contiguity when expressing their demand for bandwidth.

Even if some of the blocks in the 700 MHz band may not be fully cleared and might be affected by incumbent use, we understand that this would have a negligible impact on the value of these blocks and can easily be addressed in the assignment stage. Our understanding is that there are substantial efforts to clear the band.

Regarding the 1500 MHz SDL spectrum, at present only the core band is standardised and supported by equipment vendors, and the extent to which the extension bands can be used and the timing of the band becoming usable are uncertain. However, there is agreement amongst respondents to the consultation that no distinction needs to be drawn between these sub-bands in the auction, and that the entire band can be offered in a single lot category initially (with the lowest 10 MHz not being included in the

bidding process, but assigned to the operator who is wins the lowest block, given that their value could be substantially reduced as a result of usage restrictions to manage interference).

Given the designation of the 1500 MHz band for SDL use, there is a strong complementarity between this band and paired spectrum below 1 GHz. H3A (currently holding only 2x5 MHz of spectrum in the 900 MHz band and no 800 MHz spectrum) is likely to face complementarities between frequencies in the 700 MHz band and the 1500 MHz band in the upcoming award.

Despite the different propagation characteristics of high and low frequencies and the fact that the 2100 MHz band is currently in use, paired spectrum in the 700 MHz and the 2100 MHz band may be substitutable at the margin.

Reflecting these interdependencies, all three bands are intended to be offered together rather than in separate awards (though the award process itself may be organised in stages).

Although there are examples of operators acquiring single blocks in the 700 MHz band (e.g. in Switzerland and Denmark), there are generally considered to be benefits associated with being able to use at least 2x10 MHz in the 700 MHz band. To the extent that there might be increasing marginal returns for the second 2x5 MHz block, this could give rise to aggregation risks under some auction formats. Synergistic valuations for 700 MHz spectrum may be particularly relevant where operators also take on coverage obligations with ambitious data rates, especially for operators who do not have substantive existing spectrum holdings below 1 GHz.

2.3 Competition safeguards

Spectrum caps are an appropriate measure for the protection of downstream competition. These caps should ensure that all operators are able to obtain a critical mass of spectrum and to prevent spectrum holdings from becoming too asymmetric. To this end, caps will be defined with reference to total spectrum holdings, both overall, in relation to spectrum below 1GHz, and potentially within bands.

Given that spectrum holdings are asymmetric at present, this implies that the MNOs will face different limitations in relation to the spectrum they can acquire in the auction, with A1 being more constrained (in relation to sub-1 GHz spectrum) than TMA and H3A.

At present, there are also proposals for a joint cap (or spectrum floor), which would impose a constraint on A1 and TMA jointly.

In addition, it would be desirable to assign an obligation to provide wholesale services to MVNOs in the course of the award to replace the current MVNO obligations that have been imposed as a result of

the merger between Orange and H3A in 2012 and which are to expire in 2024. There are concerns that without such obligations MVNOs may be faced with a (tacitly collusive) effective refusal to supply so that the competitive constraints imposed by MVNOs would be weakened or lost.

However, in order to minimise the risk of legal challenge, it is important that acceptance of such an obligation should be voluntary: MNOs should have a realistic alternative to having to take on an MVNO obligation.

2.4 Coverage obligations

Using the forthcoming award to improve coverage with mobile services in line with various political commitments is an important objective. As the intended levels of coverage will require operators to roll out networks into areas where doing so is not commercially justified, achieving the envisaged coverage targets will require imposing specific obligations. Meeting these obligations will be costly and, depending on the specification, these costs may be substantial.

Indeed, respondents to the consultation have claimed that the currently envisaged coverage requirements may not be economically feasible when combined with a potentially significant cost of acquiring spectrum.

Respondents to the consultation have also indicated that it would be preferable to share the burden of meeting these extended coverage targets amongst operators, albeit in a manner that does not undermine synergies (as would be the case, for example, if the obligation to provide area coverage and coverage of main roads were split). Sharing these obligations would also avoid increasing coverage asymmetries between operators, which could have a negative impact on competition if operators subject to wide-ranging coverage obligations were perceived to provide better services.

At the same time, however, there might be strong economies of scale in the provision of coverage, which would suggest that sharing could result in large efficiency losses.

H3A also has pointed out that operators with more substantive existing spectrum holdings below 1 GHz will have an advantage in providing coverage, even if the obligation is linked to 700 MHz spectrum. Such concerns arise mainly in relation to speed and bandwidth requirements that may be difficult to fulfil with only a small amount of low frequency spectrum and because operators who currently rely to a substantial degree on sub-1 GHz spectrum have a site grid that is much better suited to providing area coverage. Such advantages could potentially distort bidding for spectrum.

2.5 Recent changes to the TKG

The recently modified Telecommunications Act (TKG) includes provisions that affect the conduct of spectrum auctions. In particular, there is a provision that requires the process to be simple, easy to understand and to follow, with the intention of giving bidders certainty over their maximum liability when placing a bid.[1] Though the letter of the law does not exclude the use of second pricing formats, the modifications made to the Act were motivated by a desire to minimise the uncertainty over final prices that is typically associated with the second price rule.

The explanatory memorandum accompanying the proposed modifications also sets out that RTR will have to consider international experience with comparable auctions and auction formats and to make the award process as transparent as possible, taking into account that restrictions of transparency may be justified if required to meet other objectives (e.g. in order to reduce collusion risks).

The modification of the TKG also has implications for setting reserve prices. Although RTR will continue to be able to deviate from reserve prices set based on the statutory frequency assignment fees, in such cases the minimum price must not be higher than 50% of the lower bound of the estimate of market value.[2]

2.6 Summary

In summary, we consider that the auction design needs to reflect the following key parameters:

Limited competition in the auction

In terms of participation, we assume that the three established mobile operators will take part in the award and that new entry is unlikely. This means that there is likely to be limited competition in the auction.

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[1] Paragraph 55(2) states that "Versteigerungsverfahren sind grundsätzlich einfach, verständlich und nachvollziehbar zu gestalten. Dies soll insbesondere dadurch sichergestellt werden, dass bei Abgabe eines Gebotes weitgehende Gewissheit über die damit maximal zusammenhängende Zahlungsverpflichtung gegeben ist."

[2] Paragraph 55(3) contains the following provision: "In begründeten Fällen kann bei der Festlegung des Mindestgebotes von der Orientierung an den Frequenzzuteilungsgebühren abgewichen werden, wenn dies auf Grund des tatsächlichen Marktwertes der Frequenzen gerechtfertigt erscheint. In diesem Fall darf das Mindestgebot höchstens 50 % der Untergrenze des nach dem vorigen Satz ermittelten Marktwertes betragen."

Combined award of all frequency bands	Bidders' valuations for the different bands are likely to be strongly interrelated: the 700 MHz and the 2100 MHz band are likely to be substitutes, and the 700 MHz band and the 1500 MHz band are likely to be complementary, for H3A. This suggests that the bands should be awarded in a single process that permits bidders to manage substitution and aggregation risks.
Use of spectrum caps to safeguard downstream competition	Current proposals are to impose several spectrum caps, namely:

(a) a cap of 50% of sub-1 GHz spectrum for all operators, which implies that A1 would not be able to bid on more than 2x10 MHz of 700 MHz spectrum, and TMA would not be able to bid on more than 2x20 MHz;

(b) a cap of 43% across all usable mobile bands (including the recently assigned 3.4-3.8 GHz spectrum), which implies that A1 could at most acquire 130 MHz;

(c) band-specific caps of at most two thirds of the available spectrum in the 700 MHz and the 2100 MHz band and 60 MHz in the 1500 MHz band; and

(d) a joint cap on A1 and TMA, limiting the two bidders together to acquire no more than 2x75 MHz of spectrum in the 700 and 2100 MHz bands.

Spectrum floors	We understand that operators have stated a need to retain a critical amount of spectrum in the 2100 MHz band (2x15 MHz) for reasons of business continuity, requesting the use of spectrum floors that guarantee this amount to each of the existing MNOs.
Separate assignment stage	In order to avoid unnecessary fragmentation of bands, spectrum should be offered initially in the form of frequency-generic lots in several categories. Winners of bandwidth will then be assigned specific frequencies in a second step, in which the priority will be to avoid unnecessary fragmentation of assignments. We consider that this frequency assignment stage could take the form of a single-round sealed-bid process using a second-price rule, which has been used successfully in past awards in Austria. Such a format gives bidders the opportunity to bid on their preferred frequencies without paying more than opportunity costs, which may be negligible if preferences are mutually consistent (as could be the case, for example, were such preferences are determined by trying to maximise the overlap between new spectrum assignments and existing frequency holdings). Should there be objections to the use of a second-price rule, it would be straightforward to use a first-price, pay-as-bid format instead.
Small blocks, subject to avoiding aggregation risks	The size of spectrum blocks should be set with a view to maximise the flexibility of bidders to assemble their preferred spectrum portfolios, subject to not creating unmanageable aggregation risks for bidders.
Coverage obligations	The coverage objective is likely to be addressed through a combination of basic coverage obligations that apply to all winners of spectrum in the 700 MHz band, and several additional coverage

obligations, each of which would need to be met by only one operator and which may be distributed across operators.

There are two fundamentally different ways in which such obligations could be assigned:

- they may be linked to specific spectrum blocks, leveraging the value of spectrum as an incentive to take on the obligation; or
- they may be assigned separate from, but alongside spectrum with incentives for operators to take on such obligations in exchange for financial incentives.

We note that an option would be to procure coverage entirely independently from the award of spectrum in a process that is legally separated and potentially open to bidders other than those who are competing for spectrum. However, we understand that it is not legally possible for the TKK to run such an entirely self-standing procurement auction process that is completely divorced from the award of spectrum.

The first approach has frequently been used in order to assign specific coverage obligations in a wide variety of auctions. The main risk associated with this approach is that spectrum may remain unsold if the obligations are too onerous and unencumbered spectrum can be acquired at a price that makes taking the blocks with the obligation unattractive. This means that coverage obligations attached to blocks may need to be defined very carefully and conservatively.

The second approach avoids this risk but is subject to other limitations. In particular, it is not possible to have net payments to operators in such a combined assignment of spectrum and coverage obligations, so that the maximum discount that an operator could obtain for taking on a coverage obligation is limited by the price it would have to pay for spectrum.[3]

With limited competition for spectrum (and potentially even more limited competition amongst operators capable of fulfilling ambitious coverage obligations), there is a risk that coverage obligations may remain unassigned.

Reflecting the risks associated with either of these two options, we consider below different auction models for the assignment of

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[3] We should note that these two restrictions rule out superior approaches such as a self-standing procurement auction for coverage that would be open to more providers than just those bidding for spectrum in this particular award, e.g. fixed network operators or smaller local players who have obtained spectrum in the recent 3.4 – 3.8 GHz auction. Even if we considered only the case of a combined spectrum/procurement auction, the 'no net payments'-rule gives rise to inefficiency.

coverage obligations tied to spectrum blocks, and separately from, but alongside the assignment of spectrum.

Assignment of an MVNO obligation

Like the assignment of coverage obligations, an MVNO obligation could be tied to a specific spectrum block or assigned alongside spectrum. The main difference between the MVNO obligation and an ambitious coverage obligation is that the a substantive portion of the cost of accepting the MVNO obligation – the potential loss of economic profits associated with more competition – is shared amongst all operators, whereas the cost of meeting a coverage obligation falls squarely on the operator charged with delivering the coverage target. This suggests that the main challenge in assigning an MVNO obligation is to break any collusive refusal to accept such an obligation.

Preference for simple design

Finally, there is a preference for a simple auction design, ideally using tried and tested formats in order to minimise the scope for legal challenge.

3 Model 1: A multi-stage with an additional procurement auction stage

3.1 Overview

This model is suitable for assigning regionally differentiated coverage obligations, each tied to a specific 700 MHz spectrum block with further coverage targets being offered in a separate auction stage.

This option, based on the well-established SMRA (Simultaneous Multiple Round Auction) format, albeit with a modified process for collecting bids that is better suited to the case of frequency-generic spectrum blocks. It would therefore be well-aligned with the preference for a simple design.

To mitigate aggregation risks arising from the complementarity between 700 MHz and 1500 MHz spectrum without relying on package bidding, we propose to assign 1500 MHz in a separate step after the assignment of 700 MHz has been completed. This should remove aggregation risks for bidders whose valuation of 1500 MHz spectrum depends strongly on whether they are able to acquire a sufficient amount of 700 MHz spectrum. This might particularly affect H3A, who may be less well placed to deploy 1500 MHz spectrum without winning enough 700 MHz spectrum, given its limited existing spectrum holdings below 1 GHz.

Although the value of winning 700 MHz may be higher if a bidder also acquires 1500 MHz, we understand that the exposure to aggregation risks from offering 700 MHz in the first step of a sequential process is of less concern as700 MHz spectrum can be used without acquiring SDL spectrum and the value impact of winning 1500 MHz spectrum is limited.

To permit substitution between 700 MHz and 2100 MHz, both bands would be offered simultaneously.

In summary, therefore, Model 1 would comprise the following stages:

Table 1: Model 1 – overview of stages

Stage 1	Assignment of 700 MHz (subject to extended coverage obligations) and 2100 MHz using an SMRA-Clock-Hybrid format
Stage 2	Assignment of 1500 MHz spectrum using an SMRA-Clock-Hybrid format
Stage 3	Assignment of specific frequencies to winners of bandwidth, using a combinatorial sealed bid auction with minimum revenue core pricing
Stage 4	Assignment of additional coverage obligations and potentially a MVNO obligation using a first price sealed bid format

3.2 Definition of lots

2x10 MHz blocks in the 700 MHz band

Spectrum in the 700 MHz band will be offered in the form of 2x10 MHz blocks. These would be frequency-generic (though they could also be frequency-specific, which might be preferable in the unlikely case that there are substantive differences in usage conditions resulting from uncertainty over the timing of the complete clearance of the band).

Packaging spectrum into 2x10 MHz blocks addresses the concern that less bandwidth might not allow the operator to fulfil the coverage requirements and that offering smaller blocks would create aggregation risks that could not easily be managed under the proposed auction format.

These lots will in any case be differentiated, and therefore fall into different categories, as a different coverage obligation is attached to each block. The obligations specify coverage requirements in different regions (defined either broadly geographically, or in terms of address groups) that will need to be met by whoever acquires the block. There is no need for these different requirements to be comparable, but it is important that they are defined in such a way that even the most ambitious obligation can be met by the least well-placed operator (likely to be H3A) with the spectrum linked to the obligation. Otherwise, there is a risk that spectrum may remain unsold.

It is worth emphasising that reducing the scope of the obligation on one block (or potentially removing the obligation completely) does not solve the problem, as other operators could try to outbid H3A on this block, knowing that H3A would not be able to switch to one of the alternative blocks. Thus, there would still be a risk that spectrum remains unsold and the associated coverage obligation remains unmet.

<table>
<tr><td>2x5 MHz blocks in the 2100 MHz band</td><td>Spectrum in the 2100 MHz band will be offered in the form of 2x5 MHz blocks. Packaging spectrum in such small blocks is in line with international best practice, provides maximum flexibility to operators and offers the greatest scope for competition for incremental spectrum. We consider that any aggregation risks that arise from efficiency gains associated with larger bandwidths should be manageable even under the proposed SMRA format, as individual bidders are unlikely to be pushed back to single blocks (even without any measures that would effectively set a spectrum floor). Even though such an outcome is theoretically possible under the proposed spectrum caps, operators should be sufficiently well matched to prevent such an extremely asymmetrical distribution of spectrum.</td></tr>
</table>

10 MHz blocks in the 1500 MHz band	Spectrum in the 1500 MHz band will be offered in the form of eight 10 MHz blocks, excluding the 10 MHz at the bottom of the band, which will be assigned to the winner of the lowest block in Stage 3.
Further coverage commitments and MVNO obligation	Lots for the fourth stage would comprise individual coverage targets which bidders could commit to cover in exchange for a reduction in the price they have to pay for spectrum, and a commitment to provide wholesale services to MVNOs on terms and conditions set out by RTR.

In terms of additional coverage targets, it is important that these be defined in such a way that no single operator has a strong systematic advantage in providing the required coverage. Otherwise, competition in the fourth stage would be very limited. This requirement will have to be borne in mind when defining the extended coverage obligations that are to be linked to spectrum blocks in the first stage, as synergies between these and the additional coverage targets offered in the fourth stage could create such strong advantages.

3.3 Spectrum caps and floors

Spectrum caps will be set as described above. The joint spectrum cap applying to A1 and TMA (at most 2x75 MHz across the 700 MHz and the 2100 MHz bands) will be applied when determining provisionally winning/standing high bids, as set out below.

Although a spectrum floor in the 2100 MHz band could in principle be implemented as another joint cap limiting **any two bidders** to winning no more than 2x45 MHz (nine blocks) in the band, we would not suggest using such an approach, as outcome restrictions sit rather awkwardly with the proposed auction format and would better be implemented in the combinatorial Model 2 (see below). If a need to guarantee a minimum spectrum endowment to each of the existing operators were to be identified, this might most appropriately be met by offering the required spectrum to each

operator (either at reserve or – if possible – at a price that is more closely aligned with market value than the reserve prices would have to be).

3.4 Auction mechanics

Stages 1 and 2

Outline of SMRA-Clock-Hybrid format

Stages 1 and 2 will be conducted using an SMRA-Clock-Hybrid format.

- The auction proceeds in discrete rounds during which bidders may submit bids subject to the activity rules.
- Lots are offered in different lot categories. The auctioneer will announce the price for each lot category in each round, and bidders will then specify the number of lots they wish to acquire in each category at the prevailing prices. Each of the 700 MHz blocks is subject to a specific coverage obligation and therefore be in a separate category.
- At the end of each round, the auctioneer determines provisional winning bids (standing high bids) using the mechanism described below. Bidders may become standing high bidders on only some of the lots they have bid on, as there is no requirement to accept all or none of the bids submitted by a bidder.
- The price in lot categories with excess demand (as defined below) will increase, and bidders will then be able to submit bids at new price levels. Bidders who hold standing high bids in a lot category and wish to submit bids for that category at the new price level must also raise their standing high bids in the category.
- The auction ends after a round in which no new bids are placed.

Establishing standing high bid in the same way as in the standard SMRA

In the traditional SMRA, the bids for each lot are evaluated independently. This could be replicated in the proposed format by simply transforming the quantities demanded by bidders into bids on individual lots at random, and then randomly selecting those that are to be designated as standing high bids.

A joint cap on the maximum number of blocks that can be acquired by a group of bidders can then be implemented simply by limiting the number of bids that can be picked as standing high bids from all of the bids (which is equivalent to saying that these bidders can only bid on a subset of the total lots available).

Like the standard SMRA, this approach potentially leaves all bidders with standing high bids on only a subset of the lots they are bidding for, which can expose them to aggregation risks and prevent 'clean' switching between different bands, for example.

Process for establishing standing high bids by ranking bidders

The SMRA-Clock-Hybrid format provides scope for some improvement by ensuring that at most one bidder in each band has some, but not all its demand designated as standing high bids in each round. Specifically, we propose to establish standing high bids in each lot category by ranking bidders in the category[4] rather than for each lot individually. This is a moderate departure from the standard SMRA auction rules. The process is described in Box 1.

Specifically, we propose first to rank those bidders who have submitted bids in a particular round at the round price at random and then provisionally assign all lots in a given category bidder by bidder, starting with the highest ranked bidder and satisfying the demand for each bidder in descending order of rank until the supply of lots is exhausted. This ensures that at most one bidder will have only part of its bid provisionally accepted.

Box 1: Selecting standing high bids by ranking bidders in each category

Suppose that we receive bids from three bidders (A, B and C) for blocks in the 2100 MHz band where there are twelve lots available. Suppose that A bids for eight lots, B for six lots and C for four lots.

We first rank bidders A, B and C at random (though other criteria are also possible). Suppose we obtain the ranking B, A, C. We then assign standing high bids by considering each bidder sequentially in the order of this ranking.

- We start with B: We have twelve lots available (as we have not yet provisionally assigned any lots). B has bid for six lots. We can provisionally assign to B all the lots it has bid for, so B becomes the standing high bidder on six lots.
- We continue with A: We have now six lots remaining. We can provisionally assign to A six of its eight lots, so A becomes the standing high bidder on six lots.
- We have no more lots available, so we stop considering any other bidders.

At the end of this process we have the following standing high bidders: B on six lots; A on six lots. C is not a standing high bidder. This method ensures that we will accept at most one partial bid in each lot category (in this example, from A), while for all other bidders we accept either the whole bid or nothing at all in that category.

An alternative option would be to establish first whether it is possible to fill the given supply by accepting only whole bids. This would be feasible in this instance, namely by accepting the bid from bidder A (eight lots) and bidder C (four lots) as standing high bids and use random ranking only if this is not feasible, though this may systematically favour some bidders. Yet another option would be to order

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[4] A different ranking may apply to different categories, not least because using the same ranking would not ensure that there is at most one bidder with partially satisfied demand across all categories (e.g. in the 700 MHz band, the second-ranked bidder may already only have part of its demand satisfied, whereas in the 2100 MHz band all of the second ranked bidder's demand can be accommodated and only the third ranked bidder would only have some of its demand designated as standing high bids).

bids in increasing order of the number of blocks demanded (and then randomly), i.e. satisfying the demand from smaller bidders first. This would systematically favour smaller bidders who would not need to bid back as often as larger bidders, which could be desirable in order to promote a more equal distribution of spectrum in the auction. At the same time, such a ranking rule will provide some additional information to some bidders about demand from competitors. A bidder who will never become standing high bidder on its full demand would know, for example, how much demand in a category comes from smaller bidders.

More generally, any non-random ranking approach is likely to create some information asymmetry by allowing bidders to make inferences about the demand from other bidders depending on how often and to what extent their bids are designated as standing high bids. This could distort bidding incentives and would not be compliant with non-discrimination requirements. Therefore, we would recommend using a random ranking.

We note that under this approach a bidder who has only part of its demand designated as standing high bids will gain some information about the total demand from higher ranked bidders, which in combination with spectrum caps may reveal some information about the number of other bidders competing, in particular if participation is limited.[5] However, we believe that this small informational advantage, which would be enjoyed by a random bidder each round, is justified by the benefits from trying to keep at most one bidder with only partly satisfied demand in each category.[6].

Under the proposed approach of ranking bidders, establishing standing high bidders would become more complex for subsequent rounds if bidders were able to retain some standing high bids at a given price level and at the same time submit bids for additional lots at a higher price level. To avoid this, *we propose to require that all active bids from a bidder in a given category must be at the same price level*.

This would require bidders who wish to submit any bids at a new price level to raise any standing high bids they may hold at the

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[5] Even bidders who have none of their demand satisfied may be able to make some inferences with limited participation. For example, with a band-specific cap of two thirds of the available spectrum and an effective cap on A1 of 2x10 MHz in the 700 MHz band, a bidder other than A1 who does not have any of its bids designated as standing high bids will know that both the other bidders are bidding up to their caps and thus, in combination with its own bid, aggregate demand. Being standing high bidder on a single block would indicate either that one competitor bids to the cap, which puts a lower bound on aggregate demand, or that both A1 and the other bidder bid on one block each, which puts an upper bound on aggregate demand.

[6] We also note that using different ranking criteria – e.g. ranking bidders in ascending order of the size of their demand in order to maximise the number of bidders who have their entire demand designated as standing high bids – would create systematic informational advantages for some bidders. This would be a further argument against using other than random ranking.

previous price level in that category, which implies that there is a small advantage to being designated as standing high bidder on all of the demand in a category, but it would speed up the process by contributing to a more steady increase of prices. This requirement though will remove some benefits for bidders who might otherwise be able to retain some of their standing high bids at a lower price level. However, we consider that these benefits are likely to be small, especially if small price increments are used once there is little excess demand. If the requirement that bidders with partial standing high bids must increase their existing bids were to be considered problematic, it would always be possible to set final prices for all bidders at the level of the lowest standing high bid in a lot category.

For the avoidance of doubt, if we were to use the simpler approach of ranking individual bids rather than bidders, no such requirement would be necessary.

Implementing a joint cap

If we wish to apply a joint spectrum cap, we need to limit the number of lots on which a lower-ranked bidder can become standing high bidder in a band, depending on the number of lots that have already been assigned to other bidders in this group in other bands. This requires a ranking of bands for establishing standing high bids. The process is set out below.

Box 2: Implementing a joint cap

> Suppose that A and B are jointly capped at 2x75 MHz across the 700 and the 2100 MHz band. We have three different lot categories with one block each in the 700 MHz band (say 700/1, 700/2 and 700/3). Assume that we receive bids from A and C for 700/1 and 700/2 respectively, and from B for 700/1 and 700/3. Suppose that we are establishing standing high bids in the 700 MHz band first (though the order in which bands are considered can be random) and that we have designated the following standing high bids in the 700 MHz band:
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> - A – 700/1 (2x10 MHz)
> - B – 700/3 (2x10 MHz)
> - C – 700/2 (2x10 MHz)
>
> This leaves a total of 2x55 MHz in the 2100 MHz band on which A and B together can become standing high bidders.
>
> Proceeding with the above bids and bidder ranking (box 1) for the 2100 MHz band (B-A-C), we would assign:
>
> - six lots to B (2x30 MHz), leaving at most 2x25 MHz for assignment to A
> - five lots to A (2x25 MHz), and
> - one lot to C (2x5 MHz).
>
> With joint caps, the higher ranked bidder is favoured more strongly, but with random ranking of bidders there should be no systematic discrimination in favour of specific bidders.

It should be noted that the imposition of joint caps can lead to more than one bidder in a band holding partial standing high bids, thus partially removing some of the advantage of ranking bidders rather

than individual bids, which would tend to reduce the benefits from ranking bidders rather than individual bids

Price increments   The principle for setting price increments is that SHBs can only be outbid by higher bids, and that a price increment is only applied if it is needed to outbid SHBs. Therefore, the price of a lot category will need to increase if, and only if, all the lots in that category already have a standing high bid at the price set for that category in the last round. If some of the standing high bids are at a lower price, they can be outbid without the need for a price increase. An example of this is provided in Box 3.

Box 3: Price increments when using generic lot categories

Suppose there are two lots available in a category. Suppose that bidding proceeds as follows.

Round	Price	Bids received from	standing high bids (bidder@amount)	Aggregate demand at round price
1	10	A, B, C, D	A@10, B@10	4
2	11	C, D	C@11, D@11	2
3	12	B	B@12, D@11	1
4	12	C	B@12, C@12	2
5	13	…	…	…

In the first round we receive bids from four bidders (A, B, C and D), all bidding for a single lot in this category, at the opening price of 10.

We select two of these bids as the standing high bids – suppose we select the bids from bidders A and B. All the available lots have standing high bids at the price set for that round (and indeed there is excess demand at this price), so the price must increase in the following round.

In round 2, the price is set at 11, and we receive bids from bidders C and D. The bids from C and D are at a higher price than the previous standing high bids, and thus become the new standing high bids. All lots have standing high bids at the price set for that round, so the price must increase in the following round (even if demand from bids received in the round exactly meets supply we need a price increment, as we need to invite new bids at a price that exceeds the standing high bids).

In round 3, the price is set at 12 and we only receive a bid from bidder B (bidder A leaves the auction). The bid from B will outbid one of the current standing high bids (which we can either select at random, or based on the bidder ranking that initially created these bids; suppose the bid from B outbids the bid from C). However, the other standing high bid will remain unchallenged at this point. Therefore, we now have standing high bids at two different levels, and we do increase the price (as a bid at a price of 12 would still outbid the standing high bid from D, which is at a price of 11).

In round 4 the price remains at 12. Suppose that bidder C bids at the new price level. The bid from C outbids the bid from D, but would not have been high enough to outbid the bid from B. Now both standing high bids are at 12, and hence we must increase the price to allow for higher bids to outbid the current standing high bids.

Note that when switching is allowed we may experience an increase in aggregate demand, which means that sometimes we may receive bids at the current price level that will fail to become standing high bids if the bids from this round result in excess demand at the current price. For example, suppose that in round 4 we also received a bid from another bidder (E) switching from another category. We would then have two new bids at a price of 12. One of these bids could outbid the bid from D, as in the previous example. However, the other bid would not outbid the bid from B, as this bid is also at 12. Therefore, this bid would trigger a price increment but not become a standing high bid. However, the bidder who is unsuccessful in becoming a standing high bid will have an opportunity to bid back in the following round at the higher price.

Therefore, we propose the following approach for setting prices:

- In the first round, the price for each lot category will be set to the reserve price for lots in that category.
- When scheduling a new round, the price in a lot category will increase if all standing high bids in the lot category are at the round price prevailing in the preceding round.

Withdrawal of Standing High Bids	We do not envisage a need for allowing bidders to withdraw standing high bids.
Activity rules	Each bidder starts the auction with an initial eligibility determined by its application and corresponding deposit.

Under the proposed approach of ranking bidders and requiring bidders to increase their standing high bids if they want to bid for additional lots in a category, the activity of a bidder in a round is calculated as:

- the sum of eligibility points for lots for which the bidder is a standing high bidder at the beginning of the round in lot categories where the bidder does not submit any bids; plus
- the sum of eligibility for all lots for which the bidder is bidding in lot categories in which the bidder submits bids in the round.

If we were to establish standing high bids by ranking individual bids, the activity of a bidder in a round would simply be the sum of eligibility points for lots on which the bidder makes a new bid maintains a standing high bid.

The activity of a bidder in a round cannot exceed the eligibility of the bidder at the start of the round.

At the end of each round, the eligibility of a bidder for the following round will be set equal to the activity of the bidder in the most recently completed round in which the bidder did not submit a waiver.

We note that relying on eligibility points can introduce switching impediments in relation to spectrum portfolios, as switches from one combination of lots to another combination that involve a loss of eligibility will be irreversible. Thus, even if at some later point relative price movements make the larger portfolio more attractive, a bidder who has dropped eligibility will not be able to switch back.

It may be possible to relax the activity rule somewhat in order to mitigate switching impediments, e.g. by using looser activity requirements that allow bidders to go slightly over their demand in the preceding round However, this also allows bidders to withhold their demand until later in the auction or to switch strategically.

Without any obvious requirement for such relaxations we would suggest using a simple eligibility points rule with the activity requirement being set at 100% throughout the auction.

Waivers	Waivers allow a bidder to skip a round without losing eligibility. If a bidder uses a waiver, then its eligibility for the following round is maintained. Waivers are often used in SMRAs, in which case bidders are typically given a limited (small) number of waivers.

Waivers mitigate inefficiencies arising from the potential switching impediments caused by standing high bids, by allowing bidders to wait to be outbid before switching their demand. The bidder can wait one round to see if it is outbid on its standing high bids, in which

case it will be able to switch its full demand, or not, in which case it may prefer to continue to bid on the band where it holds its standing high bids to avoid a situation where it wins a small number of lots in that band.

Waivers seem appropriate when bidders might face switching impediments caused by standing high bids. They also provide a safeguard against potential problems with bid submission, and the possibility for bidders to defer key decisions to reduce their activity if they need additional time for their decision.

We propose to allow each bidder to submit up to two or three waivers in Stage 1 and one or two waivers in Stage 2 (where switching impediments are not relevant, and the main purpose is as a safeguard against technical problems). A bidder may submit a waiver in any round except the first round, along with any bids it may wish to submit in the round. The effect of a waiver will be to preserve the current round eligibility level of the bidder for the following round.

A bidder may submit a decision not to place any bids.

If the bidder fails to submit a decision, its decision for the round will be defaulted as:

- submission of a waiver, if the bidder has waivers remaining and its activity in the round is less its eligibility at the start of the round; or
- not placing any new bids otherwise.

Eligibility points in Stage 1

To reflect the difference in value between sub-1 GHz spectrum and higher frequencies and the difference in the amount of available spectrum, we propose to assign four eligibility points to each 2x10 MHz in the 700 MHz band, and one eligibility point to each block of 2x5 MHz in the 2100 MHz spectrum. If the eligibility points ratio were considered to give rise to switching impediments, it may be appropriate to relax the activity rule to some extent.

Eligibility points in Stage 2

For the separate assignment of 1500 MHz spectrum, we propose to assign one eligibility point to each of the 10 MHz blocks.

End of the bidding phase

The bidding phase in each of Stage 1 and Stage 2 will end as soon as a round is completed during which no bids or waivers are submitted.

At the end of the bidding phase, standing high bids become winning bids, and bidders will win the amount of spectrum associated with the lots on which they hold standing high bids. Winners of 700 MHz lots will be required to meet the extended coverage obligation associated with their respective lot (in addition to the obligations that are being imposed on all bidders).

In terms of pricing, we can either adopt a strict pay-as-bid rule or set a uniform price per block for each category, at the level of the lowest standing high bid in that category. The latter should remove any concerns about potentially favouring individual bidders through the

process of designating standing high bids but would deviate from a strict pay-as-bid approach. It could also cause complaints from bidders who were outbid on their standing high bid even though lots eventually sell at the price of these bids. This would make the strict pay-as-bid approach preferable.

Information policy during the bidding phase

The benefits from using an open auction format are closely linked to the information disclosed to bidders about the bids received and the level of demand. However, whilst on the one hand providing more information will contribute to bidders being able to refine their expectations about the outcome and value of lots, information about competitors' bids also facilitates undesirable bid strategies and tacit collusion.

We do not consider that it is necessary or desirable to disclose information about bidders' individual bids. However, it is reasonable to provide aggregate demand information by disclosing the total number of bids at the round price for each category (which includes new bids placed in the round and any remaining standing high bids at that price from previous rounds), unless participation in the auction is severely limited and there are concerns of tacit collusion or other gaming strategies. This is not least because withholding information might sometimes lead to bid strategies aimed at probing competitors' demand, with bidders switching across categories not in response to price differences but simply to observe if prices continue to increase when they reduce demand in a given category. Such strategies distort price signals and could lead to an inefficient outcome if bidders fail to anticipate the end of the auction and switch back to the lots they wish to acquire.

Considering this, we recommend that aggregate demand for each band is disclosed, but not the individual bids from each bidder. However, if there are concerns about collusion it may be preferable to only disclose aggregate demand (in MHz) across all categories, or only prevailing prices (which will only increase if there were excess demand in the previous round). Another option would be to disclose aggregate demand in steps (as in the UK 2018 PSSR auction). However, this may provide incentives for bidders to try and gain further information by varying their bids in particular categories. Such strategic bidding aimed at probing levels of demand in individual lot categories could result in inefficient outcomes and we consider that these undesirable effects are likely to outweigh any benefit that limiting information about aggregate demand to broad steps might have.

In any case, with limited participation and under the proposed approach of ranking bidders, bidders with partially satisfied demand might be in a good position to gauge aggregate demand, and therefore disclosing this information would not have any adverse impact.

Stage 3

For the frequency assignment stage, we propose to use the well-established process of running single-round sealed bid processes for each band in which:

- the auctioneer identifies the potential band plans that give every winner a contiguous assignment of frequencies and retain any potentially unsold lots as a contiguous frequency block, assigning the lowest two blocks in the 1500 MHz band to whoever is assigned the lowest of the blocks included in the auction;
- presents each bidder with all the different assignments that the bidder might obtain across all these band plans and asks bidders to express their preference for the different options through assignment bids;
- identifies the band plan with the highest value; and
- establishes the price to be paid by each bidder using a minimum revenue core pricing approach.

This approach has been used in several previous awards and bidders should be familiar with its operation.

Should there be any objection to using a second price rule, we would need to revert to a pay-as-bid rule.

Stage 4

We propose to use a first-price sealed bid process for the assignment of additional coverage obligations and the MVNO obligation (collectively referred to as 'the targets'). This is for reasons of simplicity, but also in order to minimise the risk of tacit collusion, in relation to the risk that the MVNO obligation may be collectively refused.

Assuming that coverage targets are likely to be defined as separate small areas, we do not expect synergies from taking on different targets. Assuming further that bidders may be interested in winning and be prepared to win the maximum total discount on their spectrum fees that is possible, we consider that there are limited benefits from supporting package bids. To the extent that bidders may want to limit their exposure to taking on commitments (e.g. because of resource constraints that limit the number of target areas they can build out), it may be possible to allow them to specify an individual maximum threshold of discounts they want to win,

provided that targets are sufficiently similar that bidders do not care which ones they win.[7]

Again, with a view to simplify the process and promote competition, we propose that bids are made for individual targets separately.

A bid for a target is a monetary amount specifying the reduction in the total price payable by the bidder in exchange for taking on the obligation. The auctioneer will set a (negative) reserve price for each obligation, which could reflect the value of having the obligation met, or a reasonably conservative estimate of the cost of doing so in order to be protected against outcomes in which bidders extract too much of the social value created by delivering the obligation.

Each bidder may place bids in the fourth stage that in their totality exceed the amount the bidder would have to pay after the first three stages and that could therefore not all be accepted, given that net payments to operators are not possible. The constraint that the total sum of bids accepted for the bidder will not exceed the maximum price reduction that a bidder could obtain will be implemented when evaluating bids.

All bids for the targets will be evaluated simultaneously.

In the first instance, bids for individual targets that specify a discount in excess of the reserve price that RTR would be prepared to offer for the target are eliminated from the further assessment.

Subsequently, the auctioneer will select the feasible bid combination that generates the greatest value, defined as the difference between the value of having the targets included in the combination of bids covered[8] and the discounts specified, potentially subject to a limit of the total proportion of auction proceeds or an upper absolute amount available for the procurement of further coverage. If so desired, the MVNO obligation could be given a greater weight in the calculation of value.

A feasible bid combination in the fourth auction stage is a combination of bids that:

• does not include more than one bid for the same obligation (coverage target or the MVNO obligation);

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[7] If targets are very different and bidders do not want to win the maximum number of targets they could, a combinatorial bidding process would be required as bidders would want to place mutually exclusive bids on subsets of the available targets.

[8] If reserve prices have been set with reference to the value of having the target covered, this would simply be the reserve price. If reserve prices have been set on the basis of cost estimates and the auctioneer has not developed estimates of the value of having particular targets covered, reserve prices may still be used as a proxy, with the objective function becoming the maximisation of cost savings relative to the auctioneer's estimate.

- satisfies, for each bidder, the requirement that the total reduction for the bidder does not exceed the bidder's provisional licence price, defined as the sum of the prices determined in the first, second and third auction stage, or any maximum discount threshold nominated by the bidder;
- respects restrictions set by TKK that limit the maximum amount available for discounts (expressed as an absolute number or proportion of the auction proceeds).

In case of a tie, a feasible bid combination will be chosen at random.

3.5 Advantages and disadvantages of the model

The proposed model has several desirable features considering the requirements set out above:

- It relies on the simple and well tested SMRA format (even though the bid collection process is somewhat modified better to match the fact that there will be many generic spectrum blocks in the 2100 MHz and the 1500 MHz band).
- Though non-combinatorial, it permits bidders to manage the aggregation risks across the 700 MHz and the 1500 MHz band through a staged approach in which the more valuable and more important paired spectrum is offered first and mitigates aggregation risks in the 700 MHz band through offering larger spectrum blocks.
- The model leverages the full value of spectrum in order to achieve coverage targets, and aims to test the extent to which further coverage objectives and the desire to have an MVNO obligation accepted by at least one operator could be satisfied through a procurement auction in which bidders offer to take on such obligations in exchange for a discount on their licence prices.

However, there are also shortcomings. Specifically:

- Bidders remain exposed to possible aggregation risks in relation to the 2100 MHz band (though as noted above, these should be manageable and have not been specifically raised in consultation responses).
- The potential increase in the valuation of 700 MHz spectrum from being able to acquire 1500 MHz spectrum are not captured, so there are some residual aggregation risks in relation to these two bands.
- With coverage obligations linked to spectrum blocks, there is a risk that both the obligation and the spectrum tied to it remain unsold if the requirements are too ambitious.
- The decision to offer larger blocks in the 700 MHz band potentially limits competition for incremental spectrum and provides a focal point for a low-price outcome. This would then

limit the likelihood that additional coverage targets and the MVNO obligation can be assigned in the fourth auction stage.

- In relation to additional coverage obligations and the MVNO obligation, the model does not capture any interdependencies between the willingness to offer additional coverage or MVNO access depending on the amount of spectrum won. An operator who would be happy to meet such obligations if it were to win a larger amount of spectrum would have to form expectations about the potential discount it might obtain when bidding for spectrum.

4 Model 2: A combinatorial multi-band auction with coverage lots

4.1 Overview

The main motivation behind Model 2 is to:

- avoid the risk of unsold spectrum in the case where potentially onerous coverage obligations are tied to spectrum blocks; and to
- capture any interdependencies between the amount of spectrum won and the extent to which an operator might be prepared to meet extended coverage obligations (and any synergies in the valuation of spectrum that may exist).

Rather than having to take on extended coverage obligations if they want to acquire spectrum, bidders will be able to bid on frequencies that are subject only to basic coverage requirements, which every bidder will be required to meet, and bid on 'coverage lots' alongside spectrum blocks in order to reduce the price they pay for spectrum. These coverage lots define further obligations on the winner to meet specific extended coverage targets. They have a negative price and therefore reduce the amount that a successful bidder will have to pay for spectrum.

Thus, this process combines the assignment of spectrum with a procurement auction for coverage – albeit one in which participation is limited to those who bid for spectrum and in which net payments to providers of coverage services are not possible.

As the ability to cover specific targets may be closely linked to the amount of spectrum that a bidder acquires, we consider that a combinatorial auction format is required. Ruling out sealed bid formats, this suggests the use of a CCA (Combinatorial Clock Auction) or a CMRA (Combinatorial Multi-Round Auction).[9]

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[9] The CMRA format aims at including full package bidding in a standard multi-round ascending auction format with a pay-as bid rule. It was first used in the Danish 1800 MHz auction and a full description can be found in the corresponding Information Memorandum (see https://ens.dk/sites/ens.dk/files/Tele/information_memorandum_june_2016.pdf; and also the Information Memorandum for the 700, 900 and 2300 MHz auction - https://ens.dk/sites/ens.dk/files/Tele/information_memorandum_-_updated_feb_2019.pdf).

All frequency bands would be offered as frequency-generic lots in a single process alongside coverage lots (and potentially an MVNO obligation), with specific frequency assignments being left to a subsequent assignment stage.

In summary, therefore, Model 2 would comprise the following stages:

Table 2: Model 1 – overview of stages

Stage 1	Assignment of frequencies in all available bands alongside coverage lots and an MVNO obligation, using a CCA or CMRA format In the CCA format, there would be two sub-phases (clock phase and supplementary bid phase)
Stage 2	Assignment of specific frequencies to winners of bandwidth, using a combinatorial sealed bid auction with minimum revenue core pricing

4.2 Definition of lots

2x5 MHz blocks in the 700 and 2100 MHz bands

Spectrum in the 700 MHz band and in the 2100 MHz band will be offered in the form of 2x5 MHz frequency-generic blocks. With an auction format that permits package bidding, there are no concerns about bidders needing to acquire a minimum amount of spectrum to be able to use it efficiently.

10 MHz blocks in the 1500 MHz band

Spectrum in the 1500 MHz band will be offered in the form of eight 10 MHz blocks, with the winner of the lowest block in Stage 2 also being assigned a further 10 MHz at the bottom of the band.

Coverage lots and MVNO obligation

All spectrum lots will be offered subject to some basic coverage requirements, which are defined in such a way that it is desirable (and economically feasible) for these obligations to be met by each operator.

In addition, there would be a number of coverage lots specifying additional obligations to provide services in specific areas where otherwise such provision would not be commercially attractive. Coverage targets can be geographically diverse (e.g. different regions) and it may also be possible to offer coverage lots that specify incremental coverage requirements (e.g. incremental area

coverage).[10] Such an incremental specification would allow coverage levels to be determined within the auction rather than having the binary result of coverage targets being met (sold) or not met(unsold).

Coverage lots would be 'sold' at a price that is negative, i.e. by acquiring coverage lots, bidders essentially obtain a discount on the spectrum resources they acquire, or – put differently – bidders pay for spectrum by offering coverage commitments.

Depending on the definition of coverage lots, there may need to be bidding restrictions in order to ensure that total coverage obligations are shared amongst operators and to respect the structure of these lots (e.g. if there are lots that specify incremental coverage pushing out coverage boundaries, they can only be acquired alongside main coverage lots).

In addition, there will be an MVNO obligation that bidders could acquire alongside their spectrum lots and any coverage lots. This obligation would similarly involve a discount from the cost of spectrum.

For the sake of simplicity, we use the term 'obligation lots' in the remainder of this section to refer to coverage lots and the MVNO obligation collectively.

4.3 Spectrum caps and floors

Spectrum caps will be set as described above.

The joint spectrum cap applying to A1 and TMA (at most 2x75 MHz across the 700 MHz and the 2100 MHz bands) will be applied as a constraint on feasible outcomes.

Similarly, spectrum floors can be implemented as a constraint on feasible outcomes (e.g. only outcomes in which at least three bidders win at least 2x10 MHz or 2x15 MHz in the 2100 MHz band will be accepted). However, in order to prevent bidders from leveraging such outcome constraints, it will typically be necessary to require them to place bids that ensure that such outcomes can be achieved without having to accept larger bids from the bidder in question. For example, with a spectrum floor of 2x15 MHz in the 2100 MHz band,

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[10] Incremental coverage lots could be specified in different ways. Consider the case of a series of coverage targets CT_1, CT_2 ... CT_N, where CT_n includes, and goes beyond CT_{n-1}. These could be offered in the form of coverage lots CL_1 ... CL_N where only one of these lots will be awarded, or in the form of a coverage lot CL and a number of incremental coverage lots CI_1 ... CI_{N-1} with the restriction that bidders who are bidding on CI_n must also place bids on CL and CI_1 ... CI_{n-1}.

bidders who want to benefit from a spectrum floor would be required to submit a bid for the package which includes only three blocks in this band, at reserve price. The implication of this requirement is that a bidder can only benefit from the implicit reservation of 2x15 MHz if it were prepared to forego the option to acquire any additional spectrum (i.e. the spectrum floor would be truly a floor).

4.4 Auction mechanics

Stage 1

Overview

The CCA approach and the CMRA model differ in terms of how bids are collected and processed. While the CCA essentially proceeds through a clock stage in order to provide bidders with more information about likely market clearing packages and prices prior to running a sealed bid combinatorial auction, the CMRA is essentially a clock auction with more sophisticated options for exit/additional bids and a combinatorial assessment at the end of each round.

However, both formats share some common elements.

Both formats take a simple clock auction in which bidders respond to changing clock prices for different lot categories by adjusting their demand in different lot categories as their starting point. However, they offer different ways in which bidders can make bids for further packages:

- In the CCA, a standard clock phase is followed by a supplementary bids round in which bidders can make bids on packages on which they have not placed bids in the clock round (and increase their clock bids, as necessary), subject to caps on the bid amounts that are derived from the preferences the bidders revealed through their clock bids.
- In the CMRA, bidders can make additional bids in each clock round for packages that differ from the package they specify in their main clock bid (referred to as 'headline bid').

Thus, the CMRA allows bidders to feed in bids that they might want to place in the CCA's supplementary bids round gradually and without the risk of leaving the auction empty-handed. The following table summarises the difference between headline bids and additional bids in the CMRA.

Table 3: Headline bids and additional bids

Headline bids	Additional bids
Like clock bids in a clock auction or primary bids in a CCA *Bidders specify package, bid amount automatically calculated based on round prices*	Like supplementary bids in a CCA, but submitted throughout the auction rather than in a final sealed bid round *Bidders specify package and bid amount (cannot exceed round prices)*
Establish the bidders' activity and its eligibility going forward	Additional bids are optional and have no impact on activity/eligibility, but equally eligible to become winning bids and on par with headline bids when determining whether the auction ends
Can indicate preferred package at round prices	Can indicate close substitutes at round prices or at key switching points at lower prices

In both formats, all bids, i.e. both headline and additional bids, submitted to date are used for establishing a potentially winning combination of bids, but the CCA uses a minimum revenue core pricing rule, whereas the CMRA employs a simple pay-as-bid rule. As bidders do not need to make bids above round prices to reflect valuations – and indeed are not able to do so – bid amounts only increase progressively in response to excess demand.

Package bids

Both formats work with package bids – in the CCA clock bids and supplementary bids, in the CMRA headline bids and additional bids.

A bid specifies the number of lots in each of the categories (the three spectrum lot categories and the obligation lot categories) and a bid amount that the bidder would be prepared to pay for the package. This would be the maximum price that a bidder could be asked to pay in a CCA, or the actual price of a winning package in the CMRA.

- For clock bids and headline bids, the bid amount is calculated automatically from the clock prices of the individual lots, floored at zero or a small positive amount (as there must be no net payments for bidders).
- For supplementary bids and additional bids, the bid amount can be chosen by the bidder, subject to the constraints that arise from the activity rules.

Bidders cannot bid for packages that:

- include more spectrum lots of a given category than are available in that category;
- include more spectrum than the bidder would be allowed to acquire individually under the spectrum caps;
- include obligation lots, but no spectrum lots;
- include more obligation lots in each category than are available (typically one);

- include obligation lots in more categories than permitted as a result of any potential requirement that coverage obligations be shared;
- respect any relevant requirements arising from the specification of incremental coverage lots; and
- have eligibility greater than that bidder's initial eligibility.

If coverage lots are defined in incremental terms, there may have to be further restrictions on permissible packages (e.g. a lot require a higher level of coverage in a region, or higher speeds, may only be included if the corresponding base level lot is in the package).

Activity rules

For both the CCA and the CMRA we propose to use a simple eligibility points-based activity rule (as described above for Model 1) with a revealed preference relaxation.

The eligibility points for spectrum lots could be set as follows:

- 2x5 MHz in the 700 MHz band: 4 points
- 2x5 MHz in the 2100 MHz band: 2 points
- 10 MHz in the 1500 MHz band: 1 point

There would be no eligibility points associated with coverage lots and the MVNO lot.

The eligibility of a package is the sum of eligibility points associated with the lots included in the package, and the activity of a bidder is the eligibility of the package for which it submits a clock/headline bid.

Each bidder will have an eligibility level for each round, which after the first round is set to the smaller of its eligibility and its activity in the previous round.

Relative caps

Both the CCA and the CMRA use relative caps to allow bidders to continue to make bids for packages with eligibility greater than their eligibility, but at levels that are constrained by the round prices of those rounds in which they reduced eligibility.

Specifically, suppose that in a given round (round t) a bidder has eligibility e and submits a clock or headline bid for package X, which has eligibility $a < e$. The bidder's eligibility for the following round will be a. This will set a cap on all packages with eligibility greater than a but not exceeding e, which will be calculated with reference to the highest bid that the bidder makes for package X and the prices that prevailed in round t. Specifically, suppose that package Y is one of such packages, then the cap on the bids that the bidder can submit for Y will be equal to the highest bid that the bidder submits for X plus the difference between the round price of Y and the round price of X in round t.

We call the packages for which the bidder made bids in rounds when it lost eligibility, i.e. the bids which are relevant for calculating the relative caps on other packages, the bidder's *constraining packages*.

The CCA also constrains all bids for packages in the supplementary bids round except that for which they bid in the last clock round (the *final clock package*). This constraint, called the *final price cap* will set a cap on all packages except the final clock package, which is calculated relative to the highest bid that the bidder submits for the final clock package and the package in question based on the round prices in the last clock round. Specifically, the bid that the bidder can make on any package Y which is not its final clock package will be equal to the highest bid that the bidder submits for the final clock package plus the difference between the price of Y and the price of the bidder's final clock package in the last clock round.

CCA activity rules

Whilst early CCAs have applied a strict eligibility-point based activity rule to bidding in the clock phase, more recent implementations have enabled bidders to make clock bids on packages with eligibility greater than their eligibility (a so-called relaxed bid) provided that such a bid is consistent with revealed preference expressed by the bidder in rounds in which eligibility is reduced.

Specifically, the bidder can bid for a package Y with eligibility greater than the bidder's eligibility in the round if the bidder can make such bid under its applicable relative caps. The bidder can increase its bids for its constraining packages to the minimum level that would be required for the bidder to make a clock bid for Y, if none of these bids exceed the round price of the corresponding package.

For instance, suppose that a bidder's bid for Y is subject to a relative cap with respect to the bidder's bid for package X, which is not yet subject to a relative cap. Then the bidder will be able to make a clock bid for Y if the round price for Y is below the applicable relative cap given the highest bid that the bidder has already submitted for X, or if the bidder can make a bid for X which is no greater than the round price of X and which results in the relative cap on Y being exactly equal to the round price of Y. We call such bids for constraining packages *chain bids*.

Note that a package larger than permitted by a bidder's current eligibility may be constrained by a chain of relative caps, and we require that when placing a bid for a package with eligibility greater than the bidder's eligibility in the round, all these caps must be respected.

Allowing relaxed bids in combination with the associated chained bids complicates the activity rules in the clock phase, but greatly improves the price and package discovery process offered by the clock rounds compared with deferring such bids to the supplementary round. In our experience, it is possible to implement this relaxation of the strict eligibility points-based activity rule in an electronic auction system in a way that makes it easy for bidders to keep track of their constraints.

Supplementary bids will be subject to the same structure of relative caps, and will in addition be capped relative to the final clock package by final round prices, i.e. the difference between the bid amount on any package on which a bid is submitted in the supplementary round and the highest bid on the final clock package cannot be greater than the package difference evaluated at final clock prices.

CMRA activity rules

The CMRA will use the same eligibility and relative cap rules for headline bids and additional bids. Specifically, it requires that all bids must satisfy any applicable relative caps. In addition, the amount of any additional bid submitted in a round must not be greater than the value of the respective package at clock prices (and must exceed the value of the package at reserve). All bids submitted in the auction will be taken into account.

Bidding process, closing condition and evaluation of bids

In both formats, bidding takes place over several rounds in which the clock prices of lots for which demand exceeds supply increases.

The starting prices for spectrum lots are set in the usual way and subject to the constraints arising from the TKK.

The starting prices for coverage lots reflect the maximum discount that the auctioneer would be prepared to offer for the provision of coverage as specified in these lots. This could be set with reference to the value attributed to the provision of coverage, or a reasonably conservative estimate of the cost of providing such coverage. The starting price of the MVNO obligation would similarly reflect the maximum discount that would be available for an operator providing wholesale services to MVNOs.

Given that total bid amounts must not be negative, bidding on coverage lots should be expected to start only once the price of spectrum lots has reached a level at which bidders would be able to avail themselves of the benefit of the discount, i.e. when the price of spectrum has risen to a level that exceeds the cost to the bidder of meeting the obligation. Note that if at this point the effective discount that the bidder can obtain is limited by the rule preventing net payments, the bidder will be able to increase its bids for spectrum at zero cost as the higher spectrum cost would be reflected in a higher effective discount, up to the point at which the spectrum cost equals the current price of the obligation lots. This could result in an inefficient outcome as the bidder with the lowest cost of meeting the obligation can compete more strongly for spectrum. This inefficiency is the result of the no-net-payment rule.

CCA bidding process

Establishing excess demand and the need for price increases is straightforward in the CCA: we simply add up the quantities demanded in all clock bids for each category. Where bidders demand more spectrum lots than are available, or where multiple bidders are prepared to meet obligations at prevailing prices, the price of the corresponding lot category increases.

The clock rounds end after a round in which there is no excess demand in any of the categories.

After the end of the clock rounds, there will be single bidding round (the supplementary round) in which bidders can place bids on packages on which they have not bid during the clock rounds and increase their clock bids in line with the applicable caps.

Following the supplementary round, the auctioneer establishes winning bids by finding the value-maximising combination of bids that can be accommodated with the given supply, taking at most one bid from each bidder, subject to further constraints on outcomes (such as the joint spectrum cap) and valuing any unassigned lots (including spectrum and obligation lots) at the reserve price (with the reserve price for obligation lots reflecting the value placed on assigning these lots, which can be arbitrarily high if there is a hard constraint that these lots must be assigned, or a reasonably conservative estimate of costs, noting that the effective discount is in any case capped by spectrum prices as a result of the no-net-payment rule). If multiple combinations with the same highest bid value exist, we propose to use a hierarchy of tie-breaking rules, selecting:

- first, the combinations of bids with the largest number of obligation lots (noting that preference could be given to coverage lots or the MVNO obligation);
- second, the combinations of bids with the smallest number of unassigned spectrum lots;
- third, the combinations with the largest number of winners of spectrum lots;
- fourth, any remaining ties will be broken at random;

Base prices will then be determined using the following criteria

- the base price for each winning bid must be at least the sum of the reserve prices of all the lots included in the corresponding package, floored at zero or a small positive amount (as there can be no net payments to bidders), and cannot exceed the bid amount;
- the sum of base prices for each subset of winners (including subsets containing a single winner and the subset containing all winners) must be at least the joint opportunity cost for that subset of winners; and
- the sum of base prices must be minimised across all possible sets of prices that meet the conditions above.

If there are multiple combinations of prices that satisfy the conditions above, then the base prices would be the unique combination of prices that minimises the sum of squares of the differences between each bidder's base price and its standalone opportunity cost.

Like the CCA, the CMRA proceeds in rounds. In each round, a bidder will have to submit a headline bid at clock prices (which can be a zero bid) and may submit additional bids for other packages. Bid submission is subject to the activity rules set out above.

At the end of each round the auctioneer establishes the highest value combination of bids that can be accommodated with the given supply valuing unassigned blocks at the reserve price, subject to taking **at most one bid from each bidder**, not allocating more lots than available, and any further constraints that may apply, such as joint spectrum caps.

- If the highest value can be achieved with a combination of bids that includes **exactly one bid from each bidder** (which may be a zero bid if the bidder has stopped bidding at round prices) then the auction ends, and one of these combinations (with ties broken according to the same hierarchy of criteria described above for the CCA) becomes the winning outcome. Winning bidders then pay the amount of their successful bid.
- Otherwise a further round is needed with prices having to increase for at least some lot categories.

The need for incrementing prices is determined by assessing which bidders might be excluded in at least some of the value-maximising outcomes (so-called 'omitted bidders') and establishing in which lot categories the demand these bidders have expressed in their headline bids conflicts with that of other bidders. This is done by checking whether such bidders would continue to be omitted if their headline bids were replaced with hypothetical headline bids in which their demand for some lot categories is retained, but demand for other lot categories is set to zero – if the bidder is still omitted when bidding only for that subgroup of categories, then the price for these categories must increase.

The assessment is run separately for each bidder who must be confronted with a price increase. We propose first to check for potential conflicts in the bidder's demand, when considering each lot category individually. If no conflicts are identified when considering categories individually, we would then check collectively for all spectrum lots. If this still fails to identify any conflicts, we would check collectively for all obligation lots. Finally, if no conflicts are identified when looking at any subgroups, then the price for all the lots in the package from that bidder would need to increase.

Thus, the first step to determine which lots require a price increment is to identify which bidders could be left out in at least one value-maximising feasible bid combination (i.e. to identify the 'omitted' bidders) – as if the auction were to end without any further price increments, these bidders might be left out depending on the tie selected. The price of each of the packages on which these bidders have placed bids in the most recent round needs to increase for the auction to progress. However, this does not mean the price of all lots

on which the bidders placed bids need to increase – bidders may be omitted because their demand has clashed with the demand of other bidders in some lot categories only.

To identify the lot categories in which there is a demand conflict, we isolate for each of the omitted bidders in turn their demand for individual lot categories included in their headline bid and then assess whether the bidder's demand for that lot category is in conflict with that of other bidders. Specifically, we apply the following process to each of the omitted bidders:

- Taking the headline bid from the bidder in the most recent round, we look at the lot categories for which the number of lots in the package is greater than zero.
- Taking each of these categories in turn, we construct a hypothetical bid for a package that includes only the lots in the category under consideration and nothing else (with the price adjusted accordingly).
- We then re-evaluate the bids, replacing the headline bid from the omitted bidder with this hypothetical bid. If the bidder would still be an omitted bidder with this hypothetical bid, then we increase the price of this lot category, as the demand in this category clashes with the demand from other bidders. Otherwise, we do not require the price of the lots in that category to increase.
- If none of these lot categories required a price increment when considered individually, we repeat the process for all the spectrum lots in the bidder's headline bid considered jointly.
- If looking at the spectrum lots does not imply the need for a price increase for any of these lots, we look at all the obligation lots included in the bidder's headline bid jointly.
- If having done this we still do not identify lots requiring a price increase, we increase the price of all the lot categories included in the headline bid.

The example below illustrates this process

Box 4: Establishing the need for price increases

Assume that we have two spectrum lot categories (say A, B) with six, and twelve lots respectively, and three coverage obligation lots C1, C2 and C3). Round prices are as follows:

Category	A	B	C1	C2	C3
Round price	100	50	-40	-30	-40

Suppose that we have three bidders (Bidder 1, Bidder2 and Bidder 3) and the following bids at the end of the round (where HX identifies a headline bid, from bidder X, and AXY additional bid Y from bidder X, with headline bids shown in bold):

Bid ID	A	B	C1	C2	C3	Amount
H1	**4**	**4**		**1**		**570**
A11	4	4			1	550

A12	2	6	1	430
H2	**2**	**4**	**1**	**370**
A21		6	1	200
A22	4	2	1	460
H3	**2**	**4**	**1**	**370**

There are two combinations of bids producing the same maximum value of 920, namely [A11, H3] and [A11, H2] – one excluding Bidder 2, the other excluding Bidder 3. Both bidders are identified as omitted bidders, as there are some value-maximising bid combinations in which they are not included.

Starting with Bidder 3:

- If we replace Bidder 3's headline bid with one that only contained the two A lots, this bid could be accommodated alongside A21 and A11, producing a higher value of 950. Bidder 3 would no longer be omitted, suggesting that the price of A lots does not need to increase.
- A hypothetical bid from Bidder 3 in which only the four B lots were retained could be accepted alongside A11 and H2, giving a total value of 1120. Bidder 3 would no longer be omitted, and therefore the price of B lots does not need to increase.
- Using a hypothetical headline bid containing only the C1 lot (floored at zero) would leave [A11, H2] as the value-maximising combination. Bidder 3 would still be omitted, and thus the price of the C2 lot needs to increase.

Having looked at Bidder 3, we have identified only the C2 lot as needing a price increase.

Turning to Bidder 2 now,

- If we were to replace Bidder 2's headline bid with a hypothetical headline bid that contains only the two A lots, this would leave [A11, H3] as the unique value-maximising bid combination, still excluding Bidder 2. As the bidder would continue to be omitted even if it placed a bid on A lots only, there is conflicting demand and the price of these lots needs to go up.
- Replacing bidder 2's headline bid with a hypothetical headline bid containing only the four B lots would allow us to accept this bid alongside A11 and H3 (like the consideration for Bidder 3 above). Bidder 2 is no longer omitted, which means that the price of B lots does not need to increase.
- Replacing Bidder 2's headline bid with a hypothetical bid containing only C2 (floored at zero) would again leave [A11, H3] as the value-maximising combination. Bidder 2 is still omitted, and therefore the price of C2 needs to increase.

Overall, therefore, we have identified A lots and the C2 lot to be requiring a price increase.

The closing of the CMRA condition implies that bidders do not face any risk of leaving empty-handed without explicitly having made a zero bid. It also means that the auction can close even if the demand from headline bids at round prices exceeds the available supply (if some bidders have placed additional bids for smaller packages that would be part of the value maximising bid combination), or can continue even if headline bids can be accommodated with the given supply (as some bidders may have submitted additional bids for larger packages that could displace some of the headline bids in the value-maximising bid combination).

Information policy

As discussed above, the information policy must achieve the right balance between providing information that helps bidders to adjust their demand towards a market clearing outcome and limiting the opportunity for strategic bidding and tacit collusion.

Information policy for the CCA

As in Model 1, we would recommend that in the CCA aggregate demand for each lot category is disclosed, but not the individual bids from each bidder. However, if there are concerns about collusion it may be preferable to only disclose aggregate demand (in MHz) across all categories, or not disclose any information about aggregate demand and limit the information provided to bidders purely to price signals, which indicate where demand exceeds supply (potentially augmented by information about whether market clearing or excess supply in a particular category is responsible for prices not increasing). Information about unclaimed lots at the current round price would seem to be particularly relevant for the last clock round in order to allow bidders to establish the level to which they would have to increase their bid for the final clock package in order to rule out the possibility of being displaced completely.

It may also be possible to disclose aggregate demand only for the spectrum lots, but not the obligation lots.

Information policy for the CMRA

One complication in the case of the CMRA is that there is no clear notion of aggregate demand, given that we determine whether the auction can close based on identifying the value-maximising combination of bids including headline and additional bids.

It would be possible to disclose to bidders the level of aggregate demand from headline bids. However, as noted above, the auction may end even if there is excess demand from headline bids, and it may continue even if headline bids could easily be accommodated. This information will therefore need to be interpreted very carefully, or otherwise it could potentially be misleading.

Perhaps more helpful for bidders would be information about whether they are omitted (i.e. excluded from at least some value-maximising outcomes), and provide information about which of their bids, if any, might be accommodated in some value-maximising outcomes.

Stage 2

For the frequency assignment stage, we propose to use the well-established process of running single-round sealed bid processes for each band in which:

- the auctioneer identifies the potential band plans that give every winner a contiguous assignment of frequencies and retain any potentially unsold lots as a contiguous frequency block, assigning the lowest two blocks in the 1500 MHz band to

whoever is assigned the lowest of the blocks included in the auction;

- presents each bidder with all the different assignments that the bidder might obtain across all these band plans and asks bidders to express their preference for the different options through assignment bids;
- identifies the band plan with the highest value; and
- establishes the price to be paid by each bidder using a minimum revenue core pricing approach.

This approach has been used in several previous awards and bidders should be familiar with its operation.

Should there be any objection to using a second price rule, we would need to revert to a pay-as-bid rule.

4.5 Advantages and disadvantages of the model

The main advantage of this model is that it eliminates the risk of spectrum remaining unsold because of being tied to overly burdensome coverage obligations. It might therefore be seen to support the definition of more onerous obligations than could be imposed under Model 1. However, there is no guarantee that such obligations would be assigned, as the incentives for taking on coverage commitments are limited by the spectrum prices. Where competition for spectrum is weak, there is a high risk that coverage obligations (and the MVNO obligation) could remain unassigned.

A further advantage is that this model better captures any interdependence between the willingness to take on obligations conditional upon winning more spectrum and the potential reduction in the cost of buying more spectrum from taking on obligations. To the extent that there is a high willingness to pay for spectrum through taking on obligations, the integrated model would allow bidders to express this more easily than a model in which the assignment of spectrum and the procurement of coverage are separated and bidders need to rely on expectations about the discounts they might be able to win in a later stage when bidding for spectrum.

A last advantage is that the use of package bids fully addresses all complementarities across bands rather than capturing only the dependency of the value of 1500 MHz spectrum on the amount of 700 MHz spectrum obtained, as would be the case in the staged approach of Model 1.

On the downside, both formats are more complex than the of Model 1, and neither model sits particularly well with the requirements for an internationally well established, simple and transparent format giving maximum certainty over outcomes and prices to bidders:

- Whilst the CCA is by now well established, there may be concerns because of the opposition of operators to a second-price format that (a) leaves them exposed to uncertainty over their final liability (which makes managing budget constraints difficult) and (b) creates scope for strategic over-bidding to drive competitors' prices. The latter is an issue in this instance owing to the asymmetric constraints on operators that flow from the application of spectrum caps. For these reasons, choosing this format may be problematic.
- The CMRA avoids these concerns as it relies on a pay-as-bid rule, but the format has equally drawn objections because of the perceived complexity of having to manage a portfolio of bids round-by-round and the fact that it has not been widely used or rigorously tested.

Because of its pricing rule the CMRA is also more susceptible to demand reductions aimed at keeping down prices.

Such demand reduction is not necessarily undesirable. It may result in in lower prices, but concerns about potential deviations from the efficient outcome (in the narrow technical sense of allocating spectrum to those bidders with the highest willingness to pay) are mitigated by the fact that in these cases the results will be a more even assignment of bandwidth than in the efficient outcome. The incentive to reduce demand to keep prices down therefore provides a built-in corrective against very asymmetric spectrum holdings.

5 Conclusion

One of the main differences between this award and previous spectrum auctions is the goal of using the process to assign ambitious coverage obligations, requiring roll-out of networks into areas that are unlikely to be commercially viable. To avoid wasteful duplication of the costs associated with such obligations, they do not need to be met by all operators; and in order to avoid growing asymmetries between their networks, they should ideally be shared amongst operators.

Tying these special obligations to specific spectrum blocks has the advantage that the full value of the spectrum can be leveraged as an incentive for operators to take on the task of providing coverage where it is not justified by commercial returns. This can be done using relatively simple and straightforward auction formats. However, there is a risk that spectrum may remain unsold if the obligations are too onerous. This effectively limits the scope of the obligations tied to spectrum blocks in Stage 1 of Model 1: even the least well-placed operator must be able to meet these obligations as otherwise spectrum – and the associated obligations – may remain inefficiently unassigned.

Assigning the obligations separately from, but alongside spectrum eliminates this risk. However, this does not imply that more ambitious targets can be defined. On the contrary, as only the portion of spectrum value that would otherwise be extracted in the form of auction revenues can be offered as an incentive, all things being equal, the obligations that will be accepted would generally have to be less ambitious.

To the extent that there is some interdependence between the ability of an operator to meet substantive coverage obligations (or the cost of doing so) and the amount of spectrum acquired, offering operators the option to take on coverage obligations (or other obligations) for a discount on their spectrum fees should ideally be done using a combinatorial auction format. A staged, non-combinatorial approach as suggested in Model 1 may work if most of the value interdependencies have been captured in Stage 1, potentially leaving a relatively limited range of additional obligations that could be assigned in the fourth stage.

On this basis, the choice of model is largely determined by the way in which coverage obligations, and the value of spectrum can be defined and costed.

- If there is a high degree of certainty over both the value of spectrum and the cost of meeting the desired coverage targets for the least well-placed operator, and the least well-placed operators' costs are not substantially higher than those of the

other prospective bidders, it should be possible to define ambitious obligations whose costs are covered by the value of spectrum. In this case, a substantial proportion of spectrum value can be leveraged under Model 1, with most of the targets being tied to spectrum blocks in Stage 1. The role of Stage 4 would be relatively limited, which would also suggest limited concerns about value interdependence. To give any meaning to Stage 4, it would still be necessary to define coverage obligations in such a way that competition in the fourth stage is possible.

- If the value of spectrum or the cost of meeting the obligations are very uncertain, the scope for leveraging the value of spectrum in Model 1 is limited. This means that if this model were chosen most of the burden of assigning such obligations would fall on Stage 4. This will then work only if coverage obligations can be defined in such a way that the interdependence between the cost of meeting them and the amount of spectrum acquired is limited. Otherwise, the combinatorial approach of Model 2 would be needed.
- Moreover, if the bulk of the work in terms of assigning coverage obligations falls on Stage 4, generating revenues from spectrum fees becomes important as otherwise the incentives that could be provided to operators are limited.

In summary, this means that Model 1, which involves a much simpler auction design, should be the preferred solution if

- it were possible to tie substantial coverage obligations to spectrum blocks without the risk of creating unsold spectrum; or if
- coverage obligations can be defined in a way that minimises the interdependence between the cost of delivering these obligations and the amount of spectrum acquired and supports competition.

If neither of these conditions hold, it would be appropriate to deploy Model 2.