Coverage obligations and spectrum awards

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A report for ComReg

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Executive Summary

Types of obligation

A distinction can be made between:

- **precautionary coverage obligations**, where the obligations do not exceed the levels of coverage that might be expected anyway from well-functioning competition between network operators;
- **interventionist coverage obligations**, which can be expected to constrain the commercial choices of network operators and force coverage in excess of competitively determined levels.

Interventions are costly

Interventionist coverage obligations necessarily come with a cost to operators, as any benefits in terms of additional revenue from greater coverage are exceeded by the costs of rolling out that additional coverage, otherwise the operator would have chosen to extend coverage anyway.

Precautionary coverage obligations can reduce risks of competitive failures

There is a long tradition in Europe of setting precautionary coverage obligations on most spectrum licensees. Although these obligations are usually exceeded as coverage is extended, driven by competition between network operators, such obligations may still have useful risk management functions. These include:

- guarding against tacit collusion between network operators to defer investment and not extend coverage to save cost;
- discouraging cherry-picking entry focused only on urban areas that might undermine provision to rural areas; and
- undermining strategies for geographical market segmentation aimed at softening retail competition.

Precautionary coverage obligations are typically set symmetrically across all licensees in order to achieve these risk management functions.

Interventions might be asymmetric due to scale economies

It may not be efficient for strongly interventionist coverage obligations to apply to all network operators. If the intervention areas where coverage is required have low traffic density, there will be strong scale economies and it may be much less costly if networks in these areas are shared. Therefore, interventionist coverage obligations are often asymmetric, applying to only a subset of network operators, or to just one.

There is a trade-off between promoting network-level competition and minimising total cost when using asymmetric interventions. It may be necessary to use access measures to ensure that all operations can offer services in coverage intervention areas to avoid creating competitive differentiation in the retail market and so distorting competition.

Coverage obligations do not solve indoor coverage problems

Surveys suggest that consumers primary concern with the quality of mobile services is indoor coverage. However, variations in building materials and moves to better insulation mean that it is not feasible to address indoor coverage problems through greater obligations on outdoor coverage. Rather, the solution to indoor coverage is likely to rely on carry data over WiFi, voice calls over native WiFi calling (both supported by fixed infrastructure) and mobile repeaters.

Interventions need to be justified by market failures…

The rationale for coverage interventions should derive from identified market failures that would compromise the efficient use of spectrum or other clear policy objectives giving rise to positive social benefits from coverage. Network operators have competitive incentives to build out coverage. We need only be concerned if there are benefits from coverage extension that operators do not take into account when making their decisions – so-called *external* benefits.

… but these are likely to be modest

There are various reasons why external effects could arise. However, none of the arguments suggest that external effects are likely to be very substantial. In particular:

- there are some arguments to suggest that oligopolistic competition between network operators might lead to deficient incentives to provide coverage, primarily as a result of the use of national pricing based on bundles of services and limits on the ability of operators to monetise coverage improvements;
- there may be coordination problems related to the development of new services (for example, industrial IoT and smart transport systems) that depend on coverage; and
- there might be public safety benefits.

Furthermore, consumer surveys suggest a very limited willingness to pay for coverage enhancement, which is unsurprising given coverage problems fall disproportionately on a subset of consumers. Growth of NB-IoT (narrowband Internet of Things) is not dependent on introduction of 5G and is already supported on 4G networks.

Therefore, optimal coverage interventions need to be targeted and justified by evidence of external benefits from extending coverage beyond competitively determined levels. In particular, ubiquitous coverage is certainly not optimal, as the incremental cost of extending coverage to very remote areas will vastly exceed the incremental benefit.

Costs and benefits to the State

Interventionist coverage obligations reduce the value of spectrum and with it auction revenues. ComReg has a statutory duty to maximise the efficiency of spectrum allocation and use, rather than maximizing auction revenue. Nevertheless, when designing an interventionist coverage obligation, the foregone auction revenue reflects the anticipated cost to network operators of meeting the obligation to extend coverage. This cost should not exceed the external benefit of that coverage extension, otherwise it is not efficient to set the coverage obligation at such a high level.

Coverage interventions linked to spectrum can create auction distortions

Highly costly coverage interventions attached to spectrum in coverage lots may distort spectrum awards in various ways. In circumstances where only the most established operators have a positive value for these lots, this may reduce competition for them and entail consequences such as:

- reduced competition from a limited field of potential suppliers resulting in spectrum being sold at a price which no longer ensures its optimal use or represents poor value in the procurement of coverage;
- a coverage lot needing to be bundled with a disproportionately large share of the available spectrum to ensure it has positive value for at least some bidders;
- in combinatorial auction formats, the winner of a coverage lot leveraging its strong position to win additional spectrum it might not otherwise have won, potentially distorting competition;
- uncertainty about the value of coverage lots making it difficult to set reserve prices, depriving the auction designer of a useful instrument against gaming and collusion within the spectrum award.

More onerous coverage obligations are likely to increase the risks of both creating coverage lots that have negative value and/or asymmetries between bidders, advantaging stronger incumbents more likely to be able to dispatch the obligations at least cost.

Inflexibility bundling of spectrum with coverage may cause problems

Because coverage lots bundle a certain amount of spectrum with the coverage obligation, if the coverage lot is unsold, then the obligation would be unassigned and some spectrum would also go unsold. This approach, though it has been commonly used, forgoes the option of awarding spectrum without the coverage obligation if the obligation turned out to be unexpectedly costly.

The coverage lot approach risks achieving poor public value. The State loses the option *not* to award the coverage obligation if its cost – measured by foregone auction revenue – exceeds its external benefits.

In contrast, having the option not to award a coverage obligation is a useful tool for ensuring that value for money is achieved, especially if there is a danger that competition to serve the coverage obligation might be weak. However, to maintain the option to award spectrum without a coverage obligation, the simple coverage lot approach cannot be used. Rather, assigning spectrum and procuring coverage must be separated to some degree.

Uncoupling coverage obligations and spectrum

With more onerous coverage interventions, a better approach may be to uncouple coverage obligations from the award of new spectrum. In some cases, bidders' valuations of coverage obligations and new spectrum may only interact weakly, as awarding an operator a greater amount of new spectrum might not significantly reduce its cost of dispatching the coverage obligation. This situation increasingly applies in mature markets with existing sub-1 GHz spectrum already in the hands of network operators that can be used to meet coverage obligations. Such weak coupling may allow the procurement of coverage to be achieved in a separate process from the allocation of spectrum.

Separation of the procurement of coverage from the allocation of spectrum also has the practical advantage that spectrum can be first assigned with a precautionary coverage obligation. Then, if competition fails to deliver adequate coverage, the option always remains open to procure a coverage enhancement.

In cases where the valuations of spectrum and coverage are strongly interrelated, a unified award process is necessary to ensure efficient assignments. However, especially if a combinatorial auction of some form is used, then it is possible to offer coverage as a separate lot at a negative price within a spectrum auction. This can be combined with spectrum when making bids, but spectrum can also be assigned without the coverage obligation, or with a lesser coverage obligation. This gives the State the option of not awarding or diluting the coverage obligation if it is too costly. This approach can also be extended to allow for market testing of coverage obligations at different levels and of different forms.

1 Introduction

In this report, we consider different approaches to the setting of coverage obligations and their implications for spectrum award processes and for competition in mobile services. We focus on questions relevant to possible coverage obligations for ComReg's forthcoming award of spectrum in the 700 MHz band.

In section 2, we outline how coverage obligations have typically been set. We distinguish two cases depending on whether or not the obligation requires coverage to be extended beyond what competition between network operators might anyway deliver. Even where coverage obligations have not been instrumental in forcing operators to extend coverage, they may still have a useful risk management function in protecting against failures of competition.

We discuss the difference between population and geographic coverage targets and how much flexibility operators have in meeting their obligations. Recently, there has been greater use of 'not-spot' obligations that require coverage to be provided in specific places.[1] We identify the other aspects of coverage obligations – such as timing and service definitions – that are important for implementation and may significantly affect the costs of coverage obligations to network operators in practice.

Section 3 explores the situations where implementing a coverage obligation might be beneficial. The main rationales are presence of market failures, external social benefits of connectivity, coordination problems (for example affecting new services) and countering certain forms of tacit collusion.

Section 4 examines the implications of coverage obligations for award processes where these obligations are linked to spectrum licences. In particular, we look at the effects on competition in mobile services, auction revenue and possible competitive distortions in spectrum auctions. As coverage obligations become more onerous, costs to operators becomes greater and it becomes increasingly difficult to ensure that coverage obligations are assigned without risking various distortions to spectrum allocation.

In section 5 we will look at the broader options for procuring coverage. We will discuss the use of coverage lots and the implications of procuring coverage obligations separately from allocating spectrum licences. Section 6 concludes.

[1] By a "not-spot" we mean a location where network coverage could feasibly be provided, but there is no commercial incentive to do so.

2 Types of coverage obligations

2.1 Overview

We can distinguish two broad types of coverage obligation according to whether coverage is forced beyond what competition between network operators might be expected to deliver anyway:

- Where a coverage obligation is unlikely to go beyond the deployment plan resulting from effective network-level competition[2], we call this a **precautionary coverage obligation**. Such obligations may nevertheless still have effects on the behaviour of network operators and can have a risk management function, as we shall see below.
- Conversely, a coverage obligation may be intended to force one or more network operators to deploy networks in areas they would never have covered under a typical commercial deployment plan, or to provide coverage sooner than the network operator would otherwise have chosen. We refer to these as **interventionist coverage obligations**.

There are also many different aspects to the design and implementation of coverage obligations. In particular:

- The method of **measuring coverage** can take different forms. Often coverage obligations have been set with regard to population coverage, measured in terms of households that have access to a particular service (such as mobile broadband at a minimum speed). As shown in the Future Mobile Connectivity ("FMC") Report, targeting population coverage leads to incidental coverage of some geography and roads.[3] Although less common, some coverage obligations have been defined with regard to geographical coverage, for example expressed as a percentage of landmass meeting some service availability standard.

[2] Note that the presence of MVNOs are unlikely to significantly change the incentives for competition on coverage levels between MNOs, in that MVNOs can only offer coverage constrained by their respective host physical networks. Therefore, we focus on competition amongst MNOs. Nevertheless, it is possible for an MVNO to offer an aggregating service that roams across all national networks. However, these services are nascent and subject to some limitations (such as no in-call handover across networks). For example, see https://anywheresim.com which is a multi-network voice and data service offered in the UK. At the time of writing, we are not aware of a comparable service being available in Ireland.

[3] As per the 'FMC Report' (ComReg Document 18/103c) if an MNO rolls out a network to achieve 90% population coverage, it will (simply by virtue of where people live) incidentally achieve geographic coverage of around 60%.

- Typically, coverage obligations would be imposed as an **outdoor** requirement, either in, terms of availability of a service, or possibly a signal level requirement. However, achieving **indoor coverage** by setting an outdoor signal strength standard is not likely to be effective or efficient, as we discuss in Section 2.2 below. The use of WiFi or mobile repeaters provide alternative routes to indoor coverage distinct from any interventions to protect or extend outdoor coverage.
- Coverage obligations can vary greatly in the degree of **flexibility** they offer for meeting them. For example, an operator subject to a population coverage obligation has discretion where it builds its network, as long as it provides a certain percentage of the population with the required connectivity. Conversely, an operator subject to a coverage obligation that specifies particular households or areas that must be covered (a 'not-spot' obligation) will have much less discretion.
- Often coverage obligations – especially what we term 'precautionary' coverage obligations are applied **symmetrically** to all network operations, typically forming part of their spectrum licence conditions; for key mobile spectrum bands, often all network operators will be licensees in that band and so need to meet such common obligations. In other cases – especially for interventionist coverage obligations that may be inefficient to impose on all operators due to their high cost – an **asymmetric** obligation may fall on just a subset of licensees (potentially just a single network operator). For example, a coverage obligation may be attached to some, but not all, lots within a spectrum auction. Asymmetric obligations may be useful to benefit from scale economies with respect to traffic in an intervention area where traffic density is low; however, some form of network sharing might then be needed to allow other operators to access that infrastructure if this would otherwise create significant competitive differentiation amongst operators.
- The **timing** of obligations is also very important. Commercial roll-out plans are progressive, and different resources are needed for initial deployment of infrastructure compared with maintaining it. For example, skilled engineers are needed to plan and build new deployments, and antenna sites need to be procured. An interventionist coverage obligation might require roll-out at a faster rate than an operator might otherwise choose. The deadlines imposed for meeting coverage obligations can be at least as important as the long-run targets, as they can greatly affect the cost of meeting the obligation. There may also be an incidental impact on the resources available for maintaining/improving the rest of the network; at some point it may be

counterproductive or even infeasible to accelerate roll-out into intervention areas yet further.

- Establishing whether or not the coverage target has been achieved is dependent on the **service definition**. For example, there might be a quality standard for a specific service (e.g. the probability of making a successful voice call) or a minimum signal strength level. For data services, there may be a requirement to achieve a certain minimum data rate. As we discuss in Section 2.2 below, it makes a great difference whether the requirement applies outdoors or indoors. In some cases, the definition of these requirements may relate to a specific technology, but in others be technology-neutral.

Therefore, coverage obligations have a large number of parameters that can be varied, and the list above is certainly not exhaustive.

2.2 Indoor coverage

ComReg has recently published research on the impact of building materials on indoor mobile coverage.[4] This finds that a large proportion of mobile usage occurs indoors (Cisco estimates 80%[5]). Therefore, negative user experiences are likely to relate primarily to indoor coverage. It may be particularly frustrating for consumers if they cannot use their phone at locations where they spend significant time, such as at home or in the workplace. ComReg's 2017 Mobile Consumer Experience survey found that poor indoor call quality at home was the most frequently cited service quality issue.[6]

2.2.1 Building materials and signal attenuation

Indoor and outdoor coverage need to be treated as distinct issues. Poor indoor coverage may result from attenuation of microwave signals by building materials even in areas where outdoor coverage is adequate. This problem will become ever more prevalent as new buildings are built to higher thermal insulation standards and existing buildings upgraded. Foil-backed insulation board commonly used for thermal insulation is also highly effective in blocking radio

[4] "The Effect of Building Materials on Indoor Mobile Performance", ComReg 18/73.

[5] http://www.cisco.com/c/dam/en/us/solutions/collateral/service-provider/small-cell-solutions/platform- for-service-innovation.pdf

[6] Ibid, §2.5.

signals at microwave frequencies used for cellular communications.[7] Whilst signals may be able to penetrate building through apertures, thermally efficient glazing also uses metallic layers on glass to reflect infrared that also reduces its microwave transparency.

Looking forward, we can only expect these challenges to providing indoor coverage to become more acute. Insulation requirements for new buildings have already been tightened recently[8] and this trend can be expected to continue to promote greater energy efficiency and decarbonisation. Materials – especially metal films - that are effective in reflecting infrared radiation to contain heat within a building necessarily also attenuate microwaves at the frequencies used by mobile networks.

Given these trends, it is not feasible to expect to address indoor coverage problems by setting tougher requirements on outdoor signal levels or extending the geographical area where outdoor services must be available; this is unlikely to be a successful or sustainable solution. It is also entirely impractical to seek to set an indoor coverage obligation by reference to actually experienced performance of services within buildings. Indoor coverage problems may be specific to particular buildings and result in patchy service availability inside, with adequate indoor coverage in some buildings, but inadequate coverage in other nearby buildings, depending on their construction.

2.2.2 Solutions for indoor coverage

There are a range of possible solutions to indoor coverage problems that involve either using connectivity already available within buildings though fixed broadband connections, or actively bringing cellular signals within buildings using repeaters. For example:

- Fixed broadband connectivity allows mobile users to offload data requirements to Wi-Fi networks;
- Native WiFi calling (voice over WiFi), where an appropriately enabled mobile handset drops back to use a WiFi connection to route a call without any user intervention (in contrast to over-the-top services such as Skype or WhatApp, where a separate application must be installed and running to initiate or receive a voice call);
- Repeaters, that pick up base station signals on an outside antenna and route them through to internal antennas within

[7] Ibid, §2.4.

[8] Ibid, §2.3.

the building (and *vice versa* for signals from the handset). ComReg has recently permitted the use of multi-operator repeaters on a licence-exempt basis (subject to certain technical restrictions).[9]

In the long-run, the use of native WiFi calling is likely to be the predominant means of resolving indoor voice coverage problems. It typically does not require any additional equipment to be installed and can piggy-back on existing infrastructure. Most residential broadband customers will have WiFi-enabled routers anyway and WiFi is common in workplaces. If mobile phones are logged into these WiFi networks to provide data connectivity, then, providing the handset is capable of native WiFi calling and the network operator supports it, outbound and inbound voice calls will be seamlessly routed over WiFi when the mobile phone network is not available.

The full potential of fixed connectivity for improving indoor coverage has yet to be realised particularly in more rural areas where fixed broadband connections are absent or insufficient. In that context, the National Broadband Plan ("NBP") is an important Government initiative to deliver high speed broadband services to all businesses and households in Ireland. This is likely to provide effective solutions for data and voice connection issues indoors that do not require mobile networks.

Other market developments are also likely to improve voice connectivity. Only certain recent handsets are capable of using native WiFi calling, which limits current rates of use; this can be expected to improve over time as handsets are refreshed. At present, support for WiFi calling by network operators in Ireland is limited, but as it becomes increasingly important to support indoor coverage – and consumers become more aware of the usefulness of native WiFi calling – we would expect that no network operator could fail to offer the service, otherwise it would be competitively disadvantaged. Indeed, if, for some reason, all networks were not timely in offering native WiFi calling, despite the population of enabled handsets growing, this would *prima facie* suggest a possible competitive failure given that ComReg's surveys suggest that consumers care significantly about indoor coverage and there should be strong competitive incentives to provide it.

Therefore, there are good reasons to expect indoor coverage problems to improve through the normal forces of competition. Many residential and business customers should eventually be able to make use of native WiFi calling. Residual problems with indoor coverage are likely to be limited to particular scenarios such as:

[9] "Permitting the General Use of Mobile Phone Repeaters", ComReg 18/58.

- homes without fixed broadband connections in poor mobile coverage areas (which might be a particular concern if these are economically disadvantaged mobile-only households);
- buildings with many people passing through, where there might not be opportunity to log into WiFi networks.

To date, some network operators have offered femtocells to customers to provide indoor coverage using the customer's own internet connection for backhaul (e.g. Vodafone's SureSignal product, which provides a localised 3G signal). However, this does require the additional expense of the femtocell (typically paid for by the customer, who must also provide the supporting broadband connection). Also, the existing generation of femtocells providing a 3G signal may not interoperate smoothly with 4G mobile networks. Therefore, it is likely that in the long-run femtocells will be replaced by native WiFi calling, as the latter requires no additional equipment at the user premises, using functionality already built into the mobile handset. Indeed, ComReg notes that network operators already appear to be moving away from femtocells.[10]

Repeaters can provide another means to overcome the attenuation created by building insulation, using an external antenna. ComReg has recently decided that multiple-operator repeaters should be permitted. This would then allow a building owner a means of ensuring that indoor mobile coverage was available to all occupants, regardless of which network operator they subscribed to. Repeaters may be useful to deal with some scenarios in which native WiFi calling is inadequate (such as lack of fixed broadband or multiple transitory users).

2.2.3 Future developments

At present, not only are there a range of technologies currently available for addressing inside coverage issues, but also much of this is within the control of individual consumers. Therefore, there is relatively little reason at present to be concerned about significant market failures leading to insufficient provision of *indoor* coverage. To the extent that there are any policy concerns, these are most likely limited to specific issues such as economically disadvantaged groups without ready access to fixed broadband connections who might be mobile-only, in which case mobile repeaters may be a viable option.

The NBP should also improve access to fixed broadband in rural areas to support WiFi networks in homes and workplaces. It may also be important to ensure that consumers are well informed about the capabilities of native WiFi calling so that they can make informed choices about handsets and network operators. However, none of

[10] Ibid, §22.

this involves any particular need to set *indoor* coverage obligations as part of spectrum award processes.

Looking to the longer term, the situation for indoor coverage may become more complex and new issues are likely to emerge. The introduction of 5G mobile is likely to cause an increased focus on in-building mobile network infrastructure. As very high data rates are sought, higher frequency bands (so-called millimetre wave bands, such as 26 GHz) are likely to become important. However, these higher bands have short propagation distances and are very readily attenuated by walls. Therefore, it is reasonable to expect that millimetre wave cells will need to be installed within larger shared buildings and public spaces (e.g. office blocks, shopping centres and so on). This raises questions about how network operators might gain access to shared and public buildings and whether building owners might be able to exert some bargaining power against network operators. There are also practical questions about whether it would be feasible to collocate multiple sets of millimetre wave base stations due to space requirements or whether such infrastructure would need to be shared (perhaps provided by so-called 'neutral hosts').[11]

For these reasons, the ways in which indoor coverage will be provided are likely to evolve. To enjoy similar data rates within the home or workplace as might in the best case be enjoyed on mobile networks, consumers are likely to need to use fixed network connections backhauling WiFi networks. This is then a question primarily about the supporting fixed network infrastructure, especially in rural areas.

We are not going to consider these potential future issues, but it is worth noting that both 4G and especially 5G technologies allow for some convergence of fixed wireless access (FWA) and mobile services. The current distinction that can be made between indoor and outdoor coverage issues could become blurred, in the sense that extensions of outdoor coverage may in practice also provide potential for offering FWA services at high data rates (which might then backhaul an indoor WiFi network). However, there is then potential interaction between any policy initiatives then in place to extend high speed fixed networks into rural areas and measures to extend mobile coverage. To the extent that public subsidies are used to extend fixed networks, clearly this undermines any case for using mobile coverage extensions to address the very same problem.

[11] For further discussion on these possibilities, see the 2018 BEREC report "Implications of 5G Deployment on Future Business Models" by DotEcon and Axon Partners available at https://berec.europa.eu/eng/document_register/subject_matter/berec/download/0/8008-study-on-implications-of-5g-deployment-0_0.pdf

2.3 Precautionary coverage obligations

Despite recent use of interventionist obligations (such as requirements to cover 'not-spots' used in Denmark, discussed in Annex 1), historically most 2G, 3G and 4G licences awarded across EU Member States have applied precautionary coverage obligations. These have most commonly been set as population coverage requirements. They were expected to be (and usually subsequently were) surpassed by the typical deployment plans of competing mobile network operators.

Typically, such obligations are applied symmetrically to all licensees winning associated spectrum subject to coverage conditions (which in many cases would be all the incumbent mobile network operators). There is little risk of such symmetric obligations leading to inefficient duplication of networks in geographical areas with limited traffic, as such coverage levels would in any case be supplied under well-functioning competition.

For example, the 3.6 GHz licences awarded in Ireland in 2017 stipulated a minimum number[12] of rollout base stations that a licensee is required to work and use within three years in each region for which it was awarded a 3.6 GHz licence. The final Decision Document considered and discussed the possibility of an interventionist coverage obligation ("high rollout", described as Option 4 in the Decision),[13] but the coverage obligation as applied was precautionary in nature.

A further example are the coverage obligations set by ComReg for the 2012 MBSA process. Here ComReg set coverage explicitly to guard against cherry-picking strategies aimed at providing coverage only in the most profitable areas.[14]

Such obligations might at first sight appear unneeded, as the same, or a better, outcome for coverage would anyway be expected through competition between network operators. Nevertheless, they can play an important role in protecting against various risks of competition failing to deliver reasonable coverage levels. We describe some possible sources of such risks below. Some of these scenarios are not necessarily likely under normal circumstances; nevertheless, precautionary coverage obligations may provide reassurance in preventing such adverse outcomes, with little risk of the obligation itself creating unintended distortions.

[12] The minimum number of rollout base stations within a particular region differed depending on whether the operator had won more or less than 100 MHz of 3.6 GHz spectrum in the region.

[13] ComReg Document 16/57, Annex 5.

[14] ComReg document 12/25, §5.96.

2.3.1 Tacit collusion and network investment

Competition over coverage could, at least in theory, be undermined by tacit collusion amongst MNOs aimed at avoiding or delaying the cost of network investments needed to expand coverage.

We often think of tacit collusion as being an implicit understanding to maintain prices above competitive levels. Although in the short-run competitors may have incentives to undercut such prices to gain market share, they are discouraged from doing so by the fear of triggering future aggressive pricing responses from rivals (so-called "punishment strategies"). This simple idea suggests situations in which tacit collusion may be more prevalent: repeated interaction between a stable set of competitors unchallenged by new entry with high levels of transparency about the conduct of rivals.

Competition in mobile markets is multifaceted and involves more than just price; other competitive variables could equally be subject to tacit collusion. For instance, operators could have a tacit understanding to maintain the status quo and not to make significant network investments, such as might be needed to increase coverage. Such collusive outcomes might be fairly easy to maintain given the small number of network operators in many national markets and the comparative ease with which one network operator can monitor any significant coverage expansion by a rival operator. In effect, there could be a tacit understanding to delay coverage expansion to save additional network costs.

In some cases, the award of spectrum has been linked to significant network upgrades due to changes in the underlying technology (for example, as with the introduction of 3G or 4G). Once one network operator makes a service upgrade, there may be strong competitive pressure for others to follow suit. However, equally the large costs involved in making these transitions may – in certain cases - create incentives not to be a first-mover and only to respond if others move first. Requirements to roll-out services within a certain timeframe – even if the obligations to do so are fairly weak – may be sufficient to destabilise tacit understandings to delay rollout.

2.3.2 Cherry picking strategies

Precautionary coverage obligations can protect against the possibility of one network operator 'cherry-picking' by covering only the most profitable – most probably urban - areas. The cherry-picker would not be exposed to the costs of expanding into the less profitable rural areas, but rivals would nevertheless need to compete against the cherry-picker's lower price in the urban areas. This could undermine the viability of other network operators extending coverage to rural areas to the extent that this relies on crosssubsidisation from urban areas. Another related version of cherry-picking is that an operator only provides high speed service in urban areas and a basic service elsewhere. Therefore, without precautionary geographic coverage obligations, there could be a risk of the mode of competition flipping to one in which the emphasis was low-cost offers targeting urban customers.

Whether such cherry-picking is likely is highly dependent on the specific market context (e.g. the relative importance of urban areas and the viability of an urban-focussed service). Nevertheless, in some cases it might be useful for policy-makers to attach licence conditions which reassure network operators that they will not face the risk of cherry-picking entry; this may maintain incentives for those operators to invest in infrastructure in rural areas and maintain national pricing plans for services.

This clarity may also be helpful in the spectrum award process itself, as it is then clear that rivals are bidding on the basis of broadly similar roll-out plans, rather than some bidders aiming to cherry-pick. In open auctions, this may also help bidders in interpreting information being fed back to them about aggregate demand for spectrum in order to reduce their own uncertainties about spectrum valuation.

2.3.3 Market-sharing outcomes

A further, use of precautionary coverage obligations is to limit the extent to which multiple operators could split the market between them geographically (e.g. each provides services only in their own 'home' area) in order to soften competition. Again, coverage obligations could eliminate certain less competitive modes of competition amongst network operators.

Whether this situation is relevant or not depends on the specifics on a particular award. It may be relevant where licences cover a large geographical area, but operators might roll-out in different parts of that area (a scenario more likely for FWA or similar services, rather than typical mobile services). This is unlikely to be an issue for most EU states, including Ireland but may be relevant for some countries with large geographical extents and localised competitors.

2.3.4 Use it or lose it obligations

Finally, precautionary coverage obligations can also act as an implicit form of 'use it or lose it' obligation[15], as they prevent operators from

[15] Provided that the obligation needs to be satisfied using the specific spectrum attached to the license; otherwise the licensee could leave that spectrum unused and meet the coverage obligation using other spectrum holdings.

simply sitting on the spectrum unused. This can help to promote efficient spectrum use as the licensee is required to either use the spectrum or return it to the regulatory authority, which could then reassign the frequencies. However, this in itself is clearly not a good reason to apply a precautionary coverage obligation, as the objective could be more transparently achieved through separate licence conditions that explicitly set out the obligation.

In any case, in our view 'use it or lose it' obligations can be problematic, as there may be legitimate reasons for operators to hold spectrum unused, either to allow for future capacity expansion or to de-risk uncertain technological developments. In some cases, holding unused spectrum could even be pro-competitive to the extent that it provides better incentives for an operator to compete for additional customers or offer new services; the operator could then add network capacity rapidly and at lower marginal cost as spectrum would already be available to serve the new traffic.

To the extent that 'use it or lose it' obligations might be necessary because of ineffective competition, with spectrum being hoarded to prevent others from using it, it is likely that a more substantial intervention (e.g. via a more explicit licence condition) to address the underlying failure of competition might be required. This is not a situation that would typically apply in a well-functioning market.

2.4 Interventionist coverage obligations

Interventionist coverage obligations are aimed at *actively* extending coverage beyond the limits that competition alone might deliver. They are intended as a response to a market failure or external benefit from coverage that has resulted in competitively-determined coverage levels well below the social optimum. We will discuss some of the possible reasons that such market failures might occur in Section 3 below.

Some rural areas may be uneconomic for operators to serve, especially if costs are high due to difficult terrain and distance from supporting infrastructure (such as power and backhaul), with users thinly spread. However, lack of coverage in and of itself is not a valid reason for an intervention to provide coverage unless it is the case that there is some broader *external* benefit from providing coverage that the network operator has not taken into account. Therefore, the case for coverage interventions rests on some form of market failure or externality, rather than rural coverage being costly *per se*.

Interventionist coverage obligations necessarily come at a cost to operators, as their commercial behaviour is being constrained. Operators may earn additional revenues from being required to provide additional coverage, which may partially offset the additional costs; however, there will necessarily be an overall net cost, otherwise the operators would have chosen to extend coverage anyway.

For this reason, interventionist obligations typically require some form of incentive, explicitly or implicitly. Schemes to extend broadband availability, such as the National Broadband Plan (NBP) in Ireland, are good examples of explicit subsidies being used to procure additional infrastructure that it would not otherwise be commercially viable; this might involve a competitive tender process where bids are sought to provide some defined service (as with the NBP).

In some cases, direct subsidies have been used to extend mobile coverage in an analogous manner to the NPB in Ireland. For example, in the UK between 2011 and 2016 the Mobile Infrastructure Project funded the acquisition of base station sites and masts, with mobile operators then co-locating at these sites.[16] Therefore, it is helpful to think of coverage increments being *procured* by the State, whether or not the process of procurement is explicit.

Typically, coverage obligations for mobile services have been implemented through obligations on spectrum licences. The cost of the obligation is then implicit. The obligation reduces the value to operators, and hence the market price, of encumbered spectrum licences. In some cases, impact on spectrum value of the obligation may be readily observable, for example if there is a spectrum licence with a coverage obligation and a closely similar licence without the obligation sold in the same award process.

In more recent spectrum award process, such interventions have often been implemented through an obligation to cover particular locations, as in the 800 MHz and 1800 MHz spectrum auctions in Denmark (see Annex 1). Such obligations give operators less flexibility in their roll out, as explained in more detail in the next section.

In Section 3 below we will consider how the case for such interventions might arise from market failures and externalities causing competition between mobile network operators to under-supply coverage. Although it is common for such interventions to be achieved by means of attaching coverage obligations to spectrum, there are knock-on implications for spectrum award processes, which we will discuss in depth in Section 4.

[16] See the evaluation of Mobile Infrastructure Project by DCMS available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/651008/MIP_Impact_and_Benefits_Report.pdf

2.5 Implementation of coverage obligations

We now turn to the specifics of how coverage obligations are typically implemented. There are a large number of parameters for policymakers to choose.

2.5.1 Flexibility

Most precautionary obligations have provided a high degree of flexibility to operators to cover the areas they choose. Typically, they have been implemented by means of population coverage obligations set at a level that is likely to be surpassed by competition within the required deadline. Going back to the reasons listed above for setting precautionary obligations it is possible to achieve these with modest population coverage obligations (i.e. set at levels below what competition might be expected to deliver):

- If the concern is that network operators might be able to sustain a tacitly collusive situation where coverage is not extended, it may be enough to require only a moderate extension over existing coverage levels to destabilise the status quo and restart competition over coverage;
- If the concern is about cherry picking entry, then the population coverage obligation needs to be set sufficiently high that it cannot be met by serving high-value urban areas alone.

There should be wide latitude setting the parameters of any such coverage obligation, both in terms of the population coverage requirement target and the deadline by which this must be achieved. It may also be possible to achieve broadly similar results through other forms of coverage obligation, such as a geographical coverage obligation. However, the effects of a geographical coverage obligation may be more difficult to predict, in that it may be uncertain how a requirement to cover a particular geographical area might relate to the proportion of the population consequentially served. This unpredictability might not matter much if the intent is only to set a precautionary obligation that we expect competition to surpass.

On the other hand, if an interventionist obligation is used with the intent of extending coverage, then a geographical coverage requirement is unlikely to be effective, as it provides an incentive to provide coverage in areas that are cheap to serve on a per km^2 basis, rather than where users would benefit most. In this case, coverage patterns might even become spotty, especially as the geographical coverage requirement is increased. For example, we could create a perverse situation where there could be an incentive to locate cell sites for maximum coverage (e.g. on a remote hill) even if this is not providing useful coverage for users.

Coverage obligations on proportion of the population served avoid this immediate problem with geographical coverage obligations. However, even this approach may provide unwelcome incentives at sufficiently high population coverage requirements. This is because such obligations are typically set in terms of the proportion of the population covered, assuming people are located at their residential addresses. Setting very high population coverage obligations might be counterproductive if it is costly to reach the last few households and this diverts investment from providing coverage, bandwidth or enhanced services in areas where many people work and travel, but few people live. This is unlikely to address provision of coverage at business addresses outside residential areas or along transport corridors.

Therefore, even population coverage obligations may become counterproductive if set at very high levels, as this could force coverage to be extended into areas where the overall net benefit of the intervention is not maximised, both because providing the final increments of coverage may be very expensive, and because greater benefits may be obtained by extending coverage where more people spend more time. This means that coverage interventions need to be designed with some evaluation of the likely benefits to society of various alternative ways of extending coverage to ensure that overall net benefits (i.e. benefits less costs) are maximised.

For example, coverage along major roads will become increasingly important as more and more cars offer infotainment services with real time traffic updates, in car Wi-Fi for video and audio streaming, and track and monitor data regarding performance of the car and other telematics data that is sent back to the manufacturer. To provide these services cars will require connectivity along the route (though bandwidth requirements may be relatively low for most uses). A simple coverage obligation expressed as a requirement to cover some proportion of the overall landmass is unlikely to be particularly effective as means to deliver coverage along roads; a more targeted intervention would be needed. Equally, a simple population coverage obligation might not be particularly effective in delivering road coverage along major routes, especially in Ireland where there a relatively large proportion of dwellings are isolated.

The discussion above shows that population and especially geographical coverage requirements are likely to increasingly lead to incentives to provide services in the wrong places as their requirements become tightened. For these reasons, interventionist coverage obligations might be better implemented through more focussed measures that require coverage specifically where net benefits are greatest. Therefore, interventions are likely to require a significant degree of analysis by policymakers to ensure that the benefits of coverage extensions are maximised given their costs.

A good example of this more focussed approach are ‘not-spot’ obligations. The examples of the Danish 800 MHz and 1800 MHz awards are discussed in the box below (and further in Annex 1). These approaches provide little flexibility for operators as they require specific locations to be served. Clearly there is some danger of regulatory failure if these locations are poorly selected because of lack of knowledge about the resulting costs and benefits. However, simpler approaches of setting high population or geographical coverage obligations in an attempt to get such locations covered might also run a significant risk of misdirecting network operators to the wrong locations.

Therefore, as regulators are increasingly starting from already high (population) coverage levels, interventions have needed to become increasingly targeted to realise tightly defined objectives.

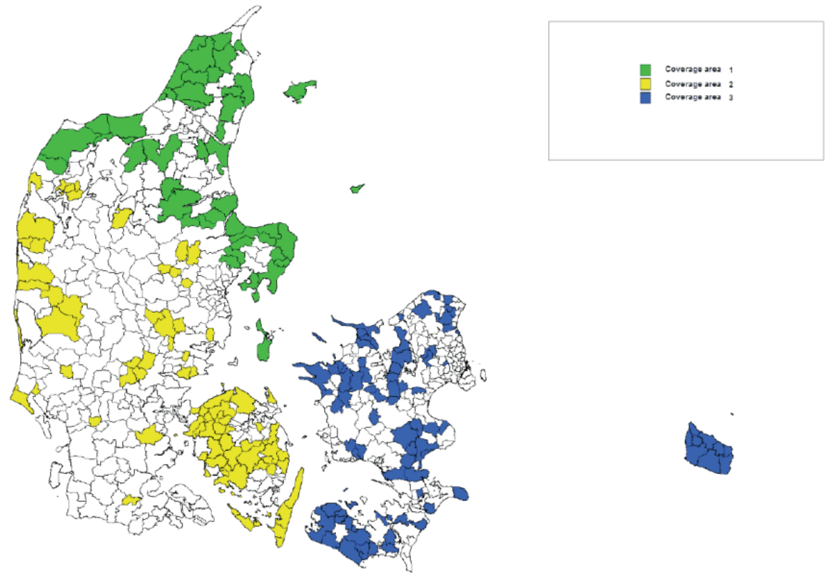
Coverage obligations in the Danish 800 MHz and 1800 MHz Awards

800 MHz Award, 2012

For the 800 MHz award in Denmark, completed in 2012, the Danish Energy Agency (DEA, at the time NITA) set interventionist coverage obligations, aimed at improving broadband availability in areas where availability of high-speed broadband was (at the time) lowest. This aimed to promote the longer-term Government objective of universal access to a broadband connection of at least 100 Mbit/s by 2020.

The DEA specified 207 postcodes where broadband availability was lowest for inclusion in the coverage obligations. These were split into three distinct sets (coverage areas), in essence defining three separate coverage obligations and allowing 800 MHz licensees to share the national coverage obligation between them (although this was not a requirement, as one licensee could be subject to all three obligations depending on the auction outcome). The three coverage areas are illustrated in Figure 1 below.

Figure 1: Danish 800 MHz award coverage areas



Source: Danish 800 MHz Auction Information Memorandum

For each coverage area, the licensee responsible for meeting the obligation in that area was required to supply a mobile broadband service with a download rate of at least 10 Mbit/s. The licensee had to ensure geographical outdoor coverage of at least 98% of the land area (with the exception of forests) and 99.8% outdoor coverage of households, enterprises, and holiday houses (with a minimum coverage of 75% in each postcode area). These levels of service were required to be in place by the end of March 2016.

There was no requirement for the coverage obligations to be fulfilled using the 800 MHz spectrum, and so the licensees could provide the required services with any frequencies available to them.

The auction format was designed to maximise the chances of assigning the coverage obligation in each of the three coverage areas to at least one licensee. The award concluded with two winners of 800 MHz licences, one of which (TDC) took on the coverage obligation for all 207 postcodes across all three coverage areas.

1800 MHz Award, 2016

A key objective of the Danish 1800 MHz auction, completed in 2016, was to improve mobile coverage in Denmark further, especially in sparsely populated areas with limited (or no) availability of voice and broadband services. To achieve this, the Danish Energy Agency (DEA) set an ambitious coverage obligation to be attached to some or all of the 1800 MHz licences awarded.

The specification of the coverage obligation was similar to that for the 800 MHz auction, but with some significant differences.

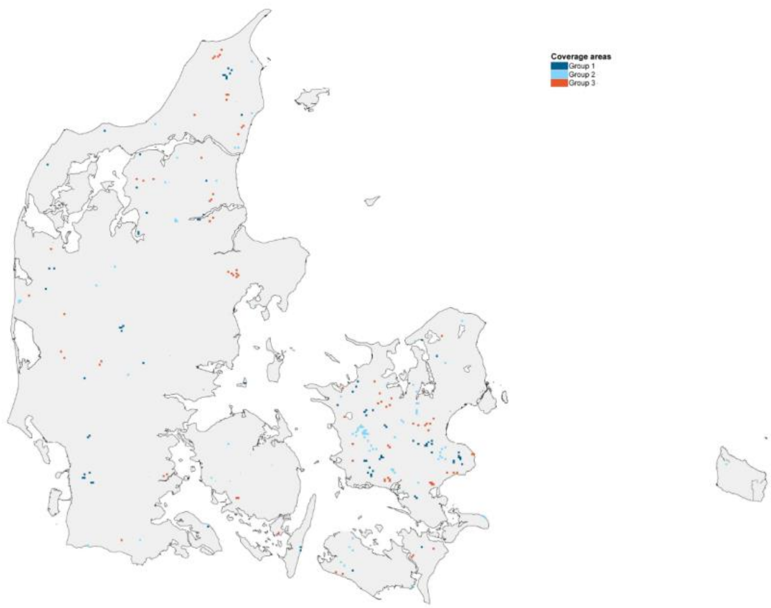
Rather than requiring access to services for a proportion of households within given sets of postcodes, the DEA instead set out a total of 2,143 specific addresses (in 245 coverage areas) to be covered under the 1800 MHz obligation(s); these were split into three non-overlapping Coverage Area Groups, distributed throughout Denmark:

- Group 1: 82 coverage areas with a total of 715 addresses
- Group 2: 82 coverage areas with a total of 712 addresses
- Group 3: 81 coverage areas with a total of 716 addresses

As with the 800 MHz award, the motivation behind the split was to offer the possibility for licensees to share the costs of the overall national obligation between them.

The distribution across Denmark of the coverage areas in each of the Coverage Area Groups is illustrated in Figure 2 below.

Figure 2: Coverage Area Groups for Danish 1800 MHz Award



Source: Danish 1800 MHz Auction Information Memorandum

(Note another key difference in the specification of the coverage obligations being that for the 1800 MHz award the coverage areas "split" the country into three parts, whereas for the 1800 MHz award each Coverage Area Group includes addresses distributed throughout the whole of Denmark.)

An 1800 MHz licensee subject to the coverage obligation for a given Coverage Area Group would be required, by 13 December 2019, to ensure access to a mobile voice service and a mobile broadband service (with a download speed of at least 30 Mbit/s and an upload speed of at least 3 Mbit/s) for the set of addresses identified in that group. There is no requirement for the coverage obligation to be met using the 1800 MHz spectrum, and so licensees can provide the required services using any frequencies available to them (including via national roaming agreements).

The award process was designed to ensure (to the greatest extent possible) that at least one licensee would be required to fulfil the coverage obligation in each Coverage Area Group. This goal was ultimately achieved, with each of the three incumbent mobile operators taking on the coverage obligation for one of the groups.

2.5.2 Service levels and trade-offs

Any intervention to increase coverage will face trade-offs as to whether a more basic service should be extended to a large number of people, or a more advanced one to a smaller group. Any intervention has a cost – whether implicit or explicit – and we can ask whether the greatest benefit is being created within a certain cost envelope. Policymakers would then have choices to make about different types of service that could be promoted within that cost envelope.

For example, one question is whether any coverage intervention should target voice or data services. In our view, coverage interventions need to be forward looking, considering the services that are likely to be of most use at the time targeted by the coverage obligation. Therefore, given current usage trends, data services are likely to be of considerably greater value that targets set only for voice coverage.

Equally, it is important that coverage obligations are not over-ambitious in terms of the bandwidth requirements, as this will greatly increase costs for little additional benefit. In particular, mobile coverage obligations should not be seeking to replicate the speeds and consumer experience deliverable over fixed broadband (which will increasingly use fibre over the timeframes being considered). Speed targets such as 30 Mbps will support many useful services, include growing demand for machine-to-machine communication, and also support voice.

2.5.3 Timing

Coverage obligations set a deadline by which licensees are required to have met the specified coverage level. This could be in the form of a single deadline, or the timing may be staged (e.g. at least part of the obligation must be fulfilled by a certain date, with the rest to be met later on).

The timing of interventionist coverage obligations is important to determining their costs, as well as the end-point that must be reached. However, MNOs are likely to have constraints on how fast networks can be built out, and costs are likely to increase (possibly dramatically) with faster roll-out objectives. If the deadlines are set too tight, operators could be faced with significant costs that might be considered unreasonable and which could divert resources away from providing/improving services in more important areas. In extreme cases, setting a coverage target too soon might even render meeting the obligation unviable. Timelines imposed for meeting a coverage obligation need to balance between user benefits of faster rollout, the cost implications for operators and the practical reality of rolling out new sites.[17]

In Germany, the 800 MHz auction applied an obligation that required licensees to cover rural areas before serving urban areas, which might be thought of as a means to allow the State to avoid having to specify a timetable for roll-out (see box below). This can be particularly useful because timing constraints may differ across operators. Instead, the German obligation allows operators to individually achieve their own roll-out timeline, whilst still encouraging a timely deployment as operators are commercially motivated to meet the coverage obligation as quickly as possible in order to be able to serve the more profitable urban areas.

On the other hand, depending on how onerous the rural deployment requirements are, this approach may have potential problems, as if operators are forced to roll out to rural areas before being allowed to serve the more profitable urban areas this might:

- put pressure on operators to deploy a rural network faster than would be optimal and divert resources from their urban network; or
- delay overall deployment/use of the spectrum because of the need to raise capital/expand their network to meet the rural requirement first.

Country specific circumstances and demographics are also relevant to how such obligations are structured. Ireland has a population density of 69 people per km^2 compared with Germany, which has 233 people per km^2.[18] Therefore, it is far from clear that an approach appropriate for, say, Germany would be appropriate for Ireland.

[17] For example, in the Oxera FMC Report (ComReg Document 18/103c), a 2.5% CAGR is based on historical site licensing data from Irish MNOs. For context, a network roll-out with 2.5% CAGR in 2020 corresponds to a new site every week, or a carrier-upgrade every two days. Oxera also note that even if the MNO was able to invest in more engineering staff, vehicles, and equipment, the process of doing so would take time and may not be commercially viable.

[18] https://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=tps00003&plugin=1

German 800 MHz auction coverage obligations – rural deployment before urban

In 2010 the Bundesnetzagentur (BnetzA) held a multiband auction to award spectrum in the 800MHz, 1.8 GHz, 2 GHz and 2.6 GHz bands[19]. Because the physical properties of sub-1 GHz frequencies differ substantially from higher frequencies, BnetzA imposed differentiated coverage obligations across bands.

All winners were required to cover at least 50% of the entire population within 5 years of the licence start. However, with the aim of improving coverage in rural areas, 800 MHz licences were awarded with special coverage obligations that required winners to provide coverage in less populated areas before being allowed to use the spectrum in more populated regions.

Each of the 16 federal states in Germany provided the BnetzA with a list of white spots, defined as towns or districts with little or no broadband provision. This list was based on the broadband mapping activities of the Federal Economics Ministry as well as surveys conducted by individual federal states. Winners of 800 MHz spectrum licences were required to (jointly) provide broadband access to at least 90% of the population in each of these white spots by 01 January 2016, but this was to be completed in a staged process. For this, the areas identified were divided into priority categories based on population:

- Priority stage 1: towns and districts specified by federal states with fewer than 5,000 inhabitants
- Priority stage 2: towns and districts specified by federal states with between 5,000 and 20,000 inhabitants
- Priority stage 3: towns and districts specified by federal states with between 20,000 and 50,000 inhabitants
- Priority stage 4: towns and districts specified by federal states with more than 50,000 inhabitants

For any given federal state, rollout of services using the 800 MHz spectrum in areas within a particular priority stage could only begin once at least 90% of the population in the towns and districts in the previous priority stage were provided with broadband access by *at least one* 800 MHz licensee i.e. rollout in priority stage 2 towns and districts could begin only when at least 90% of the population in priority stage 1 towns and districts was covered by at least one or more of the operators.

In order for the operators to be able to meet the obligation with maximum efficiency (in terms of network costs), sufficiently large capacity needed to be made available. On that basis, the BnetzA ensured that every operator was able to obtain at least 2x10 MHz in the 800 MHz spectrum band by giving bidders the possibility to request a minimum spectrum package.

2.6 Symmetric vs. asymmetric obligations

2.6.1 Symmetric obligations for precautionary motives

Precautionary coverage obligations are typically imposed symmetrically, where all licensees are required to meet the same minimum coverage targets under the same conditions. This symmetrical approach makes sense given the typical functions of a precautionary coverage obligation. For example, if the objective is to prevent one or more operators from 'cherry-picking' and serving only the most profitable areas, then a symmetric obligation is essential. A symmetric obligation is also appropriate if the objective is to guard against any risk of tacit collusion to delay roll-out.

Since these would be designed to require a level of coverage that would be expected under normal competitive conditions, there is no risk of foreclosing the market to any viable operator due to conditions that are too onerous. Similarly, there is no risk of forcing an inefficient duplication of networks in areas with low traffic density (which in turn may give rise to economies of scale and efficiency benefits in consolidating networks), as coverage levels would be competitively determined.

2.6.2 Competition vs. cost efficiency with interventions

Conversely, interventionist obligations that seek to extend coverage significantly beyond competitive levels may be more efficient if imposed as asymmetric obligations, potentially taken on by a single MNO, or shared by multiple MNOs each required to meet a different individual obligation to achieve an overall target (see the Dutch 800 MHz and 1800 MHz examples above). Applying interventionist obligations asymmetrically helps to avoid inefficient duplication of networks in rural areas, where the demand density is low and natural monopoly conditions are likely to apply due to strong scale economies in very lightly loaded networks.

When seeking to extend mobile networks out into areas where the density of users is low, there is likely to be some tension between cost efficiency and maintaining competition between networks. A coverage network may be lightly loaded with traffic given the low user density. Therefore, it may be possible to reduce overall costs by consolidating traffic, potentially even on a single network. However, this means that competition will be reduced, which may be a

[19] President's Chamber of the Bundesnetzagentur decision on combining the award of spectrum in the bands 790 to 862 MHz, 1710 to 1725 MHz and 1805 to 1820 MHz with proceedings to award spectrum in the bands 1.8 GHz, 2 GHz and 2.6 GHz, October 2009.

significant concern given the small number of suppliers typical in mobile markets. In many cases, it might be preferable to tolerate some measure of cost inefficiency to avoid creating the situation in which there is little network competition in the intervention areas.

Applying interventionist coverage obligations asymmetrically could also help to encourage participation in spectrum awards. There may be operators (either existing MNOs or potential new entrants) unable to meet the obligation, so imposing the obligation on all licensees might prevent some parties participating altogether when it might have been socially optimal for them to be awarded spectrum. This is not to say that coverage obligations should be designed for specific operators, or to allow operators serve less than a minimum (precautionary) coverage level. However, allowing for particularly onerous coverage obligations to be met by just one or a small number of operators capable of doing so may be optimal for the award of spectrum in terms of expanding coverage whilst maintaining competition in more commercially viable areas.

Whilst asymmetric coverage obligations on just one MNO may be beneficial in terms of promoting efficient spectrum assignment and use, we must also recognise that it risks competitive distortions. For example, if there is just one coverage obligation attached to a spectrum licence, then the winner can expect to receive that spectrum at a discount relative to unencumbered spectrum; this discount needs to reflect the costs of meeting the obligation, rather than provide any unjustified advantage to that operator, as might arise if there is little competition from other operators willing to take on the coverage obligation.

Furthermore, whilst most consumers might not care about the coverage differences across operators, there may be certain groups (e.g. some business customers or rural users) who favour the MNO with greater coverage, creating the potential for downstream competitive advantages for the holder of the coverage obligation. However, in this case, downstream competition at a national or geographic level can, to an extent, be maintained by imposing access measures within the intervention area, to which we turn next.

2.7 Associated access measures

Access measures may be required in conjunction with asymmetric, interventionist coverage obligations in order to:

- avoid competitive distortions that arise through a subsidy or price reduction for spectrum applying only for the operator(s) providing additional coverage; and
- ensure that the benefits of the intervention are enjoyed by as many consumers as possible (and not just consumers on one network).

Suitable access requirements might be imposed as some form of network sharing in the intervention area, such as national roaming, radio access network (RAN) sharing or site sharing.

German 800 MHz auction – cooperating to meet the coverage obligation

To support the rapid build out of networks and to meet the coverage obligation as fast as possible, 800 MHz licensees were allowed to engage in economic cooperation with other network operators, for example with arrangements on infrastructure sharing or frequency lease. Such arrangements of course had to be within the bounds of German regulation and competition law. Regarding frequency leasing, services provided by another operator would count towards the licensee's coverage targets, but the licensee would remain responsible for ensuring the targets were met.

The BnetzA did not impose any obligatory access arrangements, noting that such an obligation could only legally be imposed on a network provider with significant market power.

Licensees were allowed to share the attached coverage obligation up until 2016 by entering into cooperation agreements such as sharing infrastructure or leasing. After 5 years each licensee was required to meet the obligation using their own network.

No obligation was imposed on licensees to offer access to service providers. BnetzA did insist that there would be no objections to national roaming agreements being reached between operators.

Whilst a wholesale access obligation could facilitate competition between operators, the benefits to consumers may be limited, as prices are often nationally determined (as opposed to being increased in the rural area where the MNO might be operating alone). If a licence is subject to a wholesale access obligation, this might reduce the value of the spectrum to operators (since retail revenue could be lower with a reduced market share, albeit partially offset by wholesale revenues). In turn, the value of spectrum might constrain the required level of coverage that could realistically be attached to the licence before it becomes unviable for any operator. The Portuguese multiband auction implemented both a shared coverage obligation and a wholesale access requirement to make the burden less onerous on smaller operators (see box below).

Portuguese multiband auction – shared obligation and access requirement

The Portuguese multiband auction held in 2011 allocated frequencies in the 450 MHz, 800 MHz, 900 MHZ, 1800 MHz, 2.1 GHz and 2.6 GHz bands[20]. Of these bands, spectrum in the 800 MHz band was subject to 4G LTE rollout obligations. These obligations were lot-specific, as each of the six 2x5 MHz blocks had an associated coverage obligation. For each lot the associated obligation was to provide coverage to 80 parishes. Combined with the spectrum cap this meant that each 800 MHz spectrum winner would be subject to a coverage obligation of at most 160 parishes. The 480 parishes selected by the Portuguese regulator ANACOM were without any mobile broadband coverage. A licensee was considered to have covered a parish when its administrative centre was provided with mobile broadband services. To fulfil the coverage obligation licensees were allowed to use holdings in the 800 MHz band as well as holdings in the 900 MHz band, should they have any.

Operators in the 800 MHz band were also subject to an access obligation. One of the access obligations stipulated that winners of spectrum in the 800 MHz or 900 MHz band were required to accept a national roaming obligation to certain third parties. For third parties to be allowed access they were required to hold: spectrum above 1 GHz; and either less than 2x5 MHz holdings across the 800 MHz and 900 MHz band, or newly-won spectrum in the 800 MHz and 900 MHz band through the auction at hand. This meant that 800 MHz spectrum winners were not only required to give access to third parties, but could also be allowed to get access as a third party. For third parties to get access they were required to aim to provide coverage to at least 50% of the population within three years. The national roaming obligation would be in place for a duration of 10 years for third parties with less than 2x5 MHz holdings in the 800 MHz and 900 MHz bands, while roaming agreements with holdings over 2x5 MHz in those bands were to be terminated after 5 years.

2.8 Enforcement

To ensure that an operator complies with any coverage obligation attached to its licence, it is necessary to define the specifics of what needs to be provided under the obligation. It is important that the

[20] ANACOM, "Auction Regulation for the Allocation of Rights of Use of Frequencies in the 450 MHz, 800 MHz, 900 MHz 1800 MHz, 2.1 GHz and 2.6 GHz bands.", October 2011.

operator is clear what is required and it is measurable whether or not the requirements have been met. It is also important that bidders seeking to acquire spectrum in an award process fully understand the requirements, as this may have significant consequences for the value of the spectrum (especially in the case of an interventionist obligation).

2.8.1 Service quality vs technical conditions

Sometimes coverage is defined in terms of **quality** or **availability** of a specified service. For example, with voice services, meeting the coverage obligation might require a minimum probability of being able to make a call of certain duration without the call dropping. In terms of data, it could be defined as a minimum probability of using the service at a specified minimum transmission speed.

Compliance can be measured through appropriate sampling through test calls at different locations. For example, ComReg conducts a series of 'Drive Tests' across all of the relevant frequency bands and licence types simultaneously in order to assess the Mobile Network Operators' ("MNO") compliance with the obligations of their respective licences.[21]

Coverage can alternatively be defined in terms of **signal strength**. However, field strength at a location is not sensible standard where beam-forming is used, as signal strength will vary dynamically and might depend on what other users there are within the cell. Also, the use of antenna arrays (i.e. MIMO) complicates matters, as the data throughput at given signal strength can in principle be increased by creating multiple parallel communications channels.

Therefore, minimum signal strength requirements will increasingly become incompatible with setting technology-neutral coverage conditions, as service quality may depend on other factors (e.g. the use of MIMO antenna, the details of beam-forming algorithms and the dynamic allocation of capacity across cell users). Today, most licences are technology-neutral and therefore defining a service availability requirement is generally more desirable.

[21] Licence Coverage, as measured in the Drive Test, represents the ability to place a call at a specific location at a specific time using a standard handset; all measurements are performed from a vehicle containing a computer-controlled measuring system, which acts as a 'handset', matching an European Telecommunications Standards Institute ("ETSI") standard handset.

Portuguese multiband auction - operator specific service definition

The service definitions of the coverage obligation attached to the 800 MHz licences allocated in the Portuguese multiband auction were operator specific. The minimum transmission speeds that were to be provided were determined based on the licensee's commercial offer. Because ANACOM considered a single speed requirement to be disproportionate, the 800 MHz licensees were required to offer speeds to the parishes based on the speeds to its current subscribers. The minimum speed per licensee was determined by the highest speed the licensee provides to the 25% of its subscribers with lowest download speed offers. This minimum speed would be revised every 2 years.

2.8.2 Linking obligations to spectrum

Where a coverage obligation is linked to a spectrum licence, it should also be specific whether the obligation should be met using that spectrum to which the obligation is attached or whether other bands can be used to meet the coverage target. In particular this is important to know in advance of awarding the associated spectrum, since it will have implications for the amount of spectrum required by an operator in the award and also the value of that spectrum.

Allowing an operator to use existing holdings to meet the coverage obligation may make it less difficult and less costly for an operator to achieve an obligation, although such an approach may also limit the number of operators capable of taking on the obligation if significant prior spectrum holdings become a precondition for being able to meet the target.

Another factor to consider is what happens to a coverage obligation in the event of a spectrum trade. Does the obligation transfer to the new licensee along with the spectrum, or does it remain with the operator it was originally assigned to? Requiring transferring of the obligation in all cases could undermine trade that might help to promote competition and efficient spectrum use (especially if the seller is already meeting the obligation using other spectrum). On the other hand, if the obligation no longer applied following a trade (or stays with the original licensee), this might create strange incentives to attempt circumventing the coverage obligation through trading on the secondary market. Another question that arises is how to deal with the case that some, but not all, of the coverage obligation spectrum is traded – who then is responsible for meeting the coverage target?

It may be that regulatory intervention is required on a case-by-case basis to establish how a coverage obligation should be dealt with under spectrum trading. As a matter of general principle, trading, leasing or reconfiguration of licences should not lead to the cancellation or undermining of a coverage obligation, otherwise perverse incentives will be created. However, beyond this broad principle, there are various reasonable approaches in which the obligation might stay with the original licensee, be transferred entirely or other variations. Clearly it should be in the interests of both operators and consumers if any such rearrangement reduced the overall costs of meeting the obligation.

In this regard, ComReg's approach is that the licence conditions would be considered on a case by case basis as the exact nature of a spectrum transfer cannot be determined in advance of a notification. For example, the 3.6 GHz Band Regulations provide for a spectrum leasing arrangement to count towards the rollout base station obligation of the Lessor. Therefore, ComReg has indicated a willingness in principle to be flexible with how exactly obligations are dispatched.

3 The case for coverage interventions

In this section, we examine the circumstances in which there is likely to be an economic or other policy rationale for intervening to increase coverage. Competitive network operators may fail to provide rural coverage because it is prohibitively expensive relative to the additional revenues that an operator would be likely to gain (or retain if responding to a rival increasing coverage). However, this is not reason in itself for an intervention to increase coverage. Rather, there should be an identifiable market failure or legitimate policy objective (e.g. efficient use of spectrum, public safety etc.) of some form, giving rise to incremental external benefits from extending network coverage that network operators do not capture, and so do not take into account when deciding how far to extend coverage.

3.1 What we can expect competition to deliver

We start by considering how competition between network operators has shaped coverage and what we can expect a well-functioning market without intervention (so subject to at most precautionary coverage obligations).

Shift from vertical to horizontal differentiation as coverage has developed

During the initial development of mobile telecommunications networks with the introduction of GSM and the early stages of 3G, coverage was a key competitive differentiator. When networks were immature, there were differences in coverage and this was a significant driver of consumers' choice of network and a focus of marketing efforts by operators. This competitive pressure led to rapid roll-out covering all major population centres. However, over time, coverage has arguably become less important in consumers' choices. In part, this is due to there being less scope for clear quality differences between operators once major population centres become served.

This shift can be understood in terms of change in the nature of differentiation between different providers of mobile service offerings. Initially, differentiation was *vertical*, in that a provider with superior coverage in key areas would be seen as superior by most customers. However, as coverage has improved, differentiation has become *horizontal*, in that consumers will not all agree about which provider is better. One consumer could rank provider *A* as better than provider *B* because of superior service in the places that consumer spends time, whereas another consumer might find provider *B* better than provider *A* because that consumer works, lives and travels in different places. Also, preferences between providers are likely to be increasingly driven by other aspects of the service, such as data rates, bundled content and so on.

Therefore, we have likely shifted from a situation in which there was a strong competitive imperative to deliver coverage in key areas to one in which the focus has moved towards horizontal differentiation. As a result, there is less incentive to in-fill residual areas of poor service, particularly as any particular coverage improvement is likely to benefit only a small number of current or potential customers.

In Ireland, coverage is now similarly high across MNOs[22] and although users often report problems with coverage[23], an attempt to quantify the size of the problem seems to indicate that the overall loss of welfare is small due to the very modest willingness of consumers to pay more to support greater coverage[24]. Instead other aspects of the service proposition (e.g. bundled content, pricing) have become predominant in shaping consumers' choices. In a survey for ComReg, consumers[25] indicated that, ahead of network coverage, their current choice of provider was influenced by pricing, whether their friends and family were on the network and the reputation of the provider.[26]

Despite the possibly weak incentives for operators to compete for consumers through *improving* coverage levels, there is also a ratchet effect at work and we should expect MNOs to *maintain* coverage levels. This is because of the sunk costs of network planning and difficulties in obtaining sites make network operators reluctant to give them up. In addition, adverse consumer reactions from dropping coverage levels would also encourage operators to maintain coverage levels.

[22] 4G mobile coverage in Ireland is now above the EU average at 92% of population. See http://ec.europa.eu/information_society/newsroom/image/document/2018-20/ie-desi_2018-country-profile_eng_B4406C2F-97C3-AA9A-53C27B701589A4F3_52225.pdf

[23] As indicated by the inclusion of mobile coverage as an issue of national importance in the Programme for Government. 75% of consumers, 62% in more rural areas, are satisfied with their mobile phone network's coverage where they live. B&A, Mobile Customer Experience Review, prepared for ComReg. See https://www.comreg.ie/publication/mobile-consumer-experience-survey/

[24] 71% of consumers would not pay extra to have good service throughout their home (out of those who currently don't get such service). The average willingness to pay for coverage throughout all of their home for consumers without a reliable service was on average €2.17 extra for calls/texts and €1.98 for data. B&A, Mobile Customer Experience Review, prepared for ComReg

[25] Ireland Communicates Survey 2017 – Consumer Survey – Document 18/23a.

[26] Ibid, B&A, Mobile Customer Experience Review, prepared for ComReg.

Equally, coverage improvements, under current conditions, may be held back by the difficulties of obtaining access to, or deploying, extra sites. In part, such impediments depend on other public policies, such as planning restrictions and access to publicly-owned land and buildings for the purposes of infrastructure deployment. Clearly coverage roll-out will be encouraged by the reduction of such impediments.[27]

This is the case for Ireland due to its geographic characteristics and highly distributed and rural populations[28]. Oxera demonstrates that for a 30 Mbps target service, the costs of covering a given percentage of the population increase rapidly above 90% essentially increasing at an exponential rate above 95%.[29] This reflects the long tail of isolated rural dwellings in Ireland.

In terms of upgrading networks, we can expect operators to upgrade to 4G and beyond at current coverage levels due to network cost efficiencies, though urban areas with capacity constraints will be the priority. However, there is no particular reason to expect that these upgrades will significantly change the incentives for roll-out in the near term. Whilst it is the case that there are possible new markets, such as IoT applications in rural areas, that may increase incentives to roll-out beyond current levels, these are likely to be relevant only over longer timescales and there may be alternative competing technologies that can deliver such services, not just mobile networks, limiting the new revenues available.

3.2 Market failures

Even with effective competition between mobile operators, competition cannot be expected to deliver ubiquitous coverage. Furthermore, ubiquitous coverage would not be socially optimal, as the very high incremental costs of extended coverage to the very last few places would surely exceed any benefits of doing so. Therefore, coverage being incomplete is not synonymous with there being some market failure.

[27] The Mobile Phone and Broadband Taskforce is addressing some bottleneck problems such as planning, access to public buildings for sites. See

https://www.dccae.gov.ie/en-ie/communications/topics/Broadband/mobile-phone-and-broadband-taskforce/Pages/Mobile-Phone-and-Broadband-Taskforce.aspx

[28] Ireland has one of the most widely distributed and rural populations in Europe. For example, Ireland has a population density of 67 persons per km^2 compared to an EU average of 117 persons per km^2. Oxera, FMC in Ireland (ComReg Document 18/103c), November 2018

[29] Oxera, FMC in Ireland (ComReg Document 18/103c), November 2018

Rather, by a market failure we mean a situation in which there are some *external* incremental benefits of extending coverage that do not accrue to competing mobile network operators (i.e. positive externalities) meaning that even with effective competition, operators have deficient incentives to roll-out coverage in certain places. When operators decide where to roll-out, they compare the revenues they can gain (or protect from loss to competitors) with the costs of extending coverage; they do not take into account these external benefits.

Unsurprisingly, incentives for incremental roll-out by MNOs have declined as coverage has expanded. Any case for a policy intervention to push out coverage beyond competitive levels should be based on credible arguments for there being significant market failures or externalities resulting from other policy objectives. As discussed below, there are potential arguments that can be made for intervention, though the strength of these arguments is debateable and optimal interventions are likely to be tightly targeted.

In considering any case for intervention, it is also important to recognise that there may be various constraints and impediments on extending coverage, which if reduced might in any case encourage competitive coverage deployment to go further even without intervention. This could include issues such as planning restrictions on sites and lack of backhaul connectivity in rural areas. Interventions to improve fixed connectivity in rural areas may well have knock-on effects in encourage mobile coverage, both because this may open up new opportunities for backhauling cell sites and because good fixed connectivity within buildings may be complementary with mobile use (as discussed above, supporting mobile use through WiFi indoors).

3.2.1 Externalities in oligopolistic competition

Market failure could exist if the additional surplus associated with an incremental coverage improvement is only partially captured by the MNO making such an improvement. When an MNO considers extending coverage beyond that of its competitors, the additional costs will be largely independent of traffic volumes, as this is likely to be an unprofitable area with low usage. Costs will need to be recovered through additional revenue for the coverage extension to be profitable. However, only a small fraction of consumers will directly benefit from the incremental coverage and might use services when in the newly covered area. Because most consumers face a marginal usage price of zero due to bundle pricing, the MNO will not automatically receive additional revenues from additional usage. Nonetheless there may be consumers that value the option to use services in the coverage extension area even if they do not often actually do so. The MNO cannot discriminate its pricing between customers who benefit from the coverage increment and those who do not; while advertising improved coverage in a particular area may attract new customers, the rate of consumer switching is typically low.

Therefore, given typical pricing practices, the MNO needs to raise prices slightly for *all customers* to extract any of the additional value created by its greater coverage footprint, which means it will potentially lose some customers who do not value the additional coverage. Only part of incremental benefit of the coverage extension can be captured. As a result, coverage improvements that would be socially beneficial may not be made.

Furthermore, the evidence suggests that consumers have a very limited willingness to pay more for a service even if it did have greater coverage. ComReg's mobile consumer experience survey found that only 12% of those surveyed would be willing to pay an additional €2 each month to receive a reliable mobile phone service. Therefore, at some point increasing coverage is not an effective competitive strategy, as the higher price needed to sustain this discourages more consumers than the coverage improvement gains.

This is an instance of a very general argument for under-provision of quality within oligopolies.[30] However, intervention does not usually occur in markets for this reason alone, as it probably affects most sectors of the economy to some degree. Nevertheless, in the mobile telecoms market, there are particular reasons to be concerned about externalities in oligopolistic competition:

- the mobile communications sector is a concentrated oligopoly with a small number of network operators[31];
- 'all you can eat' or large bundle pricing means that MNOs gain no immediate additional revenue due to greater usage resulting from coverage improvements; and
- there is no price discrimination of services offered by an MNO according to coverage levels.

In a 'pay-as-you-go[32]' or 'capped' bundling pricing package, coverage roll out may induce consumers to use more data in areas where they would not have been able to use data before, generating

[30]See for example Spence, A. Michael (1975), 'Monopoly, Quality, and Regulation', Bell Journal of Economics, vol. 6, no. 2, pp. 417-429. There are also models showing that quality may be under provided even by a monopolist if consumers are heterogeneous due to the difficulties in capturing additional consumer surplus associated with quality improvements; see White, Lawrence J. (1977), 'Market Structure and Product Varieties', American Economic Review, vol. 69, no. 1, pp. 179-182. Furthermore, if consumers are not fully informed about product/service characteristics, this can create incentives for under-provision of quality; see Belleframme, Paul and Martin Peitz (2010), Industrial Organization. Markets and Strategies,Cambridge, UK: Cambridge University Press.

[31] As noted above, MVNOs have little if any role in enhancing coverage as they are limited to the footprint of their host network.

[32] 42.8% of all mobile subscriptions are pre-pay.

additional revenue for the operator. In an 'all you can eat' bundled pricing package, additional use does not result in additional revenue. Without this link, operators may not be able to extract the private value to those consumers specifically benefiting from the additional roll-out. It may be that customers in general can be charged a little more if they are willing to pay more for the additional coverage; however, trying to extract the benefit of the additional coverage by setting a slightly higher price for all customers might result in losing some marginal customers who do not benefit from the coverage increase.

If MNOs are unable, or unwilling, to capture the additional value to consumers of increasing coverage, there could be under-provision of coverage. Also, we can see that the problem is likely to arise primarily with regard to geographical areas where coverage is of interest to a small minority of customers, rather than areas where there is some chance that most customers might want service, as in the latter case providing coverage there is potentially important to the choices of many customers about network operators. In contrast, an investment to increase in coverage that benefits a small minority of customers may be difficult for an operator to monetise as additional revenue.

Measures to promote competition between MNOs are certainly helpful for reducing the impact of this potential market failure. More intense competition between mobile network operators (as opposed to MVNOs) should have beneficial effects in extending coverage somewhat. However, even with effective competition, it is possible that incentives to provide coverage may not be socially optimal due to the way in which oligopolistic competition operates, especially given the typical tariff structures (with call and data allowances and bundling of ancillary services) commonly used for mobile services.

This said, in many oligopolistic markets there may be deviations away from fully efficient levels of service quality for broadly similar reasons. However, the specifics are usually highly sensitive to the details of how price competition works within particular markets, as incentives to provide quality depend on both consumer demand responses and changes to prices, including by competitors. Economic models demonstrate that it is possible for there to be under-provision or over-provision of product quality depending on these details.[33] Therefore, regulators and competition authorities have tended not to focus on this issue and there is seldom intervention for these reasons.

Given this, whilst there are good reasons to expect that incentives for provision of coverage for competing network operators could be sub-optimal, this is not necessarily a strong reason for intervention by itself.

33 See Spence (1975), ibid.

3.2.2 Coordination problems in developing new services

Additional coverage could be pivotal for new industries and sectors that are expected to rely on increased connectivity. Pervasive and ubiquitous connectivity is predicted to support applications across transport, manufacturing and agriculture. In some of these cases (e.g. transport telematics, agriculture, certain IoT applications) services may require high levels of coverage as a precondition.

In particular, new agricultural applications may play an important role in Ireland's economy. Industrial IoT applications of dense sensor networks are unlikely to wait until 5G becomes ubiquitous in rural areas. Instead developers wanting to get new products and services to market will adopt other interim technologies that are readily available now, such as LTE-M or NB-IoT, or low- power wide-area technologies such as LoRa in a hub and spoke arrangement with centralised backhaul, possibly even using satellite. The developer of a new service or product for agriculture that depends on connectivity is likely to want to have as many options available as possible for providing that connectivity. Such services and products are likely to be developed by providers selling globally and national markets will develop at different rates in terms of the availability of advanced connectivity.

The growth of NB-IOT is not dependent of the introduction of 5G and is happening already. There were 930,806 M2M subscriptions at the end of Q2 2018. This is an increase of 24.6% since Q2 2017 and represents 15.2% of all mobile subscriptions.[34] Therefore, for such applications, the current issue is not so much the availability of technology – in that NB-IoT is available now and can already support many interesting applications – but rather coverage, increasingly provided by 4G networks.

Where mobile connectivity could reap substantial benefits for nascent services, there could be a coordination problem between providing coverage and developing those services. This 'chicken and egg' problem may mean that operators do not compete for the incremental revenue from selling connectivity to these industries. This is exacerbated by the uncertainty surrounding the growth of these new uses. Furthermore, services entirely reliant on mobile connectivity are unlikely to develop and instead developers will create 'de-risking' strategies to cope with diverse network environments and different levels of coverage of different technologies (e.g. fall-back to peer-to-peer networks for 5G connected cars) rather than push for coverage assurances from operators.

Overall, it is difficult to see a general case for significant intervention on the basis of co-ordination issues between operators and the

[34] Irish Communications Market Quarterly Key Data Report Data as of Q2 2018.

developers of new services requiring connectivity. Nevertheless, coordination problems may arise with respect of certain new services likely to be used in rural areas. Again, this suggests that coverage interventions need to be targeted to provide good value for society.

Telematics for transport may be another area where it is important for coverage to be provided at least on major routes to resolve coordination problems with developing new services aimed at this sector. However, co-ordination to ensure that connectivity available on major routes is not specifically a national problem, as the development of new services is occurring at the European or global level. For instance, the EU 5G Action Plan has identified major transport routes as a target.[35]

We note that the situation with regard to train routes is much less concerning, as other mechanisms exist to address any coverage problems. These include in-train WiFi backhauled over multiple MNOs, joint ventures between train operators and mobile networks to offer connectivity and obligations on train operators (for example to provide in-train WiFi).

In conclusion, none of these are rationales for radical intervention to secure largely ubiquitous coverage; rather they suggest targeted interventions intended to de-risk development of new services by ensuring sufficient coverage in the right places to get them started.

3.2.3 Social inclusion benefits of connectivity

Connectivity is often seen as a key driver of social inclusion. Digital inclusion through access to connectivity might be considered as a rationale for mobile coverage obligations. However, coverage obligations are not the sole tool to meet digital inclusion public policy objectives. Different forms of network connectivity are substitutes in terms of meeting digital inclusion objectives.

Access to high speed broadband connectivity for about 540,000 rural premises is expected to be provided by the National Broadband Plan. Therefore, mobile coverage enhancements are likely to make a minimal additional contribution in meeting any digital inclusion objectives. It is difficult to justify intervention in improving mobile coverage for social inclusion policy reasons.

[35] A roadmap by European Commission that sets out measures to guarantee a coordinated approach among all member states to make 5G accessible in line with the 5GAP goals of "at least one major city [per member state] to be 5G enabled in 2020", and making sure that "all urban areas and major terrestrial paths (...) have uninterrupted 5G coverage by 2025".

3.2.4 Public safety issues

There may be some arguments for using certain parts of the 700 MHz band (such as the 700 MHz duplex gap, but possibly even 700 MHz FDD spectrum) as dedicated capacity for public safety or national security reasons. For example, in Sweden, the award of 700 MHz spectrum planned in 2016 was cancelled by the Government in order to consider the option of reserving some of the spectrum for defence forces and emergency services in case of an emergency (see box below). Where spectrum is used in this way there will need to be coverage requirements to make this dedicated capacity useful in emergency situations. In particular there may be a case for ensuring provision along key transport routes to meet such needs.

Swedish 700 MHz spectrum reserved for PPDR

In 2016 the Swedish regulator PTS cancelled the planned award of licences in the 700 MHz band, in order to assess the need to use the spectrum for PPDR services. . Since then, the government has decided to award 2x20 MHz of FDD spectrum and 20 MHz of SDL spectrum for commercial use, but there is still no decision about the potential use for the remaining 2x10 MHz in the 700 MHz band. It is not clear whether the remaining spectrum might be reserved for PPDR services, continue to be used for DTT or offered for commercial use. It is also unclear whether PPDR services will end up being provided by private firms offering a commercial service, by a public operator or using a hybrid model. The Swedish Civil Contingencies Agency has been assigned the task to analyse the costs and requirements for a reliable and secure communication system.

Similarly, where 700 MHz spectrum is used for PPDR, it may be encumbered with the stringent coverage, quality of service and reliability requirements necessary for emergency use. While use of 700 MHz spectrum for PPDR is not currently harmonised across Europe, it is being considered as an option in the current 700 MHz decision.[36] In some jurisdictions, parts of the band have been considered for dedicated capacity for PPDR (e.g. Sweden and Slovenia). France has proposed allocating 2x5 MHz and 2x3 MHz in the band for PPDR.

PPDR narrowband voice and data has traditionally been provided over a privately run network using dedicated spectrum. Using

[36] ECC Report 239 on Compatibility and sharing studies for BB PPDR systems operating in the 700 MHz range

capacity on a commercial mobile network operated by an MNO is currently being explored in some jurisdictions in the EU. Making available 700 MHz spectrum for use by a commercial operator is an option to be assessed as part of, or against, these alternatives. Decisions about the best way to provide a PPDR service depend on the economic costs of providing the service using different methods, the strengths and weaknesses of different methods and the willingness to pay for such provision, which is linked to the likelihood of adverse incidents occurring.

The requirements for a PPDR network are often focussed on voice (with no obvious requirement for high data rates, although there may be some development on this front in the future) with resilience of particular importance, including resilient coverage, ideally through overlapping cells. If PPDR is provided over the 700 MHz band, there would need to be suitable adaptions made to the network to enhance coverage and resilience, and to allow for appropriate prioritisation of traffic.

To fulfil PPDR requirements, operators would need to build new sites, leading to improved coverage over commercial networks as a consequence of PPDR provision. Therefore, provision of PPDR by a commercial MNO enables a synergy with coverage enhancements available to the general public. Should 700 MHz spectrum be considered suitable for PPDR, a part of the band (e.g. in the 700 MHz duplex gap and 700 MHz guard bands[37]) could be assigned for dedicated PPDR use with associated coverage obligations, or a PPDR service could be procured from a commercial operator at a later stage as an ex-post measure. Any operator with a reasonable allocation of 700 MHz would be able to provide PPDR and other 5G emergency services.

3.3 Interim conclusions

There are possible arguments that there could be external benefits from coverage that are not taken into account by mobile network operators when they decide their levels of coverage. In particular, it is possible that coverage improvements – at least relative to the current situation of fairly extensive coverage – may be difficult for mobile operators to monetise as there is no easy mechanism for those benefiting to pay a little more. It is also possible that there could be some coordination issues, in that new applications – especially IoT and M2M uses – might be encouraged by better rural coverage, yet mobile operators cannot be sure that these new uses will take off when considering whether to make incremental coverage investments. There could be some benefits in terms of

[37] See Decision 2017/899 of the European Parliament and Council of 17 May 2017 on the use of the 470-790 MHz frequency band in the EU ("UHF Band EP&C Decision").

public safety and provision of emergency services from extending coverage, though for that benefit to be material areas where people spend time need to be covered, rather than highly remote areas.

At best, these arguments provide some basis for selective interventions aimed at providing coverage in areas where there are likely to be overall social benefits that exceed costs. They do not support any broader notion that coverage should be ubiquitous.

4 Implications for spectrum awards

We now consider the implications of interventionist coverage obligations on spectrum awards. Such interventions have historically tended to be implemented as obligations within spectrum licences.

Because interventionist coverage obligations constrain the behaviour of mobile network operators, they come with an associated cost. This will be crystallised in a reduction in the value of spectrum licenses encumbered by interventionist coverage obligations. There may be broader implications for the efficiency spectrum award processes, especially when the obligations are asymmetric, falling on just a subset of operators (and possibly just one licensee).

In contrast, what we have called precautionary coverage obligations are not expected to constrain the competitive behaviour of network operators (at least not significantly under typical conditions) and so have little cost associated with them. Precautionary obligations tend to be applied symmetrically to operators. Therefore, unlike interventionist obligations, precautionary obligations are likely to have limited effects on spectrum award processes.

4.1 Revenue and efficiency

In spectrum awards, efficient allocation is typically the main objective of the auction, rather than maximising revenue. Revenue may nonetheless be raised as revenue is a by-product of an efficient competitive allocation process. Regardless of the details of the auction format, efficient allocation requires winners to pay at least the opportunity cost of spectrum to the losers, otherwise the losers would be prepared to outbid the winners.

With reasonably symmetric bidders, changes to auction formats that reduce efficiency also tend to reduce revenue (i.e. revenue and efficiency are often aligned, rather than opposed). For this reason, arguments that spectrum auctions lead to unreasonable or even excessive revenue generation are incorrect. Rather efficiency and revenue generation are broadly aligned, as an efficient competitive process will generate revenue and an inefficient process would typically generate less revenue.

In most spectrum auction formats, auction revenue is determined by the valuations of the marginal losers for spectrum; this is what the winners need to pay to clinch the spectrum from the strongest losers. (The exact details of the award format are not relevant.) Therefore, interventionist coverage obligations will reduce the value of spectrum to all bidders – including the price-determining losers – and so reduce revenue raised.

Whilst maximising revenue is not an objective in choosing an auction design, from the broader perspective of the State, setting an interventionist coverage obligation comes at a cost in terms of foregone revenue. Therefore, in effect, incremental coverage improvements are being procured, with the reduction in auction revenue reflecting the cost of the obligation. Tougher coverage obligations will come at greater cost in terms of reduced revenue. Although revenue raising is not the objective when allocating spectrum and choosing an auction design, when designing an appropriate form of coverage constraint, we need to balance the loss of auction revenue – which represents the cost to operators of meeting the coverage obligation – with the likely external benefits of the additional coverage.

4.2 Coverage lots

Coverage obligations have typically been implemented as obligations on spectrum licences, either by attaching them to the whole band, or more often to a specific lot. When an interventionist coverage obligation is attached to a lot, the cost of additional roll out to meet the obligation must exceed any additional revenue generated, otherwise the network operator would have already rolled out in that area. Therefore, there is always a net cost of an interventionist coverage obligation to the bidder.

The value of the encumbered lot will be lower than if it were unencumbered, to the extent that the coverage obligation requires roll-out beyond competitive levels. Attaching the obligation to a lot means that the cost of serving the target areas needs to be taken into account by bidders when valuing the spectrum.

4.2.1 Avoiding negative valuations

It might be necessary to bundle a certain minimum amount of spectrum with a coverage obligation to ensure that the cost of the coverage obligation does not overwhelm the value of the spectrum to bidders (less any reserve price), otherwise the coverage lot would go unsold.

If the cost of complying with a coverage obligation attached to a lot is substantial, it might be necessary to offset this by increasing the bandwidth of this lot compared with unencumbered lots. This can also be achieved by allowing operators to request a minimum spectrum package in order to be able to meet the obligation (as done in the German multiband auction, described earlier in Section 3).

Auctions with package bidding (such as clock auctions, the CCA or the CMRA) provide the possibility for bidders to bid for packages in which a coverage obligation is linked to sufficient spectrum to make the overall package desirable (i.e. of overall positive value given the coverage obligation).

Very onerous coverage obligations could potentially involve a bidder having to win a large amount of spectrum to get that bidder to accept the obligation. In some cases, this might be a significant proportion of the spectrum available in the award. If so, the coverage obligation may have significant effects on the packaging of spectrum and also what outcomes the auction may achieve.

Given the difficulties in both estimating the costs of coverage obligations and the likely value of spectrum to bidders, there is inevitably some risk that poor regulatory choices about the coverage obligations and the spectrum packaging could result in the value of a coverage lot to an operator being negative. This would leave inefficiently unallocated spectrum, as well as failure to achieve any coverage improvement.

Furthermore, even if a coverage lot is attractive to at least some bidders, it is possible that there could be a reduction in the intensity of competition within an auction if a coverage obligation is sufficiently onerous that not all bidders would be prepared to take it on (given its reserve price). This may have consequences for the efficiency of the spectrum allocation, as that part of the available spectrum bundled with the coverage obligation is not available to all bidders. An onerous coverage obligation implemented as a coverage lot might in effect reserve spectrum for those bidders – most likely the strongest incumbents - able to meet the obligation.

These simple examples show that there is potential for coverage lots – that is some amount of spectrum with a bundled coverage obligation – to distort the allocation of spectrum. This problem arises specifically because the coverage obligation is tied to spectrum, so it is not possible subsequently to *not* allocate the coverage obligation (say because it is poor value) without also leaving spectrum unsold. This risk becomes increasingly great as the coverage obligation becomes more onerous and costly to meet.

4.2.2 Expressing the State's willing to pay

Attaching a coverage obligation to a licence essentially represents the procurement of incremental coverage, even when bundled in with spectrum.

It would be inefficient to procure a coverage increment if its cost (which is directly reflected in the reduced auction revenue) exceeds the external benefit achieved from the coverage obligation. Therefore, the commonly-used approach of procuring coverage by tying an obligation to a spectrum block implies that the State is willing to pay for coverage up to an amount that is equal to the full market value of the spectrum without the obligation[38]. There are a number of important implications that follow from this observation.

First, the incremental coverage that can be procured is limited by the value of the bundled spectrum even if the reserve price of an encumbered lot is set to zero. This is particularly relevant for the 700 MHz band. We have not conducted a detailed assessment of the likely market value of 700 MHz spectrum in Ireland, but European benchmarks suggest that it would be unlikely for the market price of a 2x10 MHz block at 700 MHz to exceed €50m. In contrast, Oxera estimate the cost of extending one mobile network to 99.5% population coverage at 30 Mbps to be in the order of €500m.[39]

Therefore, if coverage obligations are significant, it might be necessary to attach those obligations to large amounts of spectrum which could result in the allocation of that spectrum becoming concentrated. Any such distortion to the spectrum allocation represents an further social cost of allocating the coverage obligation in this way on top of the additional costs incurred by network operators in meeting the obligation.

At least in principle, it is possible to allow the price of a coverage lot to become negative within a spectrum auction (i.e. procuring the coverage obligation with some spectrum attached rather than selling spectrum). It might also be possible to procure the coverage obligation separately to the allocation of the spectrum, as we discuss in Section 5. However, these approaches require that the legal framework allows spectrum authorities to award lots at negative prices, which may not be possible in some jurisdictions.

Second, it is not at all obvious that the State's willingness to pay for procuring coverage should be linked to the value of spectrum itself, as would be implicitly expressed by bundling coverage with spectrum. For instance, suppose that there was a reasonable estimate of the external value of a coverage improvement. This should be the State's maximum willingness to pay for the coverage extension. In this case, it might be more appropriate to procure the coverage extension – whether or not as part of a broader spectrum award – separately from spectrum, with the possibility of not procuring it at all if it were too costly. We return to this idea of 'unbundling' coverage obligations from spectrum in Section 5.

[38] We are ignoring any reserve price for the spectrum lot here. If the coverage lot has a positive reserve price, then the State's maximum willingness to pay for assigning the coverage obligation is the market price of the unencumbered spectrum, less the reserve price.

[39] Oxera/Real Wireless, Future Mobile Connectivity in Ireland (ComReg Document 18/103c), prepared for ComReg, November 2018

4.3 Potential auction distortions

Onerous coverage obligations can lead to certain unavoidable distortions within spectrum auctions. The choice of auction design can only go part way to removing the impact of bidder asymmetries and risks created by lots going unsold.

For example, bidders may have different net costs of serving the incremental coverage area. Smaller operators and smaller networks may be less able to partially offset the costs of greater coverage through additional revenue. Interventionist coverage obligations may exacerbate asymmetries between bidders, in that some bidders may be more able to meet the obligations than others, leading to reduced competition for coverage lots and allowing one operator to pick up spectrum particularly cheaply. Whilst we might try to pick an auction design that is more robust to weak competition for certain lots, the reduction in competition arises regardless of the auction format, being ultimately due to the harsh coverage obligation.

An operator might be at an advantage in trying to obtain the coverage lot if it has widespread fixed infrastructure. This might allow it to meet the obligation more cheaply if it has better access to backhaul and cell sites. In turn, this could lead to asymmetric competition for the coverage lots. Alternatively, asymmetries might arise because one mobile network operator already has greater coverage than others, reducing the incremental cost of meeting a coverage obligation.

The competitive impact of such asymmetries will be even more pronounced when combined with common value uncertainty about the costs of meeting the obligation. This can lead to magnification of valuation asymmetries in bidding behaviour.[40] Therefore, we should be careful about creating predictable asymmetries across bidders, as these can have substantial effects on competition within auctions (even if there are multiple bidders potentially willing to take on coverage obligations).

Moreover, in auctions with package bidding such as CCAs, coverage obligations could create an opportunity for an operator to exploit its relatively strong position in competing for the coverage lot to leverage its cost advantage to obtain more spectrum. It can do so by bidding only for the coverage lot if it is packaged with a large amount of other spectrum. This could lead to the advantaged

[40] See Klemperer, Paul, "Auctions with Almost Common Values: the Wallet Game and its Applications", European Economic Review Conference Volume, Vol. 42 (1998), pp. 757-69.

coverage provider securing more spectrum than it should efficiently receive.[41]

A further, if rather extreme scenario, is that new entrants are unlikely to be as effective in competing for encumbered lots, as they find it more costly to meet coverage obligations than incumbents. If entrants are restricted in the lots they can feasibly bid for, this may allow the incumbents to engage in strategic bidding by driving up the prices of non-encumbered lots, thus forcing entrants that are not able to take up the coverage obligation to leave an auction empty-handed. This simple example demonstrates that the distortions created by costly coverage obligations may also affect the allocation of unencumbered spectrum lots, not just coverage lots.

A broad concern is that softened competition for coverage lots could result in the coverage provider being paid more than its actual cost of providing the coverage increment. The surplus is funded by the State through reduced auction revenue and needs to be factored in as a cost of procuring the coverage obligation in this way.

In the most extreme case, it is possible that the winner of the coverage lot gets a discount on spectrum in return for a coverage level it would have provided anyway. This is because in most auction formats the discount is determined by the costs of the marginal losing bidder for the encumbered lot, who could have much higher costs of meeting the coverage obligation. However, such a scenario would arise only under a poorly defined obligation (in that only one party could efficiently meet it) and probably would be the result of a fairly asymmetric market to start with.

These examples illustrate the potential for coverage obligations on lots to affect auction outcomes in various ways and in some cases, severely. Competitive distortions from coverage obligations can be expected to become worse the tougher are coverage obligations.

Auction distortions from collusive behaviours are also harder to prevent through reserve prices once interventionist coverage obligations are used. Given the difficulty of knowing what cost is being imposed on the coverage provider, and which might differ per bidder, there are likely to be difficulties in estimating a reserve price for a coverage lot; this uncertainty will result in setting a lower reserve price in order to control the risk of the lot going unsold. Therefore, when imposing a coverage obligation, reserve prices may become a less powerful instrument against tacit collusion or pre-auction consolidation of bidding interests.

[41] There may be adaptions of auction rules that can reduce the impact of such leveraging strategies. For example, a bidder bidding for a large amount of spectrum with a coverage obligation might also be required to make a bid for a smaller amount of spectrum with the coverage obligation. However, such measures come at some risk that bidders could be forced to make a bid of negative value, potentially leading to no bids for coverage.

5 Options for procuring coverage

When procuring an increment in coverage through an interventionist coverage obligation tied to spectrum, it is important that the State expresses some maximum willingness to pay for the increment, related to the external benefits that it will generate. The socially optimal level of coverage is less than ubiquity. Moreover, the State is likely to have a declining incremental value on ever greater coverage improvements; as coverage become more extensive, the additional benefit from increasing it further diminishes.

Having a clear view of the external benefits that a mobile coverage increment might generate is important for making broader policy choices about connectivity. For example, increasing population coverage to extremely high levels is not only very costly, but also each successive increase in population coverage creates less and less external benefit. Other forms of invention may represent better value than further increases in population coverage, for example a separate target for road coverage or covering business premises that might not count towards a population coverage obligation. There may also be other interventions (for example, improvements in rural fixed connectivity) that at some point might be better value for money than yet further increases in mobile connectivity, not least as fixed connectivity might be important to support in-building mobile use.

In this section, we run through some of the options for how an interventionist coverage obligation might be procured. Ideally, we would want to ensure that distortions of the spectrum award process are kept to a minimum. As the State is in effect *procuring* additional coverage even when this is embedded within a spectrum award process, we need to ask whether value for money is being achieved. This means ensuring that coverage is procured only when the external benefits exceed the loss of auction revenue from imposing the obligation (which measures the cost of coverage obligation).

If there is a limited field of potential suppliers of coverage extensions, this may weaken competition in an award process and could lead to sub-optimal outcomes, allowing the winner of the coverage obligation to exploit its strong position. With interventionist coverage obligations there is a severe risk that the State will only have one or two potential suppliers and award process design should recognise this problem.

Auctions offer considerable flexibility to resolve some of these problems. Although seldom used to date, auctions have the potential to explore award of alternative levels and forms of coverage obligation depending on their relative cost. The option to procure different coverage increments, or no increment at all, can exert countervailing buyer power if there is a limited field of suppliers and so help the State achieved value for money in procuring coverage. Nevertheless, if strongly interventionist coverage obligations are linked to spectrum licences, then it is likely that some distortions of the auction process will result.

5.1 Coverage lots again

As we have discussed in Section 4, the most common means of allocating interventionist coverage obligations, especially where these apply to only one or two operators, is to bundle them with spectrum. These coverage lots would typically have a reduced reserve price relative to similar unencumbered spectrum lots. The reserve price might even need to be reduced to zero if the obligation is onerous.

In principle, even a negative reserve price could be set for a coverage lot, with the State being willing to pay someone to take it. This represents the situation in which the cost of the coverage obligation exceeds the value of the spectrum on an unencumbered basis. However, in some jurisdictions there may be legal difficulties in allowing for negative bids and prices within a spectrum auction, though an analogous situation occurs in many procurement auctions run by the public sector.

There have been a number of auctions that include coverage lots in some form or another. The annex discusses the Danish 800 MHz and 1800 MHz auctions, in which coverage obligations were broken up regionally and assigned with a spectrum block. Spectrum came with a default coverage obligation that could be cancelled by winning an "exemption" lot. The use of CCA allowed bidders to bid for packages including both spectrum and exemption lots.

Whilst these Danish auctions provide a good example of how flexibility with regard to the allocation of coverage obligations can be developed within an auction, ultimately it was still the case that if no one was willing to take on the coverage obligation then spectrum would go unsold. As we have discussed in Section 4, this approach comes with the risk that the allocation of spectrum could be distorted if the coverage obligation were too costly. Therefore, these approaches that bundle spectrum with coverage – even as flexible a manner as the Danish auctions – will tend to limit the scale of coverage obligations that can be set for fear of distorting the spectrum award.

5.2 Unbundled coverage obligations

Although this approach has not been often used for mobile coverage obligations, it should be remembered that there may be little need for interventionist coverage obligations falling on just some operators to be bundled together with spectrum. This is particularly the case in mature markets where incumbent operators already have spectrum in place, especially below 1 GHz (which is needed for providing wide area coverage). When a new spectrum band is awarded, it may be that the allocation of the spectrum is only weakly coupled with the allocation of the coverage obligation (remember that we are only concerned here with some, not all, operators taking on the obligation). To be precise, this means that bidders each have some cost of taking on the coverage obligation, but this cost is largely independent on what spectrum they win in this particular award. Clearly this situation presumes that the coverage obligation is flexible in which spectrum may be used to meet the obligation.

In contrast, the allocation of an interventionist coverage obligation could be strongly coupled with the award of spectrum if that spectrum band is required for dispatching the obligation (for example, as the band is needed for the next technology generation and other possible bands would need to be re-farmed). In this case, winning spectrum within the awarded band may strongly affect the cost of meeting the coverage obligation. Where there is strong coupling, the efficient allocation of the coverage obligation depends on the efficient allocation of the spectrum and vice versa. Therefore, where there is strong coupling, it is essential to have an integrated award process for spectrum and coverage.

In practice, there may be grey areas between the weakly coupled and strongly coupled cases. However, as time goes by and network operators have established portfolios of spectrum, the weakly coupled case is becoming more relevant, as the award of a particular new spectrum band might prompt the setting of interventionist coverage obligations, but it is not necessarily essential to meet those obligations if operators have other spectrum and might in any case expect to win a useful part of that new band. This would appear to be the likely situation in Ireland going into the 700 MHz award, in that 800 MHz and 900 MHz spectrum usage rights have already been allocated and 800 MHz spectrum is not encumbered by any legacy usage.

Put simply, we would not expect an operator to need to win additional 700 MHz spectrum simply to meet any coverage obligation ComReg might set. In the intervention areas that the operator was required to cover, traffic density would be low (otherwise the operator would have chosen to cover it anyway even without the obligation). Therefore, overall spectrum requirements should be determined by traffic and speed requirements in urban areas, not in the intervention areas.

In the weakly coupled case, where existing sub-1 GHz spectrum usage rights are allowed to be used to meet the obligation, it may be possible to split the award of spectrum and the procurement of a coverage improvement into two stages within an award process. It may also be feasible to procure a coverage obligation in an entirely separate process from spectrum either before or after the award of spectrum. Therefore, it may be possible to see first what can be achieved with a precautionary coverage obligation and then only intervene later to procure a coverage improvement if coverage proves deficient.

Procuring coverage might be run just like a procurement award with an explicit payment (with the State's maximum willingness to pay for cover being represented by its budget for the procurement). This would be analogous to the NBP award currently in train in Ireland.

It is also possible to link receipts from a spectrum award with a separate procurement of coverage. For example, there could be a follow-up stage within a common award process in which bidders compete on offering discounts on spectrum prices to take on the coverage obligation. The proposed Danish multiband award for 700 MHz has this feature (see box below). Alternatively, the coverage obligation could be procured prior to the award of spectrum, with bidders bidding for coverage in terms of bidder credits that get added to their bids in a following award of spectrum.

Danish 700 MHz, 900 MHz and 2300 MHz auction

The Danish Energy Agency has proposed using competitively set coverage obligations for the award of spectrum in the 700 MHz, 900 MHz and 2300 MHz bands. The format currently proposed in the draft auction materials[42] includes coverage obligations assigned to three lots of 2x10 MHz spectrum (either in the 700 MHz or the 900 MHz band based on the preferences of the bidder with a maximum of one lot per bidder) and a coverage obligation on single 40 MHz lot of 2300 MHz spectrum.

The remaining lots and any unsold lots will be auctioned in a CMRA process. The final stage in the auction enables bidders to bid for a reduction in the amount payable for won spectrum in return for taking on coverage obligations in certain regions. In a sealed bid format bidders are able to bid the minimum willing reduction in price they are willing to accept in exchange for taking on coverage obligations in any number of 24 target regions. Each coverage target region has a maximum price reduction. Coverage targets cannot be assigned to more than one bidder and a bidder cannot have a greater reduction than their final price at the end of the earlier stages (i.e. the amount they bid for won lots and the assignment price).

A further advantage of separating the procurement of coverage interventions is that the timing of any such procurement can be

[42] https://ens.dk/ansvarsomraader/frekvenser/auktioner-og-udbud-frekvenser

determined independently of particular spectrum becoming available and being awarded. This gives regulatory authorities much more opportunity to see what can be achieved without onerous interventions. For example, a precautionary coverage obligation could be applied symmetrically on spectrum award, but the option could be maintained to procure a coverage extension from one or more network operators at a subsequent time if competitively determined coverage proved insufficient.

5.3 Coupling of coverage and spectrum

A key problem with the common coverage lot approach is that the fixed bundling of spectrum with asymmetric, interventionist coverage obligations does not allow the State to exercise its reasonable preferences in terms of not awarding a coverage obligation if its cost is too high without at the same time not awarding the bundled spectrum. This is inflexible and makes it difficult for the State to deal with weak competition in an auction and ensure value for money, as the State is not able to exercise any countervailing buyer power against a limited field of suppliers of the coverage obligation.

Full separation of the award of spectrum from the award of the coverage obligation is one possibility. However, unless coverage and spectrum are weakly coupled (in the terminology set out above), this risks inefficient outcomes, as who is best placed to get spectrum depends on who gets the coverage obligation and vice versa.

However, even if bidders' valuations exhibit strong coupling between spectrum and coverage obligations, there are still a range of options available for the State to exercise a greater degree of conditionality in procuring coverage. Perhaps the most important aspect of conditionality is the ability to choose not to procure a coverage obligation if it too costly without also leaving some spectrum unallocated. This can be easily achieved with combinatorial auction formats such as the CCA or the CMRA. In particular:

- spectrum can be offered as various categories of lots in the usual manner;
- there is a separate coverage lot set at a negative reserve price, which expresses the State's maximum willingness to pay for procuring the coverage obligation;
- bids are made for packages of spectrum and optionally also the coverage lot;
- the price of the coverage lot increases (subject to a ceiling at zero) if there are multiple bidders prepared to take it.

This approach does not guarantee that the coverage obligation is awarded, but it does ensure that it is awarded only if the cost of doing so is not too high. The reserve price expressed the State's willingness to pay for the coverage obligation, which should be linked to the external benefits that the obligation could create.

Auctions of this form vary from common experience of spectrum auctions, in that the price of the coverage lot is negative and there is the possibility of negative bids for packages if the negative price of a coverage lot outweighs the positive price of the spectrum. It is possible to require that such an auction does not result in any overall payment to bidders by allowing only positive bids. However, for the reasons that we have discussed already at length, this restriction would risk some inefficiency in the outcomes, as it might require a bidder to bundle a large amount of spectrum with the coverage lot to ensure that it could make a positively priced bid. There is no avoiding this possible source of inefficiency without the State being prepared to make payments to bidders; this is one of the fundamental auction distortions that can arise from excessively costly coverage obligations regardless of the choice of auction design.

This approach also lends itself to flexible approaches in which there are coverage obligations at different scales or levels. For example, there could be a light and a heavy (interventionist) obligations (say two not-spot obligations, one extending the other). A combinatorial auction format could allow bids to be made for one or other coverage obligation (again with negative prices on the coverage lots and positive prices on the spectrum lots). Bidders could flip between the two levels of coverage obligation in the course of the auction on the basis of relative cost. Only one coverage obligation would be awarded, but the auction could determine whether it was more efficient to award the light or the heavy obligation.

It is also possible to extend this approach to awarding various combinations of coverage lots (for example, an obligation to cover population or premises and a separate obligation to cover major roads). To the extent that the coverage obligations might overlap, the State's willingness to pay might exhibit substitutability. That is the willingness to pay for allocating multiple coverage obligations is less than the value for allocating each one alone. Such objectives can be readily expressed in a combinatorial auction by including the opportunity cost to the State of any unallocated coverage lots when determining the winning combination of bids.

We have only provided a thumbnail sketch of how spectrum auctions can be extended to allow market determination of the nature and extent of coverage obligations. Nevertheless, concerns about extending mobile coverage and the availability of 700 MHz spectrum across the EU is likely to promote extensions of auction formats to accommodate more flexible allocation of coverage obligations. The current state of the art is no longer the use of coverage lots that create a fixed linkage between coverage and certain amount of spectrum, as this approach significantly risks leaving highly valuable spectrum unallocated if the costs of an interventionist coverage obligation are underestimated.

6 Conclusions

We can distinguish interventionist coverage obligations that require typical competitively determined coverage levels to be exceeded from precautionary coverage obligations that guard against competitive failures that might cause under-provision of coverage.

Precautionary obligations – even though they do not force additional coverage beyond the competitive level – have been widely used as they protect against competitive failures, such as tacit collusion not to extend coverage or cherry-picking strategies by some operators focussed on higher margin urban markets. Precautionary obligations are typically applied symmetrically.

Interventions to extend outdoor mobile coverage are not appropriate to provide indoor coverage, which can only be feasibly provided using a mix of fixed connectivity to support WiFi and mobile repeaters due to the differences in propagation of signals into buildings according to their construction.

Interventionist obligations come with a cost, as network operators are being required to extend coverage beyond what they would voluntarily choose. This leads to a reduction in auction revenues if these obligations are applied to spectrum licences.

Interventionist obligations are often applied asymmetrically, as it may be more cost effective for a subset of network operators – possibly only one – to serve the intervention area in order to benefit from scale economies. This may require associated access requirements to avoid creating asymmetries between operators.

Interventions need to generate external benefits that exceed their costs in terms of reduced auction revenues for there to be an overall net social benefit to imposing them. Therefore, there needs to be material and identifiable market failures or other strong policy objectives creating these positive external benefits to justify intervention. There are credible sources of external benefit, but we cannot expect these external benefits to typically be generally large. Therefore, intervention needs to be targeted.

Onerous interventions that impose large costs on network operators may distort spectrum award processes. In some cases, only a subset of bidders are able to take on coverage obligations, reducing competition. Large amounts of spectrum may need to be bundled with obligations to make them attractive to bidders, potentially distorting the allocation of spectrum.

Bundling spectrum and interventionist coverage obligations into coverage lots, as has been often done, risks not allocating spectrum if coverage obligations have been set too harshly and coverage lots go unsold. This also forgoes the option for the State not to award the coverage obligation if it cannot get value for money for the coverage extension being procured.

Over time mobile operators have accumulated a variety of spectrum usage rights in different bands. This may make acquiring spectrum in a new band inessential for meeting a coverage obligation. Therefore, the valuation of spectrum being awarded may only weakly interact with the costs of meeting a coverage obligation. This may make it possible to split the award of spectrum and the procurement of a coverage improvement into two stages within an award process. It may also be possible to procure a coverage obligation in an entirely separate process from spectrum either before or after the award of spectrum. This also makes it possible to see first what can be achieved with a precautionary coverage obligation and then only intervene later if coverage is deficient.

If spectrum and coverage obligations do strongly interact, it is possible to offer spectrum lots (at a positive price) and coverage obligations (at a negative price) in a single auction. Combinatorial auction formats are very suitable for doing this. This can allow the State to choose not to award a coverage obligation, or to scale it down, if its cost is too great without also causing spectrum to go unallocated.

Annex: The Danish coverage auctions

Danish 800 MHz Auction Format

The Danish 800 MHz auction followed a "Combinatorial Clock Auction" (CCA) format, but included an innovative component that allowed bidders to bid for regional exemptions from the coverage obligation that was attached to the 800 MHz licences. The auction thus allocated these exemptions together with 800 MHz spectrum itself by restricting feasible winning outcomes to those that would ensure that the coverage obligation overall would be met.

Available spectrum and lots

A total of 2x30 MHz was available, split into two lot categories:

- **A lot**: a single 2x10 MHz frequency specific lot (791-801 MHz paired with 832-842 MHz), with additional usage restrictions compared to the rest of the available spectrum; and
- **B lots**: four 2x5 MHz frequency generic lots (spanning 801-821 MHz paired with 842-862 MHz)

The A lot was subject only to the coverage obligation in coverage area 1. B lots were subject to the coverage obligation in all three coverage areas.

Both the A and B lots had a reserve price of DKK 50 million.

Since it was not necessary for the coverage obligation to be met by more than one winner, exemptions from the coverage obligations were also made available in the award. These were offered as a separate lot category for each of the three coverage areas:

- **Category E1**: Exemption from the coverage obligation in coverage area 1;
- **Category E2**: Exemption from the coverage obligation in coverage area 2; and
- **Category E3**: Exemption from the coverage obligation in coverage area 3.

Each exemption had a reserve price of DKK 10 million. Hence, to win an unencumbered A lot a bidder would have to pay at least DKK 60 million, and for a B lot with no coverage obligation the minimum price would be DKK 80 million.

The winner of an exemption lot would not be required to fulfil the coverage obligation in the corresponding coverage area. For example, a winner of B lots and E3 would be required to fulfil the coverage obligation in coverage area 1 and coverage area 2, but not in coverage area 3. A winner of the A lot (and no B lots) and E1 would not be liable for meeting the coverage obligation in any of the coverage areas.

The number of exemption lots available in each category is flexible and dependent on the number of winners of A and B lots, in that the number of exemptions that can be awarded for any given coverage area will be at most one fewer than the number of winners of lots with the relevant coverage obligation attached. This is important to ensure that the coverage obligation will be fulfilled in each coverage area by at least one bidder (provided sufficient spectrum is sold i.e. if only the A lot is sold, there is no obligation on the licensee to take on the coverage obligation in coverage areas 2 and 3).

A cap of 2x20 MHz applied to all bidders.

(Note: if there was only one applicant for participation in the award, the applicant would be able to select the A and B lots it wished to acquire at reserve prices, subject to the spectrum cap, but no exemption lots would be available).

The auction process

The auction format used was a CCA, with two stages:

- the Principal Stage, in which the number of each type of lot (including spectrum lots and exemption lots) to be awarded to bidders, and the base prices they would have to pay for those lots; and
- the Assignment Stage, in which the specific frequencies to be awarded to winners of B lots, and any additional prices to be paid by winning bidders, would be determined.

The Principal Stage

The Principle Stage consists of:

- multiple primary rounds; and
- the supplementary round.

During the primary round, bidders submit primary bids for packages of lots at given round prices. If a bidder submits a bid for a package including at least one exemption lot, if it hasn't already done so in a previous round it must simultaneously submit a bid at reserve price for the same package without any exemption lots (the 'required non-exempt package').

Primary bids are subject to activity rules, based on an eligibility points system (which is more complicated than standard due to the exemptions):

- The A lot is worth 2 spectrum eligibility points (SEPs), and each B lot is worth 1 SEP. Each exemption lot is worth 1 exemption eligibility point (EEP).
- Each bidder starts the auction with 4 SEPs, and cannot bid for packages containing spectrum worth more than that (this means that the bidder can bid for at most seven combinations

of spectrum lots (the 'Permissible Packages'): A on its own, A plus 1 or 2 B lots, 1-4 B lots).

- The number of exemption lots a bidder can bid for varies depending on the spectrum lots included in the package. A bidder will start the auction with seven different endowments of EEP, one for each permissible package. For the packages containing either the A lot only or all four B lots, only one EEP will be available (since the bidder would only be able to win an exemption for coverage area 1). For all other permissible packages the bidder will have 3 EEP.
- During a round, a bidder will only be allowed to bid for a package if (i) the SEPs associated with the package do not exceed the bidders current spectrum eligibility; and (ii) the bidder still has sufficient EEP endowment *for that specific package* to bid for any exemption lots included.
- At the end of each round, a bidder's eligibility is adjusted. For the next round: its spectrum eligibility is set to the SEP associated with the package bid for in the previous round; its EEP endowment for the package bid for in the previous round is set to the number of exemption lots included in the previous round bid; and its EEP endowments for all other packages remain unchanged.

The process for establishing whether a further primary round is required (and if so, which lot categories require a price increase) is more complicated than in a standard CCA (without exemptions) as it is important to ensure there is an outcome in which at least one winner is subject to the coverage obligation in each coverage area. A provisional winner determination process is run based on all bids submitted so far, establishing the combination of bids (provisional winning bids) that yields the highest total value of bid amounts, such that:

- the aggregate demand for lots in all provisional winning bids does not exceed the supply of lots (the availability of exemption lots is determined by the number of A lot and B lot winners); and
- at most one bid from each bidder is selected.

This may yield multiple tied combinations of provisional winning bids.

If one of these combinations allocates every bidder at least as many lots in each lot category as it included in its current primary bid, then there is no excess demand and the primary rounds end.

If no such outcome exists, then it is considered that there is excess demand for any lot category where, in *any* of the tied provisional solutions, any bidder is allocated fewer lots than it had included in its current primary bid. Another round is required and prices are increased for lot categories with excess demand.

Once the primary rounds close, the **supplementary bids round** is run. This is a single round in which bidders can:

- increase bids for packages they already bid for in the primary rounds;
- increase bids for packages for which they submitted a required non-exempt bid in the primary rounds; and/or
- submit bids for packages for which they are eligible to bid, but chose not to bid for in the primary rounds (if the package includes exemption lots, the bidder must also bid for the corresponding non-exempt package).

The supplementary bid amounts for all packages other than the package bid for in the final primary round would be subject to a relative cap (we do not provide details here).

Following the supplementary round, winners would be determined on the basis of selecting the combination of bids from amongst all primary and supplementary bids submitted that maximises total bid value, subject to the conditions that:

- the aggregate demand for lots in all winning bids does not exceed the supply of lots (noting that the availability of exemption lots is determined by the number of A lot and B lot winners); and
- at most one bid from each bidder is selected.

Note that the requirement on aggregate demand

Base prices would be determined using an opportunity cost based pricing rule.

Assignment stage

Since the B lots were awarded in the Principal Stage as frequency-generic lots, and Assignment Stage is run in order to establish the specific frequencies to be assigned to each B lot winner, using a second-price sealed bid process.

The frequency options available to each winner would be determined for each winner, based on the number of A lots and B lots they have won and such that:

- each winner is assigned contiguous frequencies (noting that any B lots awarded to the A lot winner would be located adjacent to the A lot); and
- unsold B lots are placed at the lowest position in the band that still allows for any B lots assigned to the A lot winner to be located adjacent to the A lot.

If there is flexibility over the frequency assignments, winning bidders could submit bids to express preferences over the frequency options available to them.

The winning bids would be established based on the set of bids that maximises the total of the bid amounts and represents a feasible assignment of frequencies.

Winning bidders would be required to pay an Additional Price (which could be zero), calculated using an opportunity-cost based pricing rule.

Danish 1800 MHz Auction Format

The 1800 MHz award process applied a slightly different approach to assigning the coverage obligation to that used for 800 MHz licences, with bidders able to apply for taking on the coverage obligation in (at most) one of the Coverage Area Groups (see box in Section 2.5.1) in return for being awarded a 2x10 MHz block at the reserve price. The auction would then proceed to assign the rest of the spectrum and any remaining coverage obligations, with bidders also able to bid for exemptions to providing the coverage obligation in one or more of the Coverage Area Groups (only if there were coverage obligations still needing to be assigned at this point).

In total there were four stages to the auction, detailed below.

Available spectrum and lots

A total of 2x64.9 MHz or 2x65 MHz of spectrum was available, depending on whether Hi3G won additional spectrum and its existing 2x10 MHz licence could be moved (which would free up 0.1 MHz at the bottom of the band for assignment) – for simplicity, in this explanation of the award process we assume 2x65 MHz was available (in particular as Hi3G did win spectrum, so this was the scenario that occurred).

The spectrum lots available fell into two categories:

A lots: three frequency generic 2x10 MHz lots, each with a coverage obligation for one of the three Coverage Area Groups attached; and

B lots: the remaining spectrum, plus any of the A lot spectrum not allocated in the initial stages of the auction (see below), available as frequency generic 2x5 MHz blocks. By default, the coverage obligation for any of the Coverage Area Groups not assigned with an A lot would be attached to all of the B lots.

The A lots had a reserve price per lot of DKK 50 million, whilst the reserve price for the B lots was 25 million (i.e. the A and B lots had the same per MHz reserve price).

Exemption lots in up to three categories would also be offered in the case that any of the A lots were unallocated:

- **Category C1**: Exemption from the coverage obligation in group 1;

- **Category C2**: Exemption from the coverage obligation in group 2; and
- **Category C3**: Exemption from the coverage obligation in group 3.

A reserve price of DKK 0 was applied for each exemption.

A spectrum cap of 2x30 MHz applied to all bidders in the auction.

First auction stage

The first auction stage was for assigning the A lots, which bidders could apply for as part of their application. A bidder could apply to be assigned at most one A lot together with a Coverage Area Group.

If no bidders applied for an A lot, not A lots would be assigned.

If three or fewer bidders applied for an A lot, each of those bidders would be assigned an A lot at the reserve price (DKK 50 million).

If more than three bidders applied for an A lot, a sealed bid process would be used to determine the three winners. Bidders that applied for an A lot would be invited to submit a singled sealed bid for being assigned an A lot; the three highest bids would win, and the winning bidders would be required to pay a first auction stage price equal to the fourth highest bid amount.

Second auction stage

In the second auction stage, winners of A lots would be assigned a specific Coverage Area Group. This would be based on bids for the different Coverage Area Groups submitted by the winning bidders as part of their application (and that would have allowed them to express their preferences over the different groups).

The A lot winners would be liable for a second auction stage price (which could be zero) for being assigned a specific Coverage Area Group, calculated using an opportunity-cost based pricing rule.

Third Auction Stage

In the third auction stage, the B lots and any exemption lots available would be assigned.

If all A lots were assigned in the first auction stage, then there would be seven B lots (with no coverage obligation attached), and no exemption lots required.

If any of the A lots were unassigned, the corresponding spectrum would be included in the third auction stage as B lots (i.e. there would be nine, eleven, or thirteen B lots), plus exemption lots for each Coverage Area Group not already assigned alongside an A lot.

The third auction stage used the novel Combinatorial Multiple Round Auction (CMRA) format, developed by DotEcon and first used for the Danish 1800 MHz award. With the CMRA, the auction proceeds over multiple rounds and bidders can submit one or more package bids in each round, subject to constraints based on current round prices and activity rules that restrict bidding behaviour based on bids submitted in previous rounds.

Each package bid, in this case, would be for a number of B lots plus any exemption lots (if applicable, and at most one per exemption lot category) the bidder wished to bid for. In any given round, a package bid can be either:

- A 'headline bid' – a bid for a package at round prices specified by the auctioneer (only one headline bid is possible each round); or
- An 'additional bid' – bids for other packages, where the bidder can specify a bid amount (subject to certain constraints).

At the end of each round, bids are evaluated to determine whether the auction stage should end or if another round is needed (and in which case, which lot categories prices should increase for). This process is complex and is not described in detail here, but broadly speaking the third auction stage would end when it is possible, taking into account all bids submitted so far, to accept exactly one bid from every bidder (which may be a zero bid if a bidder has dropped out of the auction) and there is no outcome achieved by not accepting a bid from one or more bidders that would yield a higher total value of bids. If such an outcome does not exist, the auction continues for another round with prices increasing for one or more lot category.

The key rule regarding the exemption lots is that any feasible outcome has the requirement that the number of exemption lots awarded for any exemption lot category must be at most one less than the number of B lot winners. This guarantees that if any B lots are awarded, at least one winning bidder will be assigned the coverage obligation for each of the Coverage Area Groups included in the third auction stage.

Winning bidders would be liable to pay a third auction stage price that is equal to the amount of their winning bid.

Fourth Auction Stage

Recall that the A lots and B lots are frequency generic. The fourth auction stage determines the specific frequencies to be assigned to each winning bidder, using a second-price sealed bid process.

The frequency options available to each winner would be determined for each winner, based on the number of A lots and B lots they have won and ensuring each winner is assigned contiguous frequencies. Winning bidders could submit bids to express preferences over the frequency options available to them.

The winning bids would be established based on the set of bids that maximises the total of the bid amounts and represents a feasible assignment of frequencies.

Winning bidders would be required to pay a fourth auction stage price (which could be zero), calculated using an opportunity-cost based pricing rule.