European Commission

Study on Spectrum Assignment in the European Union

FINAL REPORT

A study prepared for the European Commission

DG Communications Networks, Content & Technology by:

LS telcom VVA PolicyTracker

Digital Single Market

This study was carried out for the European Commission by

Saul Friedner
Richard Womersley
Andrea Moyano

LS telcom AG
Im Gewerbegebiet 31-33
D77839 Lichtenau
Germany

Pierre Hausemer
Georg Bolits
Francesco Pitton

Valdani Vicari & Associati
Via Torino 61
20123 Milano
Italy

Martin Sims

Unit 116 Chester House, Clarendon Business Centre,

81-83 Fulham High Street,London SW6 3JA

UK

Internal identification

Contract number: 30-CE-0812503/00-12

SMART number: 2016/0019

DISCLAIMER

By the European Commission, Directorate-General of Communications Networks, Content & Technology.

The information and views set out in this publication are those of the author(s) and do not necessarily reflect the official opinion of the Commission. The Commission does not guarantee the accuracy of the data included in this study. Neither the Commission nor any person acting on the Commission's behalf may be held responsible for the use which may be made of the information contained therein.

ISBN 978-92-79-68724-2

doi:10.2759/509541

© European Union, 2017. All rights reserved. Certain parts are licensed under conditions to the EU.

Table of Contents

ABSTRACT **6**

ABSTRAIT **6**

EXECUTIVE SUMMARY **7**

Introduction 7

Status of spectrum authorisation and assignments across Member States 7

Wider adoption of all existing authorisation choices would help to unlock benefits for enabling new 5G services 8

The selection procedures for future mobile assignments will be vital to ensure benefits of 5G services 9

Recommendations 10

SOMMAIRE EXECUTIF **13**

Introduction 13

Statut de l'assignation dans les États membres 13

L'adoption de méthodes d'autorisations plus larges aiderait à débloquer les avantages pour l'activation de nouveaux services 5G 14

Les procédures d'assignation mobile seront essentielles pour réaliser les bénéfices de la 5G 15

Recommandations 16

1 OVERVIEW OF EXISTING EU SPECTRUM FRAMEWORK **19**

1.1 Current EU spectrum public policy framework 19

1.2 Definition of General Authorisation and Individual Rights of use 23

2 STATUS OF EXISTING SPECTRUM AUTHORISATION APPROACHES ACROSS 28 EU MEMBER STATES **32**

2.1 Status of spectrum authorisations and assignment approaches used across EU Member States 32

2.2 Overview of spectrum bands identified for 5G in the EU 43

3 ANALYSIS OF SPECTRUM GENERAL AUTHORISATION AND INDIVIDUAL ASSIGNMENT APPROACHES FOR FUTURE POLICY **45**

3.1 Introduction 45

3.2 Methodology for analysis 46

3.3 Scenarios for testing different spectrum access approaches 53

3.4 Summary of approaches to authorisation 83

3.5 Summary findings 86

3.6 Impact of elements and conditions of mobile spectrum assignments on market outcomes....87

3.7 Overview of findings....103

3.8 Identification and analysis of the impacts that the selection of an assignment approach might have on the Member States 107

4 CONCLUSIONS 120

4.1 Status of general authorisation and individual rights of use across Member States...120

4.2 Impact to assignment procedures and conditions attached to the rights of use for spectrum 122

5 APPENDIX A – MOBILE ASSIGNMENTS DATA 125

5.1 Introduction....125

5.2 Overview of spectrum assignments in Member States....125

5.3 Member States divided into quartiles based on ARPUs 129

5.4 Prices paid for various licence lengths in selected spectrum bands 130

5.5 Ranking of spectrum auction prices since 2007 132

5.6 Licence length since 2007....133

5.7 4G availability across EU Member State and auction price ranking....134

5.8 Coverage requirements 135

5.9 Reserve prices since 2007....137

5.10 Data on network availability and network speed....138

5.11 Total number of national operators and number of operators offering 4G networks ..139

5.12 Proportion of users subscribing to mobile broadband services....140

5.13 Consumer prices....141

5.14 Spectrum award dates across EU for 800 MHz and 2600 MHz....142

5.15 The grouping approach to comparing inputs with outcomes....142

6 APPENDIX B – STAKEHOLDER ENGAGEMENT 148

6.1 Overview of the public workshop....148

6.2 Stakeholder representation 151

6.3 Approaches to assignment process 156

7 APPENDIX C – EXPERT WORKSHOP 157

7.1 Purpose of the workshop 157

7.2 Findings from the workshop 157

Abstract

This report has been written by LS telcom, PolicyTracker and VVA for the Directorate General for Communications Networks, Content and Technology (DG Connect) of the European Commission. It examines the approaches used by Member States for authorising and assigning spectrum with a view to determining which methods might be most appropriate in the context of future 5G services. The study was based on four key inputs:

- Interviews with administrations and other stakeholders in all 28 Member States;
- An examination of available data concerning the elements used in authorisations and assignments and the impacts of those elements on the mobile industry and markets;
- The analysis of four use-case scenarios, which represent possible development paths for 5G services. These use cases were validated and reinforced by an expert academic panel;
- A public workshop where delegates contributed to the development and analysis of the scenarios.

The study has determined that whilst stakeholders would generally prefer to continue licensing spectrum on an exclusive, individual basis, wider adoption of a greater variety of spectrum assignment approaches would benefit the introduction of 5G services, unlocking some of the new use cases whilst supporting Digital Single Market objectives.

Abstrait

Ce rapport, produit par LS telcom, PolicyTracker et VVA pour la Direction générale des réseaux de communication, de contenu et de technologie (DG Connect) de la Commission européenne, examine les approches utilisées par les États membres pour planifier et gérer le spectre afin de déterminer lesquelles pourraient être les plus adaptées aux futurs services 5G. L'étude se base sur 4 principaux volets :

- Entretiens avec les administrations et les parties prenantes dans les 28 États membres;
- Un examen des éléments utilisés pour autoriser l'usage du spectre et leurs impacts sur l'industrie mobile;
- L'analyse de quatre scénarii qui représente des possibles développements des services 5G. Ceux-ci ont été validés et renforcés par un groupe scientifique spécialisé;
- Un atelier public où les délégués ont commenté l'analyse des scénarios.

L'étude a déterminé que, bien que les opérateurs mobiles et les autorités nationales en charge de la régulation du spectre préfèrent continuer à délivrer des licences sur une base exclusive et individuelle, une plus grande variété d'approches de gestion du spectre profiterait à l'introduction de services 5G, facilitant l'émergence de nouvelles utilisations dans les marchés verticaux rendue possible par la 5G tout en soutenant les objectifs du marché unique numérique.

Executive summary

Introduction

The next generation of mobile communication technology (5G) will bring a wide range of new services and applications to EU citizens, businesses and the public sector. To prepare for its introduction, the necessary and relevant spectrum should be made available which will require the appropriate assignment policies being in place.

This study has considered the current approaches used across the EU Member States for authorising and assigning spectrum with a view to examining:

- which spectrum assignment procedures and usage conditions (e.g. auctions and coverage obligations) have a **positive impact on the electronic communications market** including use cases such as mobile, IoT, connected vehicles and utilities;
- which authorisation approaches (ranging from general authorisation to individual rights of use) are **more adequate for the development of 5G**;
- whether a more convergent and consistent approach to these authorisation procedures within the EU could **deliver more timely availability and efficient use of spectrum for 5G**;
- whether a consistent approach to the use of elements and conditions for making spectrum assignment across the EU **resolves current specific problems, delivers spectrum for 5G more effectively and impacts mobile operators business decisions.**

The study has determined that whilst both regulators and mobile operators would generally prefer to continue adopting the current approach to spectrum authorisation and assignment approaches, wider adoption of a greater variety of approaches would benefit the introduction of 5G services, unlocking some new use cases and supporting Digital Single Market[1] objectives.

Status of spectrum authorisation and assignments across Member States

There is heterogeneity between Member States with regards to decision-making on whether to use General Authorisation or Individual Licensing. Even though other authorisation approaches, such as LSA and light licensing regimes, are available, there seems to be little enthusiasm from the industry and the general perception is that the methods that are mostly in use today are sufficient.

[1] Digital Single Market (DSM) is one in which the free movement of persons, services and capital is ensure and where the individuals and businesses can seamlessly access and exercise online activities under conditions of fair competition, and a high level of consumer and personal data protection irrespective of their nationality or place of residence, EC, 2015 https://ec.europa.eu/digital-single-market/en/digital-single-market

The fragmentation of authorisation approaches and assignments within the so-called 5G pioneer bands (i.e. 700 MHz and, 3.5 GHz) increases the complexity of the situation because this potentially impacts timing of EU-wide availability of 5G services. However, no Member States have yet taken a decision on the authorisation of the 26 GHz band and approaches are currently under consideration and may be decided before the outcome of the finalisation of the 5G specification (scheduled for 2020). There is a risk of fragmentation in national approaches if final decisions are made without coordination between Member States. This could further limit the opportunity for harmonised deployment of some of the possible services in the 26 GHz band across the EU and limit the potential benefits.

We also found there are large variations in the elements and usage conditions in spectrum assignment processes across Member States. Few one-to-one associations between conditions and market outcomes were observed, except that low prices in spectrum auctions could be seen to be associated with better availability of 4G networks, and longer licence lengths associated with higher CAPEX.

Overall, countries which practiced a group of investment friendly practices, namely low reserve prices; market-led coverage obligations[2]; and long licence lengths exhibited more positive market outcomes, namely wider network roll-out; better quality and choice of services; higher take-up of services and greater competition. Evidence also suggests that stacking up costs and uncertainty for operators through high auction prices, overly restrictive coverage obligations and short licences have a negative effect on the market.

One other notable observation is that declining licence lengths can have a negative impact on market outcomes because market and economic certainty in accessing spectrum is important to right holders. The tendency towards shorter licences does not seem to have been a deliberate policy choice but reversing this could have a positive impact on 5G since long licence durations are needed to satisfy the requirements of each of our scenarios.

Wider adoption of all existing authorisation choices would help to unlock benefits for enabling new 5G services

Given the general stakeholder preference for the status quo, and to elicit more specific responses from stakeholders the project developed four possible economic and technical 5G use case scenarios that could materialise (separately or in combination). The scenarios considered were:

1. **Mega MVNO** – large MVNOs form which utilise any available wireless network/connectivity regardless of technology to provide services to its customers
2. **Self-organising Networks** – technology makes the business of rolling-out networks more effective by handling many of the technical interactions

[2] Market-led coverage obligations mean obligations that strike a balance between MNO profitability and wider social benefit from adopting such an approach

3. **Infrastructure Economics** – the cost of rolling-out 5G is such that operators would need to heavily share infrastructure
4. **Vertically driven** – it is industry verticals (e.g. transport, healthcare, construction) that lead the roll-out of 5G, not the Mobile Network Operators (MNOs).

The scenarios considered the changes that could occur in the market and assessed whether the current regulatory framework and national practices would be suitable to accompany such changes.

The study found that the current authorisation framework is generally fit for purpose for delivering current services as Member States have at their disposal a toolkit which allows them to choose the most appropriate authorisation and assignment approaches to suit their market conditions and type of spectrum usage.

However, 5G will lead to significant changes since use cases that extend beyond traditional mobile broadband are central to its ethos. The spectrum access requirements and technical and performance characteristics of these 'vertical' services differ widely driving the way in which spectrum will be used and the associated regime under which it should be authorised and assigned.

Stakeholders interested in rapid or relatively straightforward access to spectrum may lead the change by applying pressure to SRAs (e.g. through public consultation processes) to encourage the use of light licensing, concurrent allocations and shared (e.g. LSA) approaches. Such approaches will enable new business models to take shape, new entrants to the sector and for new services to evolve in areas and markets that are not traditionally targeted by mobile operators. This will also support EU policy goals with respect to the development of the internal market.

Many use cases will be dependent on common access across EU borders and would require Member States to make spectrum available within a similar timeframe, and on a similar basis. The lack of a harmonised approach to authorisation for these types of applications could create fragmentation in the internal market and limit free movement, or in the best case scenario delay the widespread adoption of certain technologies or services.

The selection procedures for future mobile assignments will be vital to ensure benefits of 5G services

The majority of the stakeholders consulted, notably SRAs and MNOs, did not consider any significant change to the current authorisation approaches and assignment processes to be necessary or desirable. For verticals, any authorisation or assignment process would be considered, as long as their quality of service requirements can be satisfied and their long investment timescales can be supported. They also considered consistency of regulatory arrangements across the EU essential to avoid fragmentation and achieve economies of scale.

The results of the scenario analysis clearly indicates that it is essential to use of a range of authorisation approaches and assignment processes to achieve the full benefits of the envisaged 5G use cases. These benefits are strengthened if a pan-EU approach to certain elements is taken.

Operator business models, a fundamental aspect of which is the use of exclusive spectrum, will need to change to drive investment in 5G networks and enable new services. New business models will focus on different use cases and geographical boundaries and on innovative services that are not currently part of most MNOs current portfolios (e.g. provision of fully integrated services to verticals such as autonomous vehicles and connected car). Without new approaches to assignments, particularly the elements and conditions that affect investment (e.g. licence length and reserve prices) spectrum usage is unlikely to expand beyond the current operators, and services will continue to roll out in the same fashion as today (often with roll-out delays in certain bands).

We therefore conclude that other forms of spectrum authorisation will be necessary to allow access to spectrum to a much wider set of service providers to deliver new and innovative 5G services. In addition, a consistent approach to authorisation and assignment amongst all EU Member States would result in timely access to spectrum across a more diverse range of operators and deliver widespread availability of new services over a larger geographical area.

Recommendations

We have identified a number of recommendations which could help encourage a wider, more consistent and more extensive adoption of a range of authorisation and assignment approaches to bring the benefits of 5G to all EU Member States in a more timely and cost effective way, which include:

1. **Member States should explicitly identify and allocate sufficient spectrum (i.e. for innovative 5G services and verticals) to be made available on a non-exclusive/non individual basis to support those use cases for which it is necessary.** This could be achieved through greater use of general authorisation and/or through active encouragement of sharing, trading and leasing. Without this step, many of the identified benefits of 5G may not be fully realised.
2. **The Commission should investigate what constitutes sufficient and suitable 5G spectrum to ensure 5G benefits are realised for all use case scenarios.** This should include a consideration of all mobile bands (e.g. < 1 GHz, 1-6 GHz, >6 GHz).
3. **Once the necessary amount of suitable spectrum has been identified, this spectrum should be harmonised throughout the EU and assigned and authorised in a consistent way in each Member State.** This is particularly important for the industry verticals as their services regularly extend across EU borders (e.g. trains, healthcare, ITS) and as their business models are based on the need for cost efficient technologies and equipment (energy, utilities)
4. **The timing of authorisation of new bands together with their associated licence durations should be harmonised across Member States so that future renewals and possible changes of use are aligned within a consistent timeframe**. For example, the harmonised timing for the release of the 700 MHz band should be accompanied by harmonised licence durations to ensure that when the various national licences expire, any new opportunities to re-farm or re-organise the usage of the band to take account of new technologies can be implemented across the EU at the same time.

5. **For higher frequency bands (e.g. 26 GHz), assignment plans should be harmonised across Member States and appropriately sized blocks considered when authorising spectrum for different services**. With the large mix of different blocks of spectrum possible for 5G, a European assignment plan should be agreed prior to authorising access to the spectrum. A minimum set of harmonised authorisation conditions to ensure the best possible cross-border situation and most cost efficient and timely deployment should be developed. As 5G technology specifications have not yet been finalised, such a plan will need to await their formal publication (e.g. 2020) but the principles could be put in place before this.
6. **Member States should aim to align existing licenses and refarm bands to support future 5G band plan requirements (e.g. contiguous wide bandwidths) thus potentially enabling sharing between operators and new service providers.** One solution to the fragmentation issue (which could occur in any band where a change of technology leads to a need to redefine the band channels) is to ensure licensees can trade or lease spectrum, amongst themselves to allow re-farming to take place without the need to retract and re-licence the band.
7. **Administrations should be encouraged to adopt those elements which have been shown to encourage investment namely:**
   - **low reserve prices;**
   - **market-friendly coverage obligations; and**
   - **long licence lengths.**

   Whilst these elements have not been shown to be individually beneficial to investment in mobile services, taken together they can have a positive impact. These elements should therefore be considered core to any future spectrum awards.

8. **Member States should be given the flexibility to include any elements they wish in their award to facilitate their individual market needs (within reason)**. Several elements of assignment and authorisation have been shown to have minimal impact on the mobile market. Member States should therefore have the flexibility to implement those elements as best suits their market needs.
9. **Member States should be encouraged to implement non-national authorisation of some 5G spectrum in particular in higher frequencies where propagation characteristics restrict coverage**. It is unlikely that MNOs will roll-out services (in particular in the higher frequency bands) across the whole country. It would therefore be logical to allow other operators to use the same spectrum bands in the unserved areas. Awarding spectrum on a national basis may be therefore unadvisable. A consistent approach within the EU will also be important to ensure the best possible cross-border situation and most cost efficient deployment.
10. **Member States need to make sure that harmonised 5G spectrum is available to those wishing to implement new or innovative services in a way that does not preclude them on the basis of:**
    - **timely availability**
    - **excessive cost;**
    - **overly complex authorisation mechanisms; or**

- **restrictive access governed by a closed award process.**

Unlike MNOs whose business planning extends over many years, new 5G operators offering niche or bespoke services are likely to be less able to plan ahead when it comes to spectrum award. As such, there should be spectrum available, which can be accessed by such organisations on reasonable terms, conditions and timescales.

Sommaire exécutif

Introduction

La prochaine génération de technologies de communication mobile (5G) offrira une large gamme de nouveaux services et d'applications aux citoyens, aux entreprises et au secteur public de l'Union Européenne. A cette fin, le spectre adéquat devrait être mis à disposition et cela dépendra de la mise en place des politiques d'assignation du spectre appropriées.

Cette étude a examiné les approches actuelles des États membres de l'Union européenne pour attribuer et assigner le spectre, notamment :

- quelles procédures d'assignation du spectre (par exemple, les enchères) et conditions associées (par exemple, les obligations de couverture) ont **un impact positif sur le marché des communications électroniques**, y compris le marché du mobile, l'internet des objets, les véhicules connectés et les services publics ;
- quels types de licences (licences générales ou autorisations individuelles) sont **les plus appropriées pour favoriser le développement de la 5G ;**
- si une approche coordonnée, cohérente et convergente des procédures d'assignation à l'échelle européenne permette une **mise à disposition du spectre plus rapide et plus efficiente pour la 5G ;**
- si une approche cohérente des conditions pour l'attribution du spectre dans l'ensemble de l'UE **résout les problèmes spécifiques actuels, offre un spectre 5G plus efficacement et influe sur les décisions commerciales des opérateurs mobiles**.

  L'étude a montré que, bien que les opérateurs mobiles et les régulateurs préfèreraient continuer d'utiliser les méthodes actuelles d'attribution et d'assignation du spectre, l'adoption d'une plus grande variété d'approches profiterait à l'introduction de services 5G, et permettrait de nouveaux cas d'usage en 5G tout en soutenant les objectifs du marché unique numérique[3].

Statut de l'assignation dans les États membres

Il existe une hétérogénéité entre les États membres en ce qui concerne la décision sur l'utilisation de l'autorisation générale ou des licences individuelles. Même si d'autres approches, telles que les régimes LSA et licences légères, sont disponibles, il semble y avoir peu d'enthousiasme de l'industrie et le consensus est que les méthodes qui sont principalement utilisées aujourd'hui sont suffisantes.

[3] Le marché unique numérique (Digital Single Market ou DSM) est celui dans lequel la libre circulation des personnes, des services et des capitaux est assurée et où les individus et les entreprises peuvent accéder et exercer en permanence des activités en ligne dans des conditions de concurrence loyale et un niveau élevé de protection des données personnelles et des consommateurs quelle que soit leur nationalité ou leur lieu de, EC, 2015 https://ec.europa.eu/digital-single-market/en/digital-single-market

Il existe déjà une fragmentation dans les bandes dites pionnières de la 5G (i.e. 700 MHz et 3,5 GHz) car certaines agences de régulation ont déjà décidé des approches d'attribution et d'assignation du spectre. Cette approche augmente la complexité de la situation, car cela peut potentiellement avoir un impact sur le calendrier de la disponibilité des services 5G à l'échelle de l'UE. Aucun État membre n'a encore pris de décision concernant la bande 26 GHz, mais les approches sont actuellement à l'étude, et des décisions pourraient être prises avant la finalisation de la norme 5G (prévue pour 2020). Il existe un risque de fragmentation dans les approches nationales si les décisions finales sont prises sans coordination entre les États membres. Cela pourrait limiter l'opportunité d'un déploiement harmonisé de certains des services dans la bande des 26 GHz dans l'ensemble de l'UE et donc en limiter les avantages potentiels.

Étant donné la grande variation des conditions d'assignation et d'utilisation du spectre mobile dans les différents États membres, nous avons trouvé peu de correspondances directes à exploiter, à l'exception d'une corrélation entre le prix des licences et la qualité/disponibilité des réseaux 4G (un prix plus bas étant corrélé avec une meilleure disponibilité), et plus la durée des licences est longue, plus les dépenses d'investissement (CAPEX) sont élevées.

Néanmoins, nous avons constaté que dans l'ensemble, les pays avec des pratiques favorables à l'investissement, à savoir des prix de réserves bas (dans le cadres d'enchères), des obligations de couverture tenant compte du marché[4]; et les durées de licences plus longues, ont affiché des résultats plus positifs, à savoir un déploiement plus large du réseau; une meilleure qualité et choix des services; une utilisation plus large des ces services par les utilisateurs, et une concurrence accrue. Il existe également des éléments suggérant que l'accumulation de coûts et d'incertitudes pour les opérateurs, des obligations de couverture trop restrictives et des licences courtes ont un effet négatif sur le marché.

Une observation notable est que la diminution des durées de licence peut avoir un impact négatif sur le marché, car plus de certitude commerciale et économique concernant l'accès au spectre est importante pour les opérateurs. La tendance à offrir des licences plus courtes ne semble pas être une tendance délibérée et globale, mais elle représente un sujet de préoccupation. Inverser cette tendance pourrait avoir un impact positif sur la 5G car des durées de licences relativement longues sont nécessaires pour satisfaire les exigences de chacun de nos scénarios.

L'adoption de méthodes d'autorisations plus larges aiderait à débloquer les avantages pour l'activation de nouveaux services 5G

Compte tenu de la préférence générale des parties prenantes pour le statu quo, le projet a développé quatre scénarios d'utilisation économiques et techniques potentielles de la 5G, afin de susciter des réponses spécifiques des parties prenantes. Les scénarios considérés sont :

[4] Les obligations de couverture menées par le marché impliquent des obligations qui établissent un équilibre entre la rentabilité de MNO et un avantage social plus large en adoptant une telle approche

5. **Mega MVNO** – MVNO qui utilise tout réseau / connectivité sans fil disponible indépendamment de la technologie pour fournir des services à ses clients
6. **Réseaux auto-organisateurs (Self-organising Networks)** – la technologie rend le déploiement de réseaux plus facile et efficace
7. **Economie de l'Infrastructure** – le coût du déploiement 5G est tel que les opérateurs doivent partager l'infrastructure
8. **Leadership de secteurs de l'industrie** – Ce sont les secteurs de l'industrie (par exemple, les transports, la santé, le secteur de la construction) qui initient le déploiement de 5G, et non les opérateurs mobiles.

Les scénarios considèrent des changements qui pourraient survenir sur le marché et ont permis de déterminer si le cadre réglementaire et les pratiques actuelles sont adaptés pour accompagner ces changements.

Notre étude a révélé que le cadre d'autorisation actuel est adapté aux services actuels. Les États membres disposent d'outils qui leur permettent de choisir les approches d'autorisation et d'assignation les plus adaptées à leurs conditions de marché et du type d'utilisation du spectre.

Cependant, l'avènement de la 5G entraînera des changements importants à cet égard, car il est attendu que de nombreux cas d'utilisation s'étendent au-delà du large bande mobile traditionnel. Les exigences de ces services «verticaux» en matière de spectre diffèrent considérablement de celui des services mobiles traditionnels, par leurs caractéristiques techniques et de performance spécifiques, ce qui explique que la manière dont le spectre sera utilisé, et, par conséquent, le régime d'autorisation de ce spectre, sera différent.

Les parties prenantes intéressées par un accès rapide ou relativement direct au spectre pourraient prendre l'initiative et exercer une certaine pression sur les régulateurs (par exemple dans le cadre de consultations publiques) afin d'encourager l'utilisation des licences légères, des allocations simultanées et des approches partagées (par exemple, LSA). Une analyse des scénarios d'utilisation développés dans le cadre de l'étude illustre comment une adoption plus large des choix d'autorisation existants pourrait être mis en œuvre. Cela permettrait l'émergence de nouveaux modèles commerciaux, de nouveaux entrants dans le secteur et de nouveaux services qui ne sont pas servis par les opérateurs mobiles. Cela appuierait également les objectifs politiques de l'UE en ce qui concerne le développement du marché intérieur.

De nombreux cas d'utilisation dépendront de l'accès commun dans toute l'UE et exigeraient des États membres que le spectre soit disponible dans des délais similaires, et sur une base similaire. L'absence d'une approche harmonisée pourrait créer une fragmentation sur le marché intérieur et limiter la libre circulation, ou dans le meilleur des cas, retarder l'adoption généralisée de certaines technologies ou services pendant de nombreuses années.

Les procédures d'assignation mobile seront essentielles pour réaliser les bénéfices de la 5G

La majorité des parties prenantes consultées, en particulier les SRA et les MNO, n'ont pas jugé nécessaire ou souhaitable de modifier considérablement les processus d'attribution et d'assignations actuels. En revanche, les secteurs industriels (les «verticaux») envisagent

favorablement toute approche de licence tant que leurs exigences en matière de qualité de service peuvent être satisfaites et que leur longue durée d'investissement peut être protégée. De plus, la cohérence des dispositions réglementaires en Europe leur parait essentielle pour éviter la fragmentation du marché et réaliser des économies d'échelle.

L'analyse des scénarios indique qu'il est essentiel d'envisager une gamme d'approches d'attribution et d'assignation du spectre, pour tirer pleinement parti des cas d'utilisation 5G envisagés. En outre, ces avantages sont renforcés si une approche paneuropéenne est mise en place.

Les modèles d'affaires des opérateurs devront changer pour générer des investissements dans les réseaux 5G et permettre l'émergence de nouveaux services. En effet, les nouveaux modèles d'affaires concernent des cas d'utilisation, des couvertures géographiques et des services innovants qui ne font pas actuellement partie de la plupart des portefeuilles actuels des opérateurs mobiles (par exemple, la fourniture de services dédiés à certains domaines ou secteurs de l'industrie, comme par exemple, les voitures autonomes et connectées). Sans nouvelles approches des assignations du spectre, en particulier les éléments et les conditions qui affectent les investissements (par exemple, la durée de la licence et les prix de réserve dans le cadre d'enchères), l'exploitation du spectre ne devrait pas être très différente de la situation actuelle (souvent avec déploiement retardés dans certaines bandes).

Nous concluons donc que d'autres formes d'autorisation du spectre seront nécessaires pour permettre l'accès au spectre à un ensemble beaucoup plus large de fournisseurs de services, afin de permettre l'émergence de services 5G nouveaux et innovants. En outre, une approche cohérente entre tous les États membres de l'UE favoriserait un accès coordonnée au spectre pour une gamme d'opérateurs plus diversifiée et fournirait une disponibilité étendue de nouveaux services sur une plus grande zone géographique.

Recommandations

Nous avons identifier un certain nombre de recommandations qui pourraient favoriser une adoption plus large, plus cohérente et plus approfondie d'approches d'autorisation et d'affectation pour apporter les bénéfices de 5G à tous les États membres de l'UE de manière plus rapide et rentable, y compris :

1. **Les administrations devraient identifier et allouer explicitement un spectre suffisant (c'est-à-dire pour les services 5G innovants) à mettre à disposition sur une base non exclusive / non individuelle pour soutenir les cas d'utilisation pour lesquels une telle approche est nécessaire**. Cela pourrait être réalisé grâce à une utilisation accrue de l'autorisation générale et / ou à le recours à des incitatifs de partage, de mise à disposition temporaire, et de marché secondaire du spectre. Sans cela, bon nombre des avantages identifiés de la 5G pourraient ne pas être pleinement réalisés.
2. **La Commission devrait déterminer sur ce qui constitue un spectre 5G suffisant et approprié pour s'assurer que les avantages de la 5G sont réalisés pour tous les scénarios de cas d'usage.** Pour cela, toutes les bandes mobiles devraient être considérées (e.g. < 1 GHz, 1-6 GHz, >6 GHz).

3. **Une fois que le spectre approprié a été identifiée, ce spectre devrait être harmonisé dans l'ensemble de l'UE et attribué et assigné de manière cohérente dans chaque État membr**e. Ceci est particulièrement important pour les secteurs industriels spécifiques (les verticaux), car leurs services s'étendent régulièrement à travers les frontières de l'UE (par exemple, les transports, la santé, etc..) et leurs modèles d'affaires sont basés sur l'accès à des services à bas coût (énergie, services publics).
4. **Le timing de l'autorisation de nouvelles bandes et la durée de licence associée devrait être harmonisé entre les États membres afin que les renouvellements futurs et les éventuels changements d'utilisation soient synchronisé**s. Par exemple, le calendrier harmonisé pour l'attribution de la bande de 700 MHz devrait être accompagné d'une durée de licence harmonisée afin de s'assurer que, lorsque les différentes licences nationales expirent, toutes les nouvelles opportunités de réorganisation de l'utilisation de la bande puissent être mises en œuvre dans l'ensemble de l'UE en même temps.
5. **En particulier pour les bandes de fréquences plus élevées (par exemple, 26 GHz), les plans de fréquences devraient être harmonisés entre les États membres et les blocs de taille appropriée considérés lors de l'attribution du spectre pour différents services.** Avec le grand mix de différents blocs de spectre possibles pour la 5G, un plan d'assignation européen devrait être convenu avant d'autoriser l'accès au spectre. Un ensemble minimum de conditions harmonisées pour assurer la meilleure situation transfrontalière possible et le déploiement le plus rentable et le plus rapide devrait être développé. Comme les spécifications de la norme 5G n'ont pas encore été finalisées, un tel plan devra attendre la publication officielle de cette norme (attendue en 2020), mais les principes pourraient et devraient être mis en place avant cela.
6. **Les États membres visent à aligner les licences existantes et à réaménager les bandes pour qu'elles prennent en charge les futures exigences du plan de fréquence 5G, c'est-à-dire des largeurs de bande contiguës, permettant ainsi le partage entre les opérateurs et les nouveaux fournisseurs de services.** Une solution au problème de fragmentation (qui peut se produire dans n'importe quelle bande où un changement de technologie entraîne la nécessité de redéfinir les assignations) est de permettre que les titulaires puissent échanger le spectre entre eux (spectrum trading et/ou leasing) pour permettre le réaménagement de la bande sans avoir besoin de passer par la case régulateur, en retirant le spectre (ne renouvelant pas des licences) pour ensuite réaménager la bande et réassigner.
7. **Les régulateurs devraient être encouragés à adopter les éléments qui favorisent l'investissement, à savoir:**

- **Prix de réserve bas dans le cadre d'enchères;**
- **Obligations de couverture qui tiennent compte de la réalité du marché ; et**
- **Durées de licences relativement longues**

Bien qu'aucun de ces éléments ne puisse, seul, être déterminant, notre étude a montré que, ensemble, ils peuvent avoir un impact positif. Ces éléments devraient donc être considérés comme essentiels à toutes les attributions futures du spectre.

8. **Les régulateurs devraient également avoir la souplesse nécessaire pour inclure tout élément raisonnable dans leurs critères d'attribution pour répondre aux besoins individuels du marché**. Nous avons montré que plusieurs éléments relatifs aux méthodes et conditions d'attributions du spectre ont un impact minimal sur le marché du mobile. Les administrations devraient donc disposer de la souplesse nécessaire pour mettre en œuvre ces éléments en fonction des besoins de leur marché.

9. **Il faudrait favoriser la mise en œuvre d'autorisation non nationale d'un spectre 5G en particulier dans les fréquences plus élevées où les caractéristiques de propagation limitent la couverture.** En effet, il est peu probable que les opérateurs mobiles déploient des services (en particulier dans les bandes de fréquences plus élevées) sur tout le pays. Il serait donc logique d'autoriser d'autres opérateurs à utiliser les mêmes bandes de spectre dans les zones non desservies. L'attribution du spectre à l'échelle nationale est donc peu recommandée. Une approche cohérente au sein de l'UE sera également importante pour assurer la meilleure situation transfrontalière possible et le déploiement le plus rentable.

10. **Les administrations doivent veiller à ce que le spectre 5G harmonisé soit disponible pour ceux qui souhaitent mettre en place des services nouveaux ou innovants de manière à ce que les facteurs suivants ne soient pas des obstacles:**

- **Disponibilité du spectre dans un temps raisonnable**
- **Coût disproportionné**
- **Méthodes d'autorisation trop complexes; ou**
- **Accès restreint dû à un processus fermé ou trop limité**

Contrairement aux opérateurs mobiles dont les plans d'affaires s'étendent sur de nombreuses années, les nouveaux opérateurs 5G offrant des services niche ou personnalisés sont susceptibles d'être moins capables de planifier à l'avance en ce qui concerne la demande et disponibilité du spectre. C'est pour cela qu'il devrait y avoir un spectre disponible auquel ces futurs acteurs pourront accéder dans des conditions et délais raisonnables.

1 Overview of existing EU spectrum framework

In this section, we set out the background to the project and highlight the relevant existing spectrum policy activities and the EU Directives that determine the approaches to spectrum authorisation and assignment in the EU.

1.1 Current EU spectrum public policy framework

The first step in considering the effects of each of the different spectrum authorisation and assignment mechanisms in the EU, is to identify the current framework for spectrum policy activities that impact these approaches.

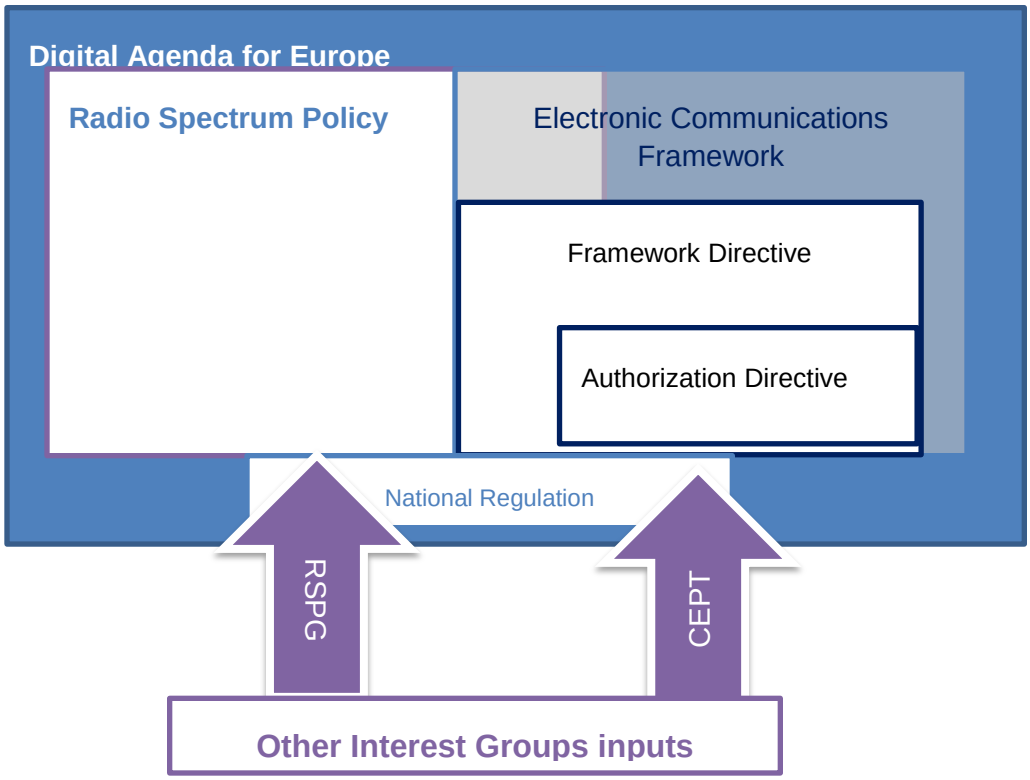


Figure 1: EU telecommunications regulatory framework overview

The figure above summarizes the framework under which the approaches to spectrum regulations are conducted by Member States within the EU. As the frames become smaller, public policy becomes more specific, leading to conditions more specifically related to authorisation and assignment of spectrum in support of EU policy objectives, as established by Article 5 of the Authorization Directive 2002/20/EC, amended by Directive 2009/140/EC, Article

3[5]. Below, we describe briefly how each of these frames addresses spectrum authorisation and assignment.

The **Digital Agenda for Europe** was launched in May 2010 by the European Commission (as a Communication to the European Parliament and European Council) and aimed to boost the growth of Europe's economy by "deliver[ing] sustainable economic and social benefits from a digital single market based on a fast and ultra-fast internet and interoperable applications"[6]. Given that the foundation of the digital market relies on the provision of ultra-fast internet, the technologies to provide such (e.g. fixed and mobile) need to be promoted and fostered. In this Communication, it was pointed out that there was a lack of investment in the rollout of networks and that one of the actions that needed to be taken was to "create a harmonized approach to radio spectrum."

The Radio Spectrum Policy Group (RSPG) within the European Union was established to '(…) assist and advise the Commission on radio spectrum policy issues such as radio spectrum availability, harmonisation and allocation of radio spectrum, provision of information concerning allocation, availability and use of radio spectrum, methods for granting rights to use spectrum, refarming, relocation, valuation and efficient use of radio spectrum as well as protection of human health[7]. Under this mandate, the RSPG provides input and advice to the Commission, where appropriate, in view of possible adoption of a range of regulatory measures.

In relation to this project, we have identified a number of RSPG reports and opinions[8] below that provide the necessary inputs and procedures we have considered for the overall analysis of authorisation and assignment approaches which is given in more detail in section 3:

- RSPG Opinion on spectrum related aspects for next-generation wireless systems (5G)
- RSPG Opinion on Licensed Shared Access
- RSPG Opinion on spectrum sharing
- RSPG Opinion on Collective use of spectrum
- RSPG Report on collective use of spectrum and other sharing approaches
- RSPG Report on Assignment and pricing methods

---

[5] DIRECTIVE 2009/140/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 November 2009 amending Directives 2002/21/EC on a common regulatory framework for electronic communications networks and services, 2002/19/EC on access to, and interconnection of, electronic communications networks and associated facilities, and 2002/20/EC on the authorisation of electronic communications networks and services. Article 3. Amendments to Directive 2002/20/EC (Authorisation Directive) Directive 2002/20/EC is hereby amended as follows: 3) Article 5 shall be replaced by the following: "Article 5. Rights of use for radio frequencies and numbers. Member States shall *facilitate* the use of radio frequencies under general authorisations."

[6] COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS A Digital Agenda for Europe. COM 2010 (245) Final. Brussels 2010.

[7] COMMISSION DECISION of 26 July 2002 establishing a Radio Spectrum Policy Group (Text with EEA relevance) (2002/622/EC).

[8] RSPG Opinions and main deliverables web page http://rspg-spectrum.eu/rspg-opinions-main-deliverables/

- RSPG Report on Efficient Awards and Efficient Use of Spectrum

Integral to the EU coordinated and harmonised regulatory approach is the **Framework Directive**[9], which sets out clear, common ground-rules for regulators to determine national rules for electronic networks and services. The Framework directive dictates, with respect to spectrum management, that Member States shall:

- Encourage the efficient use and management of radio frequencies, including network and service neutrality;
- Encourage trans-European networks and services;
- Cooperate for the strategic planning and harmonization of the use of spectrum across the Community, especially regarding the availability and efficient use of the resource necessary for the functioning of the digital internal market[10].

The most relevant provision of the Directive, in the context of this study, concerns the mechanisms established to assign spectrum in the Union: general authorisations or individual right of use, under objective, transparent, non-discriminatory and proportionate criteria[11]. In addition, it mandates that the Member States ensure that undertakings are permitted to transfer and lease spectrum between users[12].

The **Authorisation Directive**[13] focuses on the legal tools that allow any undertaking to provide telecommunications services, and it clearly distinguishes these from the right to use spectrum. It outlines the criteria that should be applied when facilitating the use of spectrum and essentially dictates that the Member States shall authorize the use of spectrum under a general authorisation approach[14]. It is only under specific circumstances that Members States may find it necessary to make an exception to that general rule and grant individual rights of use, which can be granted on the following basis:

- Avoiding harmful interference,
- Ensuring technical quality of service,
- Safeguard efficient use of spectrum, or
- Fulfil other objectives of general interests.

[9] Directive 2002/21/EC on a common regulatory framework for electronic communications networks and services, amended by DIRECTIVE 2009/140/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 November 2009.

[10] Directive 2002/21/EC, as amended by DIRECTIVE 2009/140/EC ,Article 8a

[11] Directive 2002/21/EC, as amended by DIRECTIVE 2009/140/EC, Article 9 (7)

[12] Directive 2002/21/EC, as amended by DIRECTIVE 2009/140/EC, Article 9b

[13] Directive 2002/20/EC on the authorisation of electronic communications networks and services, amended by DIRECTIVE 2009/140/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 November 2009.

[14] Directive 2002/20/EC, as amended by DIRECTIVE 2009/140/EC, Article 5

These exceptions grant enough leverage to enable Member States to take decisions for authorising frequencies via either a general authorisation or individual right of use or some hybrid approach.

The first **Radio Spectrum Policy Programme (RSPP)** was adopted in 2012[15] and sets out concrete objectives and strategies to harmonise and plan the use of spectrum across EU Member States, including spectrum assignment, by:

- Applying for the least onerous, transparent and non-discriminatory authorisation system,
- Maximising flexibility and efficiency in spectrum use,
- Promoting Union wide services,
- Fostering competition and innovation in a technology and service neutral approach,
- Promoting the harmonisation of the use of frequencies,
- Fostering collective and shared use of spectrum,
- Ensuring effective use of spectrum by taking measures such as penalties and incentive fees,
- Avoiding fragmentation of the internal market by adopting non-divergent selection criteria and procedures for harmonised allocated spectrum.

Another important piece of regulation is the Radio Spectrum Decision[16], which granted the Commission with the option to implement harmonization for the authorization of certain bands, specifically looking forward to the deployment of 3G technologies, amongst others. Article 4 grants the Commission the possibility to submit to the Radio Spectrum Committee the measures necessary to ensure harmonized conditions for the availability and use of certain bands

In addition to the legal and regulatory framework described above, technical bodies such as the CEPT[17], provide the technical basis to support spectrum harmonization across Member States[18].

One of the working topics concerning spectrum harmonisation is an analysis of how to achieve more cohesive policy regarding spectrum assignment around the EU, which would enable Europe to be one of the leading global markets in development and deployment of 5G

---

[15] Decision No 243/2012/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 14 March 2012 establishing a multiannual radio spectrum policy programme. European Parliament and Council. March 2012.

[16] Decision 676/2002/EC. of the European Parliament and of the Council of 7 March 2002 on a regulatory framework for radio spectrum policy in the European Community (Radio Spectrum Decision)

[17] European Conference of Postal and Telecommunications Administrations https://www.cept.org/

[18] "(…) the Commission is authorized a mandate to the CEPT to agree on technical harmonization measures with the aim of securing a par-European approach to radio spectrum availability across the sectors relevant to Community policy." Nikolinakos, Nikos. EU Competition Law and Regulation in the Converging Telecommunications, Media and IT Sectors. Kluwer Law International. 2006. Page 434.

technologies[19]. One recent representative publication is the **RSPG opinion on 5G,** which defines a suggested roadmap towards the adoption of the 5G standard for Europe by 2020. It identified the pioneer bands (e.g. 700 MHz 3400 – 3800 MHz and 26 GHz) that have been recommended for the early deployment of 5G and bands that are considered 'promising' for use by 5G (e.g. 31.8 -33.4 GHz and 40.5 – 43.5 GHz). The RSPG opinion emphasises for instance the need for harmonisation measures concerning the '26 GHz band' and recommends that Member States '*make available a portion of this frequency band for 5G in response to market demand…*'.

In accordance to this roadmap, the Commission asked the CEPT to develop the harmonized technical conditions for the spectrum use looking forward to the adoption of 5G technologies[20]. The aim was to obtain clear and strong conclusions as to the best possible approach that would guarantee the continued provision of wireless communications for the launch of 5G technologies intended in 2020. One of the key elements that was highlighted in this mandate was the importance of obtaining timely availability of spectrum throughout the Union.

1.2 Definition of General Authorisation and Individual Rights of use

As mentioned previously, general authorisations are intended to be the first choice mechanism to get/grant access to radio frequencies, while individual licences are meant to be used only in exceptions. A general authorisation regime allows Member States to adopt a more flexible approach that provides many benefits, including rapid and simple access to a variety of bands that support a range of different services. General authorisation can also mean that multiple services can access the same portion of spectrum, thus encouraging efficient use of spectrum and helping to enable innovation by permitting controlled sharing of spectrum resources. Furthermore, this approach stimulates different ecosystems and different applications serving different users (e.g. wireless microphones, remote sensors and vehicular radars), thus providing a wide range of potential users with access to spectrum in a timely and open manner.

Licence exemption is the legal instrument used by Member States in the EU that enables the use of radio equipment without individual authorisation or coordination. There is no requirement for a fee to be paid for access but users must adhere to certain harmonised technical and operational conditions. These conditions set out the specific technical parameters such as RF transmit power, frequency bands, bandwidth and nature of use. The equipment used under these conditions must not cause harmful interference in order to be exempt from licensing.

The example applications enabled under general authorisations include:

[19] "The goal is that the benefits of 5G-based services are available to all European citizens in a timely manner, driving industrial and societal transformation and economic growth in Europe from 2020 and beyond." RADIO SPECTRUM POLICY GROUP STRATEGIC ROADMAP TOWARDS 5G FOR EUROPE. Opinion on spectrum related aspects for next-generation wireless systems (5G). Brussels, 09 November 2016 RSPG16-032 FINAL.

[20] Opinion of the RSC pursuant to Advisory Procedure under Article 4 of Regulation 182/2011/EU and Article 4.2 of Radio Spectrum Decision 676/2002/EC. Mandate to CEPT to develop harmonised technical conditions for spectrum use in support of the introduction of next-generation (5G) terrestrial wireless systems in the Union.

- Use of short range devices in accordance with ERC/REC 70-03, such as WLAN, Short Range Radar, wireless audio, home automation
- Private Mobile Radio at 446 MHz (PMR446)
- Fixed Wireless Access in 5.8 GHz on a licence exempt basis
- WiGig in the 60 GHz band

The harmonised technical conditions and operational nature of licence exempt equipment has led to rapid growth of mass-market equipment, such as Wi-Fi and short-range devices (e.g. wireless key fobs). Therefore, it is imperative that technical coexistence studies demonstrate the compatibility between licence exempt devices and other spectrum users. However, the impact of authorisation on a licence exempt basis means reversal of the decision can be very difficult and a lengthy process. There is practically no way to remove the use of all deployed equipment in its entirety. ERC Report 111[21] suggests it can take at least five years for users to change equipment.

Individual rights of use limit access to a single type of use, or operator (if exclusive) to ensure protection of the service being provided against harmful interference. In turn, this allows Member States to establish a competitive and dynamic market for the provision of wireless services where demand for spectrum exceeds supply[22]. The sub division of spectrum into suitably sized portions or blocks is a method that allows Member States to assign spectrum in a way that supports current mobile technology standards and competition. The complexities of some spectrum assignment procedures (such as spectrum auctions) can be subject to a wide range of considerations, criteria and circumstances that are dependent on the specific economic and market situation of the individual Member States. These aspects are discussed in more detail in section 3 of the report.

Based on the legal frameworks and circumstances within Member States, decisions on the use of general authorisation are applied based on issues such as:

- Frequency band and available bandwidth
- European/international harmonisation
- Technical and operational characteristics

---

[21] "Regulatory procedures to be followed when changing frequency allocations", ERC Report 111, June 2001

[22] This prerogative may be exercised based on DIRECTIVE 2009/140/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 November 2009 amending Directives 2002/21/EC on a common regulatory framework for electronic communications networks and services, 2002/19/EC on access to, and interconnection of, electronic communications networks and associated facilities, and 2002/20/EC on the authorisation of electronic communications networks and services. Article 3. Amendments to Directive 2002/20/EC (Authorisation Directive) Directive 2002/20/EC is hereby amended as follows:, 3) Article 5 shall be replaced by the following: "Article 5. Rights of use for radio frequencies and numbers 1. Member States shall facilitate the use of radio frequencies under general authorisations. Where necessary, Member States may grant individual rights of use in order to: — avoid harmful interference,— ensure technical quality of service,— safeguard efficient use of spectrum, or— fulfil other objectives of general interest as defined by Member States inconformity with Community law.

- Economic and market situation (i.e. an established or emerging ecosystem)

ECC Report 132[23] provides useful guidance and criteria under which general authorisation approaches are appropriate, these include when:

- coordination between users is not necessary
- use in all parts of the country is possible
- user individualisation is not necessary
- the use of a frequency or of a frequency band is possible by a number of users within a particular area
- spectrum is available on a long-term basis.

The above list provides indicative examples and is not an exhaustive list. Member States may determine other criteria under which they adopt general authorisation. For example, in the UK there is ongoing policy effort to reflect technical[24] and market developments[25] that as a result of these developments might require changes to technical characteristics to support new technologies.

[23] ECC Report 132, Light licensing, licence-exempt and commons, June 2009

[24] A Framework for Spectrum Sharing, Ofcom 2015

[25] Communications Market Report 2016, Ofcom, August 2016

1.2.1 A process with three components

Deciding on the authorisation approach that is most appropriate for users to access spectrum can be considered as a process with three components:

- The first element is to decide which **authorisation regime** is most appropriate for the band and applications: the starting point of which in every case should be general authorisation (i.e. the rule according to the EU regulatory framework). Upon assessment of the 4 elements mentioned in Article 5 of the Authorization Directive, Member States may decide to authorise spectrum under individual licences.
- A second component is to decide on an **assignment mechanism** or procedure, provided a decision in favour of the need to limit the number of rights as well as of individual licences has been taken. Here SRAs would take into consideration factors such as the likely scarcity of the band and the need to use spectrum efficiently. For example, if there was little demand for the frequencies to be assigned, a first-come-first-served assignment procedure might be seen as the most appropriate given that in this case, administrative costs and burden are very low, compared to a procedure that includes an auction or beauty contest.
- The third component is to determine which of the specified **conditions** of the ones included in the Authorisation Directive will be attached to the licence. Conditions such as coverage obligations (if appropriate) typically relate to economic and social objectives, while other conditions such as an obligation to share the band are typically based on considerations such as the envisaged usage and spectrum efficiency.

In the decision-making process the first component – the authorisation approach – usually comes first but the second and third elements can be mixed together to create a structure which achieves the desired policy goals.

In the table that follows, we use an analytical framework to develop the distinctions suggested by CEPT and the RSPG to create a categorisation of spectrum access types, which includes newer approaches, namely Licensed Shared Access (LSA) and Dynamic Spectrum Access (DSA).

Type of spectrum access	Details and examples	General authorisation ^	Individual right of use ^	Collective use	Exclusive use	Users must notify or get licence	Regulator controls usage	Fees #	Charges ∞
1. Licence exempt	Open access for certified devices E.g. low power Wi-Fi, SRDs, mobile user equipment , VSAT users	★★★★★		✓	✖	✖	✖	✖	✖
2. Light licencing (nominal)	As above but licence or notification required. E.g. Some PMSE usage; radio amateurs; High power outdoor Wi-Fi	★★★★	★	✓	✖	✓	✖	✓ or ✖	✖
3. Light licensing (restrictive)	As above but includes individual frequency co-ordination and restrictions on number of users E.g. some SAP services; UK 1800 MHz DECT guard band	★★★	★★	✓	✓ or ✖	✓	✓	✓ or ✖	✓ or ✖
4. Private commons	The exclusive licensee gives access to its spectrum under specified conditions.	★★★	★★	✓	✖	✖	✖	✓	✓
5. Dynamic Spectrum Access (DSA)	Incumbent grants automated short term access for third party using database or sensing. E.g. TV white space	★★	★★★	✓	✖	✓ or ✖	✓ or ✖	✓ or ✖	✓ or ✖
6. Licensed shared access (LSA)	Access granted to a third party by an incumbent user, typically a government body.	★	★★★★	✓	✖	✓	✖	✓	✓
7. Exclusive individual licensing	Exclusive rights to specific portion of spectrum for individual user. E.g. mobile licences		★★★★★		✓	✓	✓	✓	✓

Table 1: Definitions of different spectrum access types

Key

^ Star system indicates the characteristics of the licencing type. e.g. four stars for general authorisation and one star for individual rights of use indicates that Light licensing (nominal) is most similar to the general authorisation approach.
# Payments designed to recover administrative costs
∞ Payments designed to distinguish between competing operators and increase spectrum efficiency e.g. payments made at spectrum auctions

1.2.2 Approaches to licensing in the EU

As we established earlier, the initial premise upon which the decision making process on authorisation starts is general authorisation for the use of spectrum. However, exceptions may be granted when specific conditions (see section 1.1 for details) are met, which give ample leverage to the Member States to implement national decisions. These exceptions are widely used. For example, individual rights of use are often granted on an exclusive basis to users such as mobile operators. This is because spectrum in the lower frequency bands (e.g. sub-1 GHz) is limited (relative to frequency bands which have more available bandwidth) and exclusive access to specific frequencies ensures protection from interference.

There are other examples of network deployments using a range of different technologies where operators prefer individual rights of use for spectrum access. For example, frequencies are typically assigned to Fixed Wireless Access (FWA) network operators on an individual basis. This is to ensure protection from interference and coordination between many individual licensees. Similarly, private mobile radio systems require individual licences so that many different users can coexist in limited geographical area. Each service has a distinct set of technical and operational requirements and parameters that have historically led to a decision by SRAs to adopt individual rights of use instead of general authorisations. This is because these systems require protection from interference from other users.

In the case of spectrum bands such as 2.4 GHz and 5 GHz used for Wi-Fi in which consumer (and enterprise) equipment is exempt from licensing, the nature of the technology means that frequencies can be re-used many times over a given area. Users of Wi-Fi, Bluetooth and other such technologies in the EU operate on an unrestricted general authorisation. They are not required to have a licence nor do they have to notify the regulator of their use. However, in some cases (such as higher power Wi-Fi devices used outdoors), which carry a greater danger of interference, and therefore scarcity, a more explicit form of authorisation may be required in some countries.

A challenge for this study is that, as well as using general authorisations and individual rights of use, spectrum licensing also incorporates approaches which do not fall neatly into either category. For example, it is possible to have light licences which require only an online registration or light licences where supply is limited and assignment is via an auction, such as the Concurrent Spectrum Access licences awarded to 12 operators in the UK[26].

Additional perspectives are required to understand the range of licensing types currently used in spectrum management and we explore these in the section that follows.

[26] In 2006 12 companies were given Concurrent Spectrum Access (CSA) licences to use the DECT guard band (1876.7-1880 MHz, paired with 1781.7-1785 MHz) in the UK. The licences allow use of the same spectrum on a low power shared access basis and users must coordinate deployments with each other. See https://www.ofcom.org.uk/__data/assets/pdf_file/0032/90977/Consultation-DECT-guardband-final-for-publication.pdf p6

1.2.3 Collective use or exclusive use?

As suggested by the RSPG[27] there is another dimension within spectrum licences: whether they give the right to exclusive use of the specified frequencies, or whether the spectrum is shared with other users. The RSPG represented this in the diagram below, pointing out that spectrum licences often lie midway between general authorisation and individual right of use, rather than falling exclusively into one category.

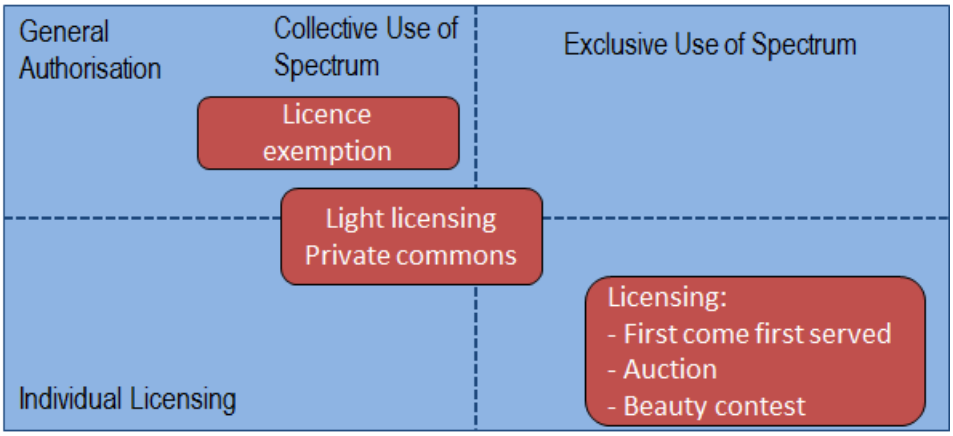


Figure 2: Spectrum authorisation and licensing categories

For example, in a private commons the licensing structure can be similar to a general authorisation in that anyone may use the band under certain conditions, although an organisation does hold an individual right of use for the specified frequencies.

1.2.4 Several shades of light licensing

Like the RSPG, the European Conference of Postal and Telecommunications Administrations (CEPT), has argued that the term light licencing is used to refer to practices which could either be characterised as a type of general authorisation or as a type of individual licensing.

In a 2009 report,[28] CEPT said that while light licensing gave administrations greater power than the licence-exempt regime, the term was being used to mean an approach which used individual frequency planning or coordination, as well as one which did not. It could mean a simplification of a procedure rooted in licensing individual rights of use or it could mean nothing more than filling in an online form with no prospect of refusal. Light licencing could also indicate restrictions on the number of users, or no restrictions.[29]

CEPT summarised these distinctions in the table below.

---

[27] RSPG *Report On Assignment And Pricing Methods* 2009 p6

[28] ECC REPORT 132 LIGHT LICENSING, LICENCE-EXEMPT AND COMMONS June 2009

http://www.erodocdb.dk/Docs/doc98/official/pdf/ECCRep132.pdf

[29] The report also notes that light licensing can refer to just the use of IT systems and the Internet to simplify the licensing process.

Individual authorisation (Individual rights of use)		General authorisation (No individual rights of use)	
Individual licence[4]	**Light-licensing**		**Licence-exempt**
Individual frequency planning / coordination. Traditional procedure for issuing licences.	Individual frequency planning / coordination. Simplified procedure compared to traditional procedure for issuing licences. With limitations in the number of users.	No individual frequency planning / coordination. Registration and/or notification. No limitations in the number of users nor need for coordination.	No individual frequency planning / coordination. No registration nor notification.

Table 3: Key characteristics of different "licensing regimes"

Figure 3: Table of key characteristics of different licensing regimes. Source: CEPT

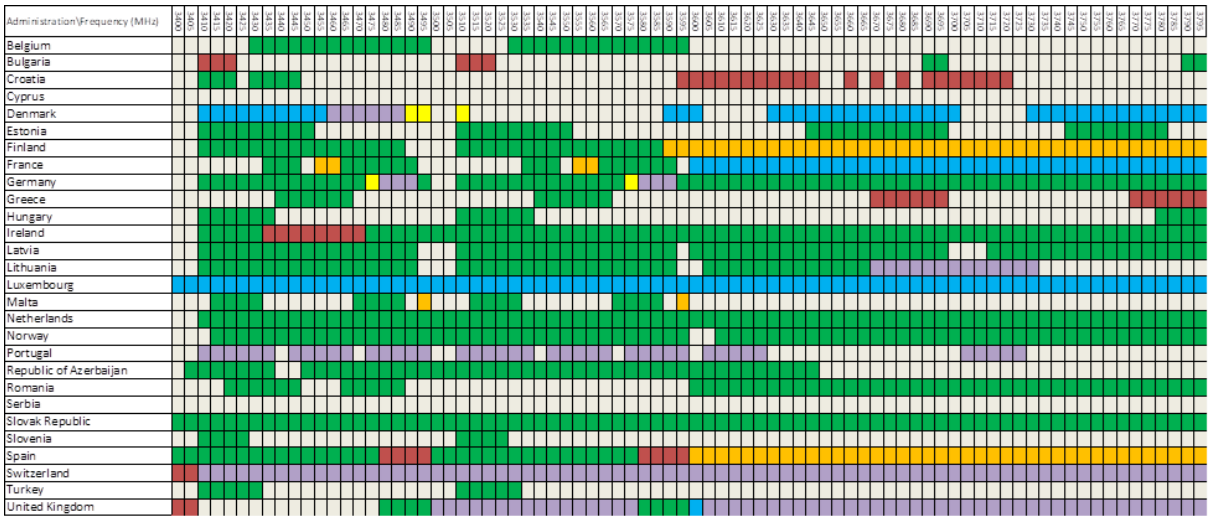
1.2.5 Categorising types of spectrum access

The intention in Table 1 of section 1.2.1 was not to list every possible way of accessing spectrum, but to create broad categories based on earlier research which will aid understanding. There are potentially scores of permutations and different combinations being used across Europe for the same licences[30], so to list them all would confuse rather than inform. The best way to analyse the decision making process and make policy proposals is therefore to use the seven spectrum access types identified in Table 1: However, we recognise that these are broad categorisations and there will frequently be a need to be more specific.

Further, according to the current EU regulatory framework, decisions regarding which type of spectrum access to grant for each one of the bands and services rely on the sole discretion of each of the administrations or designated authority in each Member State. This results in a variety of approaches where the same frequencies, allocated for the same services, might encounter very different ways of being licenced, as a result of the analysis each Member State conducts towards markets and industry stakeholders.

This has been exemplified by the fragmented way in which spectrum has been assigned across the EU. In particular, there has been varied timing of availability of certain bands (i.e. 800 MHz and 2.6 GHz) across EU Member States for 4G LTE deployments and multiple approaches in which the selection procedures have been conducted in the EU. Furthermore, there has been fragmentation in the assignment of frequencies in the 3.4 – 3.8 GHz band across all EU Member States as evidenced in the figure below.

[30] See ECC REPORT 132 p 22



Legend

	Category	Definition
	Vacant	Unused or no information provided
	Mobile/Wireless broadband	Includes MFCN, BWA, FWA, WLL, WiMAX, LTE and similar terms
	FS	Fixed Service point to point links
	FSS	Fixed Satellite Service Earth station receivers
	Other	Includes Military and related terms, PMSE/ENG-OB, amateur and other miscellaneous terms
	Unknown	Technology neutral or information not available
	Mixed	Combination of 2 or more above categories in use within the same range

Figure 4: Use of frequencies from 3400 to 3800 MHz in Europe. Source ECC PT1 (17) 011 Annex 5

1.2.6 Spectrum sharing

Spectrum sharing is a technique that has been used by SRAs for many years. It is generally based either on a geographical basis (in which users of the same frequency co-exist in different locations far enough not to cause interference to each other) and/or on a temporal basis which means users can access the same frequency, at possibly the same location but at different times.

Traditionally, sharing takes place where incumbent users have geographically limited use (such as the military) or can occupy the white spaces, i.e. the unused frequencies in the gaps between active channels, on a short term basis (such as Programme Making and Special Events systems).

New spectrum sharing tools have been developed such as geo-location databases that require incumbent services to maintain regular updates on their use of assigned frequencies (channel, power and location) in a database so that other users can identify where spaces exist. In Europe, Ofcom in the UK has implemented a geo-location database and there are pilot studies in Finland, France, Italy and the Netherlands.

2 Status of existing spectrum authorisation approaches across 28 EU Member States

2.1 Status of spectrum authorisations and assignment approaches used across EU Member States

In this section, we provide the outcome and responses from stakeholders across each of the 28 Member States of the EU. We describe the approaches used by Member State since May 2011 to determine the use of general authorisations or individual rights of use, including the different circumstances in which they are used and the conditions applied to those rights. Appendix B provides some charts summarising responses from stakeholders.

2.1.1 Approaches to GA or individual licences

2.1.1.1 SRAs:

Spectrum Regulatory Authorities (SRAs) emphasised that General Authorisation is the default option for assigning frequencies to communication services as per Article 5 of the Authorisation Directive. However, the derogation clause means that EU 28 SRAs predominantly use Individual Rights for electronic communication services. Generally, SRAs do not anticipate an end of the Individual Licensing regime for wireless broadband spectrum bands in the near future. SRAs overwhelmingly stated the following criteria must be met regarding a certain band for individual exclusive licensing to be applied:

- Avoiding harmful interference;
- Ensuring technical quality of service;
- Safeguarding efficient use of spectrum;
- Fulfilling other objectives of general interest (e.g. military applications) as defined by Member States in conformity with Community law.

If these criteria are not relevant or demonstrated for a certain band, then the regulators purportedly use General Authorisation.

Substantial heterogeneity prevails between Member States with regards to the processes underpinning the decision-making on whether to use General Authorisation or Individual Licensing. In some Member States (e.g. Hungary, Lithuania, Portugal, Malta, Ireland), the SRA reportedly has the right to decide on the authorisation options for all given spectrum bands, including the right to decide on whether to use General Authorisations or Individual Rights of Use. However, there are substantial differences as regards whether other agencies or ministries need to be consulted. In some Member States, the pertaining ministry and other stakeholders can take part if they wish but the SRA is not required to consult them (e.g. Ireland), whilst in other Member States, the SRA is required to formally consult with the ministry (e.g. Latvia).

In another set of Member States (e.g. Greece, Luxembourg, France, Poland), the SRA is generally tasked with preparing a first draft decision stipulating the authorisation regime option for a certain band, which then needs to be approved and formalised by the pertaining ministry.

Between these 'most used types' are several hybrid forms. For instance, in Denmark, decisions on the authorisation of spectrum are taken by the SRA, but in cases of scarcity of the resource, the ministry gets involved depending on whether essential public interest considerations need to be addressed (e.g. broadcasting). In a few Member States (e.g. Netherlands), it is the parliament that has the competence to make the decision, but in practice it is often the Ministry of Finance that takes the final decision after notifying the parliament.

Some Member States have specific sets of procedures that clearly set them apart from their European peers: For instance, in the Republic of Cyprus, the regulatory agency is itself part of the ministry. In this case, a dynamic exchange between the Department of Electronic Communications and ministry staff leads to a final decision on which authorisation regime to use. In Belgium, in some cases the ministry decision reportedly needs to be signed by the King in a royal decree.

Finally, across all Member States, the decision-making process on whether to use General Authorisation or Individual Licensing builds on formal consultations with market players.

Across all SRAs involved in this study, the use of new regulatory approaches that have developed more recently - such as Private commons, DSA or LSA – has been found to be rare amongst EU Member States, as shown in the figure in appendix B section 6.2.2. The key reason for this, according to SRAs, is that there is currently no market demand (from MNOs) for these new regimes across all usages, given that during their regulatory procedures, including public consultations, very few or no stakeholders demand such assignment approaches.

Authorisation approaches GA vs Individual assignment or combination of the two

Interviews with stakeholders reveal that UK and Germany are perceived as practising a very inclusive policy-making process (i.e. effective public consultations are performed with market players in preparation of policy-making process and regulatory decisions) free of political interference (i.e. reserve prices are set on the basis of proper market analysis). Netherlands, Italy and France are instead perceived as having excessive political interference in the setting of reserve prices.

2.1.1.2 Industry

MNOs:

MNOs strongly favour exclusive licensing, as they perceive mobile spectrum as the key differentiator to serve their customers and a strategic asset and see it as harmful to share it with others. Quality of service and high spectral efficiency are further arguments brought forward by MNOs to justify a continued need for exclusive individual licensing.

MNOs are generally not in favour of a comprehensive overhaul of authorisation regimes for 5G. One MNO company said:

> *"5G will, like other generations of mobile technology, need exclusive licenses, which already have good authorisation mechanisms and that, may be supplemented by licence-exempt spectrum, and again, NRAs have methods for making that available. So no changes are needed"*

The majority of interviewees were either noncommittal (mainly due to the uncertainty related to 5G) or in favour of maintaining the current status quo of authorisation regimes. However,

some interviewees advanced the options that in view of 5G and the associated spectrum scarcity, the introduction of LSA, shared unlicensed spectrum for some indoor applications and the LTE helped by licensed spectrum might be potential expedients to explore

Amongst those stating that a moderate review of existing authorisation regimes would be necessary, many respondents highlighted that they felt that too little is known about 5G to be sure of whether a fundamental policy re-think, including a greater combination of different authorization regimes is required.

MNOs are concertedly in favour of a harmonisation of regulatory regimes across the EU and worldwide, with a salient priority on the former (see figures in appendix B). According to MNOs, the underlying reason for this preference is that MNOs, which operate transnationally, could save considerable time and resources if they did not need to adapt to the specific regulatory regimes of individual Member States.

Many MNOs criticised the fact that bands are liberated at different speeds across Member States. This has a negative consequence for frontrunners, as MNOs in Member States that liberate bands quickly might often still not be able to deploy services countrywide, due to interference issues with adjacent Member States that are slower in liberating the pertaining bands[31].

Verticals:

Verticals concur in their assessment that as long as the Quality of Service agreements, particularly in the transport and energy sectors can be guaranteed at all times, any approach to licensing is feasible.

Verticals highlight that consistency of regulatory arrangements across Europe is essential to avoid fragmentation and to address implications on the cost of devices (e.g. excessive multi-frequency support, different standards) and time to market deployment. The table below highlights some vertical applications and the preferred authorisation regime in each case.

Applications	Characteristics	Preferred authorisation regime expressed by stakeholders
Ultra-reliable low latency communications (URLLC): Applications for maintenance services for grid systems after electricity network failure detections	Remote connections to grid systems needed	Private commons might be feasible in order to remotely connect to the grid. The exclusive licensee could give access to its spectrum for the time needed to do the maintenance
Ultra-reliable low latency communications (URLLC): Critical infrastructure (e.g.	Rely on end-to-end service guarantees (independent of	Individual exclusive licenses

[31] For example, a German MNO, who won spectrum in the 800 MHz band in Germany in 2010, could not deploy LTE in the 800 MHz band in any border region for several years (due to incumbent use in Austria and France).

Applications	Characteristics	Preferred authorisation regime expressed by stakeholders
high-voltage grids)	network load)	
Ultra-reliable low latency communications (URLLC): Factory automation applications	Rely on end-to-end service guarantees	Individual exclusive licenses
Ultra-reliable low latency communications (URLLC):: Fault localisation	Require high QoS and low latency	Individual exclusive licenses
Ultra-reliable low latency communications (URLLC): Identification in smart grids	Require high QoS	Individual exclusive licenses
Massive machine type communications (mMTC): Smart metering	Data collection from measurement points with latency requirements cited in the range of one to several seconds. The spectrum is used to transfer information from remote sensors to a central point	It can work without dedicated spectrum, shared spectrum solution is considered beneficial (e.g. reducing spectrum acquisition costs, improving time taken to access spectrum).[32] It could also rely on license exempt spectrum, as long as there is no lack of communication for several hours
Ultra-reliable low latency communications (URLLC): Transmission system operators (TSOs)	The need of spectrum is not predictable, as it depends on high voltage peaks and the associated very sophisticated QoS demands	Individual exclusive licenses
Ultra-reliable low latency communications (URLLC): Train control	Monitoring and controlling train movements. Stringent requirements for availability and QoS, Interoperability requirements.	Individual exclusive licenses
Enhanced mobile	Improved peak/average/cell-	Individual exclusive licenses,

[32] http://www.digitaleurope.org/DesktopModules/Bring2mind/DMX/Download.aspx?Command=Core_Download&EntryId=524&language=en-US&PortalId=0&TabId=353

Applications	Characteristics	Preferred authorisation regime expressed by stakeholders
broadband (eMBB): High throughput and capacity in localised hot spot and congested areas	edge data rates, capacity and coverage	supported in a local service area by a license exempt, light licensing, or a licensed shared access approach
Ultra-reliable low latency communications (URLLC): other examples including remote surgery, intelligent transport, infrastructure protection	Requirement for emerging critical applications have stringent requirements for capabilities such as throughput, latency and availability.	Individual exclusive licenses

Table 2: Vertical applications, characteristics and preferred authorisation regimes

In any case, the general opinion of verticals was that, if a technological solution demonstrably capable of safeguarding compliance with their various Quality of Service agreement under General Authorisation was to be developed, then there would be no obstacles to using General Authorisation for vertical use cases.

2.1.2 Approaches to licence conditions

2.1.2.1 SRAs:

In the vast majority of EU28 Member States, sharing is foreseen and enabled and there are no barriers from a regulatory point of view, apart from very few examples such as Belgium, where spectrum sharing is reportedly not yet supported by the national SRA (even though allowed). The majority of SRAs have already performed extensive consultations on the relevance and desirability of spectrum sharing, but reportedly, there was no demand from the market and no tangible added value was identified to further pursue the issue.

With regards to the 5G context, SRAs highlighted that it was too early to identify spectrum sharing opportunities or any other approach to addressing scarcity, as a preferable method of increasing efficient use of spectrum. According to SRAs, the desirability of sharing will depend on WRC-19 outcomes, and the prospective scarcity of certain priority bands (particularly where availability of bandwidth maybe limited) as well as the nature and number of incumbents operating in priority bands.

SRAs highlighted that spectrum sharing is generally only beneficial if the shared use of a specific frequency by two or more users can lead to a relatively more intense use and does not cause harmful interference.

Several SRAs stated that there could be potential future benefits associated with spectrum sharing in scenarios where current frequency use is sporadic and limited in geographical coverage. This could be the case for PMSE, which already shares in the UHF band with broadcasting and could be shared in other bands with other users such as PMR.

It was clarified that sharing might become most relevant in higher frequency bands (e.g. over 30 GHz), where there is relatively little usage today, and spectrum scarcity is currently not

such an issue. In the future, sharing could potentially be beneficial in higher bands (more spectrum, less favourable propagation characteristics), but it was again highlighted that this will very much depend on the type and intensity of use and the type of shared access (sharing in frequency, geography, time or based on technology such as polite protocols or low power use). In this context, it was repeatedly highlighted that the feasibility and desirability of sharing will depend on future evolutions of the very technologies that enable sharing.

> *'There is no big demand for sharing in Lithuania. We have only one case: 2310 MHz -2390 MHz. We have some pilot projects and have issued license for one civilian operator and one military operator in those bands...We do not have any more demand for sharing at this point. We see sharing benefits only talking about 5G but not now.' SRA, Republic of Lithuania:*

Trading is allowed in most Member States, but similar to sharing, there is currently very limited uptake. SRAs highlighted that, especially in the case of MNOs, competition issues can arise easily (e.g. forming oligopolies) so trading of spectrum between operators is subject to competition scrutiny by the SRAs or other independent national agencies. In this context, some SRAs stated that competition issues associated with trading and sharing would make it more cumbersome and costly to scrutinise unfair competition practices (e.g. potential anti-competitive agreements or anti-competitive spectrum accumulation).

> *'A more flexible approach of the telecom operators would be helpful – regulatory approach is friendly, but the consent of the operators wanting to trade is also needed.' Polish SRA*[33]

> *'Those who have the bands in which trading might be most desirable aren't willing to put them on the market and allow competitors access to their most valuable resources.' SRA in Ireland*

Member States do not widely use Licensed Shared Access (LSA) as an authorisation approach. Scepticism still prevails on LSA and the associated administrative burden. However, some Member States commissioned studies into Licensed Shared Access[34] including:

- Italy – Pilot sharing scheme in the 2.3 GHz band for mobile;
- Netherlands – Sharing trial in the 2.3 GHz band between PMSE and mobile;
- France – Sharing trial in the 2.3 GHz band between the regulator and the Ministry of Defence for mobile;
- Finland – Sharing trial in the 2.3 GHz band between PMSE and mobile.

2.1.2.2 Industry

MNOs:

[33] However Poland has seen a significant number of spectrum trades in 3.6–3.8 GHz local licences (former WiMax licences) and thinks this phenomenon could increase in the next few years.

[34] LSA implementations https://cept.org/ecc/topics/lsa-implementation

In general, MNOs argued that licence conditions for 5G need to be structured in a manner conducive to optimising the potential for private investment. This would include low reserve prices in auctions, long licence durations and rollout conditions that align with customer expectations (e.g. general service obligations and not band specific coverage obligations). Notably, there was no difference between smaller and bigger MNOs with regards to preferred approaches to license conditions.

MNOs argue that for 5G millimetre wave bands, due to the short-range propagation characteristics, coverage should not be regulated. Some MNOs also stated that geographically comprehensive coverage of mmWave-band 5G might require License Shared Access (i.e. to allow the re-use of the spectrum where the operators were not using it). MNOs stressed that coverage obligations should only be applied for lower bands and in urban environments. For rural and demographically scarce environments, MNOs favoured an approach by which they would be able to address coverage obligations in cooperation, for example by sharing infrastructure costs, as this would avoid investment duplication.

MNOs also highlighted that 5G comprises a variety of different use cases (e.g. IoT, mobile broadband, critical communications) with dynamically shifting and very disparate demands, which would make it very difficult to create sensible coverage obligations for 5G. Some MNOs therefore argued that coverage obligations should not be used for 5G at all, whilst others urged that any eventual obligation should be applied only if supported by market analysis or concrete policy objectives. One MNO highlighted that 5G coverage obligations, if necessary, should be linked to specific spectrum blocks available in the auction or the auction format should be set up so that it ensures that only one operator will be obliged to cover a specific uneconomic area, so as to avoid “wasteful duplication of infrastructure”.

MNOs were generally highly sceptical with regards to spectrum sharing, justifying this on the basis of high Quality of Service requirements and of their purported high spectral efficiency. MNOs clarified that, having once won spectrum in an auction, they are incentivised to keep it for themselves.

In this context, MNOs urged to wait for the outcomes of WRC-19, before determining the level of scarcity and the related need for sharing. MNOs did however highlight that they would be open to share bands that are currently licensed to non-MNOs.

In terms of the current status quo, there is very little spectrum sharing between MNOs across the EU. However, it seems that there is an increasing trend to share infrastructure and networks between MNOs, especially in rural areas. Spectrum trading is also limited, and where it has happened, it was mainly in the context of Mergers and Acquisitions. MNOs repeatedly underlined that spectrum auctions are preceded by comprehensive ex-ante analysis forecasting operators’ targets and related spectrum needs. As these ex-ante analyses purportedly tend to be accurate, and MNOs bid for spectrum accordingly, any sharing or trading would be indicative of failure from an MNOs perspective.

Verticals:

Verticals strongly indicated that licensing conditions should adapt to ensure that roll-out obligations are met and to avoid existing situations of spectrum hoarding. Accordingly, “use it or lose it” clauses are needed. We observed that verticals have a very different take on coverage obligations from MNOs. Verticals highlighted that for some vertical solutions like ITS (e.g. connected cars) and especially safety related matters (e.g. e-health), coverage obligations for 5G would need to be part of the license conditions. They emphasised that vertical-specific requirements may need to be considered with the licensing conditions.

These requirements typically include high reliability, availability and low latency depending on the service being provided. For instance, a utility/water companies would require wide area geographical coverage of its end point assets, which are often in rural areas away from the general population, and therefore a geographic coverage obligation would satisfy this type of requirement

Feedback gathered from verticals from the automotive and utilities indicated a general openness to sharing as long as the pertaining quality of service requirements are met.

2.1.3 Approaches to the assignment process

2.1.3.1 Policy objectives

2.1.3.1.1 SRAs:

Policy objectives are generally issued by the national parliament or the ministry in charge. Several SRAs stated that they are sometimes formally or informally involved in contributing to the definition of policy objectives. In these cases, SRAs stated that the final policy objectives generally reflect the recommendations brought forward by the given SRA.

The majority of SRAs highlighted that it is common practice for the entity in charge of defining the policy objectives to perform formal consultations with the private sector (i.e. this is the status quo).

2.1.3.1.2 Industry

MNOs:

All MNOs interviewed voiced a strong preference for minimalistic and 'lean' policy objectives. In general, MNOs agree that policy objectives should aim at encouraging investment and that they should be designed in a way as to avoid unnecessary burdens or costs on private entities. MNOs are divided in their view on whether or not policy objectives should be issued with a view to increasing market competition. It appears that MNOs in countries like Germany, Sweden, Denmark or the UK are generally supportive of such policy objectives, whilst MNOs with experience in markets such as France and the Netherlands (in which supposedly competition-friendly policy objectives had tangible negative effects on incumbents) tend to suggest that policy objectives should not aim at increasing market competition.

MNOs strongly emphasised that they are in favour of transparent and inclusive processes underpinning the determination of policy objectives. In this dimension, MNOs evaluated the performances of different EU Member States very differently. Germany and the UK were mentioned as a good example due to a transparent and inclusive process that generally leads to empirically founded, non-intrusive policy objectives. To the contrary, Austria, the Netherlands, France and Poland were repeatedly highlighted as not so good examples in this regard. However, stakeholders did not make any link to the specifics of SRAs or ministry's models as described in Appendix B.

Moreover, most MNOs were critical of political attempts to increase competition, most notably in the form of spectrum reservations for new entrants. In this context, the French and Dutch examples were repeatedly called disastrous.

Verticals:

The verticals interviewed underlined that for energy and transport applications, policy objectives need to take into account the applications' much longer lifetime when compared to other operators. They underlined that once a Distribution System Operator (DSO) undertakes an investment, the policy objectives should not make it necessary to alter the infrastructure before the lifetime comes to an end (with lifetimes that might exceed 30 years).

Verticals also said that policy objectives should be conducive for providers to be able to serve needs of verticals and that they should ensure a favourable climate for investment.

2.1.3.2 Elements and conditions

In this context, elements and conditions are the key aspects considered by SRAs when assigning spectrum. They typically comprise aspects such as selection process type (auction, beauty contest), selection rules (type of auction, criteria and relative points in a beauty contest), spectrum caps and spectrum floors, new entrant spectrum reservations and pre-qualification criteria.

2.1.3.2.1 SRAs

It has emerged that there are some differences between Member States in terms of the formal decision-making processes underpinning the determination of elements and conditions (e.g. in terms of entities involved, the management level working on it, etc.).

SRAs showed some level of concern about time lag between the allocation of spectrum and the deployment of services (see figure in appendix B section 6.3.1). Some SRAs emphasised the multiplicity of factors involved:

> *"That's not the only issue. Sometimes investment, coverage, quality of service and competition, and impact on the general public are equally important. One example of a time lag: technology innovation in UHF band (700 MHz), which will be given to mobile operators. In my country we need a very long time to move from DVB-T to DVB-T2." Czech Telecommunication Office*

SRAs approach to deciding the elements and conditions of an assignment procedure rely predominantly on a case-by-case analysis with generic frameworks as a background reference point. Ensuring competition was for most the dominant consideration.

2.1.3.2.2 Industry

MNOs:

According to MNOs' perception, there are substantial differences between Member States in terms of the way elements are defined as well as about the elements themselves. As per results of the interviews conducted, the UK and Germany were judged as best-case examples, due to their generally low reserve prices, which are complemented by stringent coverage obligations and service penetration targets that foster operators' infrastructure deployment. Other positive points highlighted relate to the perceived little political interference in the setting of reserve prices and no market distortion following new entrant reservations.

The Netherlands, France and Poland were generally perceived as bad examples. The Netherlands reportedly has a very politicised way of defining elements, including "arbitrary coverage obligations" and badly formulated competition clauses. In the case of France, there

was strong criticism by MNOs with regards to the 700 MHz auction, for which the reserve prices were reportedly higher than the final prices paid by German MNOs[35].

In general, MNOs were found to be in favour of a harmonisation of spectrum assignments - in the sense of establishing common rules to prevent delays in the assignments of bands - as well as of an alignment of the timing of auctions. MNOs generally conceded that the decision making processes of the competent authorities on the auction processes are generally made in a transparent way, even if they do not always agree with the auction design[36].

MNOs were more concerned than SRAs about time lags between the allocation of spectrum and deployment of services (see graph below).

Key examples of time lags provided by MNOs are the following:

- France, where the 700MHz auction took place at the end of 2015, but the spectrum will only be made available in 2019. The operator in question can already start the rollout in Paris and a few other locations, but will only be able to fully use it in 2019. Slightly attenuating this issue, the MNO only had to pay in tranches of 1/4th of the full price over the four-year period;
- In Belgium, reportedly some auctions tend to be held before there is an effective (market and/or technology) need to use the given spectrum. For instance, the 2.6 GHz band auction is considered to have been held too early causing financial costs to the operators although the band was reportedly still not being used. Some MNOs voiced their fear that similar risks could arise with regards to 5G bands being auctioned prior to technology maturity.

Amongst MNOs, there was a broad consensus that the need to encourage investment should be the key criteria in determining the elements and conditions. MNOs were concertedly critical of political influence on the setting of reserve prices. Some MNOs recommended that the proceeds of spectrum auctions should not be calculated into the budget of governments.

Verticals:

Apart from the caveat that conditions should always facilitate and incentivise investment, there was no strong feedback from verticals on the elements and conditions.

2.1.3.3 Future technologies

We asked stakeholders about the future prospects and plans for authorising and assigning spectrum identified for 5G. Industry is still working on the developments of 5G, therefore the questions were targeting views from stakeholders on potential plans and how spectrum could be authorised in future.

[35] According to an MNO, this was because the military was planning to purchase several Eurofighters, for which the foreseen budget was insufficient, so the minister of finance intervened and increased the reserve prices.

[36] We gathered a strong feedback from a French MNO, which stated that in general French MNOs tend to prefer auctions with price discovery, over the course of which one can see how the values for different bands evolve (e.g. clock auctions), but in their views the French regulator favours overly complicated auction designs.

SRAs:

Regulators remained vague on future prospects/plans for specific bands:

> *COMREG (Ireland): "There is no harmonised 5G standard, we don't know what it is, what it will do, how it will operate and what its limitations are." However, "in line with the opinion of the RSPG, we consider the 700 MHz band is a very valuable coverage band for future 5G services."*
>
> *Croatian Post and Electronic Communications Agency (HAKOM): No special arrangements in place yet for 5G but "we're trying to free up some bands for testing. We have consulted with a neighbouring country (Slovenia) and in future will consult with equipment makers and operators to see if we can do joint testing for 5G."*
>
> *Many NRAs simply plan to follow European recommendations e.g. Luxembourg 'We are following the work of the RSPG/RSC and CEPT and will implement their decisions.'*

Some SRAs are currently conducting internal studies on specific bands (predominantly 700 MHz, 3.4-3.8 GHz), whilst many will only begin investigations in 2017.

> *'EETT is currently working on studying appropriate ways of allocation, authorisation and assignment of 5G pioneer bands (700 MHz, 3400-3800 MHz, 24.25-27.5 GHz).' SRA in Greece*
>
> *'Poland is taking part in ITU and CEPT working groups, which are responsible for preparing materials for WRC 2019, including supporting 5G frequencies.' Polish SRA*

The German SRA appeared quite advanced, alluding that UMTS bands will be used for 5G. The regulator also stated that the frequencies in the 3.4 - 3.8 GHz range are to be provided for future business models, especially with regards to 5G applications (for example, Industry 4.0, Internet of Things). The aim is to provide sufficient frequencies for all business models with a view to achieve the highest possible efficiency in the use of spectrum. Some SRAs believe that the existing framework is flexible enough to accommodate new technologies.

Subsequent to the study interviews, Ofcom published an update on 5G spectrum in the UK[37] and announced the first set of three '5G bands' which are the 700 MHz, 3.4–3.8 GHz and 26 GHz bands. This proposed set of bands aligns with those set out in the RSPG Opinion on 5G and supported by the European Commission.

2.1.4 Key messages from stakeholder feedback

The data concerning current and potentially future approaches to spectrum authorisation and assignment procedures and their implications was gathered from around 50 stakeholders

[37] "Update on 5G spectrum in the UK", Ofcom, Feb 2017 https://www.ofcom.org.uk/__data/assets/pdf_file/0021/97023/5G-update-08022017.pdf

including SRAs within Member States, the mobile telecommunications industry, and several industry verticals.

We summarise the key messages taken away from these stakeholder interviews below.

SRAs emphasised that General Authorisation is the default option for communication services (Art 5 Authorisation Directive). However, the derogation clause means that EU 28 SRAs predominantly use Individual Rights for licensing mobile spectrum and do not anticipate an end of the Individual Licensing regime for wireless broadband spectrum in the foreseeable future. However, SRAs do consult with industry to determine how best to make mobile spectrum available to the market.

In this respect, UK and Germany are perceived as practising a very inclusive policy-making process, free of political interference (i.e. reserve prices are set on the basis of proper market analysis). In contrast, Netherlands, Italy and France are perceived as having excessive political interference in the setting of reserve prices as exemplified by the responses. This indicates the inconsistent approaches adopted across EU Member States.

MNOs strongly favour exclusive licensing, which suggests assigning mobile spectrum in this way is the key differentiator to their business. Quality of Service and high spectral efficiency are further arguments brought forward by MNOs with regards to a continued need for exclusive individual licensing. Furthermore, MNOs prefer SRAs to adopt lean, fair and transparent assignment approaches with inclusive policy making processes (such as consultations) free of political interference like in the UK and Germany. These views highlight the preference for continued use of traditional mobile spectrum assignment approaches going forward.

Verticals views were similar in some ways to MNOs however, if a technological solution is demonstrably capable of safeguarding compliance with their various Quality of Service requirements, then there would be no obstacles to using General Authorisation for vertical use cases. Verticals also indicated that consideration for assignment conditions should always facilitate and incentivise investment with a view to meet their long term procurement cycles.

Overall, the lack of greater actual use of various assignment mechanisms stems from the fact that in almost all cases Member States have found little or no demand for using light licensing or other general authorised approaches. This is because the majority of spectrum bands coming to the market recently have been exclusively used for mobile services and the large investments required in the future limit the number of interested operators and hence demand for spectrum from alternative users.

2.2 Overview of spectrum bands identified for 5G in the EU

The development and deployment of 5G networks will create new ways to access services and applications. The technology and standards, although still under development, will enable new business models and create new players providing innovative services across different industry sectors. This is exemplified by new techniques that will be introduced in 5G networks such as network slicing. This technique enables separate individual network resources to be supplied to different types of services but all using the same physical network infrastructure for example smart grid slice, a connected car (V2X) slice and enhanced mobile broadband slice all provided by a single physical network.

In the EU, a number of specific pioneer bands were identified by RSPG in its Opinion on 5G[38] for use by 5G. The 700 MHz, 3.5 GHz and 26 GHz are three 'pioneer' bands clearly identified to deliver 5G in Europe by 2020 at a large scale. Other bands the RSPG considers promising for 5G in the longer term include the 32 GHz and 42 GHz bands. These candidate bands offer a mix of sub 6 GHz and mmWave spectrum bands to deliver the broad range of 5G services such as enhanced mobile broadband, ultra-reliable low latency communications and massive machine-type communications.

The list below describes the rationale for choosing the pioneer bands:

- Spectrum below 1 GHz provides extended wide area coverage and good in-building penetration with enough bandwidth available to support multiple network operators and deliver a mix of services including smart metering, enhanced mobile broadband, everywhere and IoT applications;
- Spectrum between 1 GHz and 6 GHz provides for outdoor coverage, additional capacity, very high throughput links with sufficiently wide bandwidth available for multiple network operators and the capability for network slicing to support multiple network resources and services;
- Spectrum above 6 GHz is provides very wide bandwidths (in the order of 200 MHz – 2 GHz) that are suitable for the enhanced Mobile Broadband speeds (Gbps) specified within 5G. This spectrum is ideal for small area local capacity hot spots for both indoor and outdoor.

Until such time as agreements can be reached on how these bands should be authorised, and due to the fact that the authorisation framework is so flexible, the situation regarding frequency assignment remains fragmented. In some countries, e.g. France and Germany, the 700 MHz band has already been awarded by auction[39] and an allocation of one block to PPDR usage in addition to some targeted coverage conditions in remote areas in France[40] has been made. Similarly, for the 3.4 – 3.8 GHz band there is extensive fragmentation in the way Member States have authorised the use of this band for existing technologies. This includes making multiple assignments to many different, often regional licensees on a relatively short term basis for Fixed Wireless Access services.

In contrast, the 24.25 GHz – 27.5 GHz band is allocated to fixed and Earth exploration satellite services across the EU. Although, many assignments are individually licensed to different users and operators, there is potential for accessing spectrum on a shared basis. This is highlighted by the coexistence studies taking place within CEPT (e.g. ECC PT1 – IMT Matters) which intends to demonstrate the extent of sharing possible in this band. The fact that sharing of 5G bands is being considered means the traditional approach to mobile assignment may be changing towards other authorisation methods and techniques.

---

[38] Radio Spectrum Policy Programme: the roadmap for a wireless Europe, European Commission, June 2016 https://ec.europa.eu/digital-single-market/en/radio-spectrum-policy-programme-roadmap-wireless-europe

[39] Mobile Broad-band - Project 2016, https://www.bundesnetzagentur.de/EN/Areas/Telecommunications/Companies/FrequencyManagement/ElectronicCommunicationsServices/MobileBroadbandProject2016/project2016_node.html

[40] ARCEP targets remote areas in 700MHz auction proposals, June 2015 http://www.mobileeurope.co.uk/press-wire/arcep-targets-remote-areas-in-700mhz-auction-proposals

3 Analysis of spectrum general authorisation and individual assignment approaches for future policy

3.1 Introduction

Feedback from the stakeholder surveys indicated that the national frameworks they had in place is sufficient for their current and in some cases future authorisation requirements. It was also clear that there remains some uncertainty about how to authorise spectrum for 5G particularly in the mmWave bands.

Given this feedback from stakeholders and absence of any evidence of support to alternative solutions, we developed some future 'what if' scenarios. These scenarios consider future changes that could occur in the market and whether the current regulatory framework and national practices would be suitable to accompany such changes. We describe the future scenarios in more detail later in this chapter.

We consulted a panel of experts (see appendix C) who supported the overarching principles and concepts of the four proposed scenarios. Furthermore, the scenarios were the main focus at our public workshop at which we discussed in detail some of the use cases and implications of choice of authorisation and assignment method.

The outcome of the workshop identified the need to understand how the different connectivity requirements for 5G impact service levels and thus determine what needs to be done differently in spectrum assignment as a consequence. For example, it is possible that Member States decide to assign spectrum in different ways thereby potentially creating problems for uses cases that depend on harmonised and consistent access to spectrum.

In section 2.1 we presented the outcome of the stakeholder surveys and interviews which provided the status of current authorisation approaches used by each of the 28 Member States of the EU including general authorisations and individual rights of use.

In this section, we address the remaining study questions, which have been broken down into two distinct areas as shown below:

General authorisations and individual rights of use:

1) *identify and describe under which circumstances and for which particular spectrum usages, the choice of either general authorisations or individual rights of use (or a combination of both)* ***is more adequate****, taking into account the advent of 5G technologies including its expected market and technological developments, its networks' characteristics and architecture, the various levels and methods of protection against interference required, Internet of Things applications etc. as well as the principle of an effective and efficient use of spectrum;*
2) *identify and describe which elements of general authorisations or individual rights of use would* ***benefit from a more convergent and consistent approach within the EU*** *to deliver better outcomes in terms of timely and efficient availability and use of spectrum, development of innovative new services and business models and a successful introduction of 5G in Europe, and consequently identify specific aspects which would most benefit from secondary policy development.*

Selection processes for authorising the use of radio frequencies ("assignment procedures") and conditions attached to the rights of use for radio frequencies ("spectrum usage conditions")

1) *describe the approach used by each of the 28 Member States of the EU since May 2011 to determine (i) the policy objectives and the elements of the assignment procedures (including an overview of the process and the authorities involved or consulted) and (ii) the licence conditions;*
2) *describe and quantify to what extent (i) elements and conditions of spectrum assignment procedures1 and (ii) spectrum usage conditions will have an impact on the assignment results, such as for example on the price paid for the spectrum, the timeframe between allocation and assignment and effective use, the trading or leasing of spectrum, spectrum sharing and on mobile markets, such as in terms of the number of players (and new entries), the competitive dynamics generally (including MVNO share of mobile users), and network coverage in order to identify which might be most significant in the context of 5G deployment needs;*
3) *identify and quantify to what extent (i) elements and conditions of spectrum assignment procedures and (ii) spectrum usage conditions will have an impact* ***on operators' business*** *decisions regarding investments in network deployment and provision of electronic communication services with a view to foster the availability of 5G services across the EU;*
4) *identify for which elements and to what extent a consistent approach within the EU with regards to assignment procedures and spectrum usage conditions, including with competition law principles, would contribute most significantly to alleviating specifically identified problems and delivering more timely and appropriately available spectrum with a view to foster the availability of 5G services, and consequently identify specific aspects which would most benefit from secondary policy development.*

3.2 Methodology for analysis

The scenarios were derived based on evidence gathered from the stakeholders interviews, the academic expert panel (see appendix C for summary of this), additional research and feedback from the public workshop and other secondary research relating to spectrum usage models which would utilise alternative approaches (with respect to those commonly used by Member States) to authorisation and assignment. They are described in detail in the next section.

The scenarios were developed and verified by an expert panel who indicated they must leverage:

- Timely access to the market
- Wide coverage (i.e. network roll-out) in areas that address more localised, niche demands rather than those traditionally served by MNOs
- Quality of service linked to vertical use case requirements
- Willingness to invest / business decisions
- Market dynamics (i.e. level of competition and choice)
- Spectrum mobility (i.e. ability of spectrum to move from one party to another)

To assess the appropriateness of different authorisation approaches, we applied each approach to the different scenarios to understand the benefit each represented in that particular scenario, and the opportunity that would be lost if the status quo was to continue. To inform the different scenarios, the following assumptions were taken into account concerning changes that would take place within the mobile industry as a result of the implementation of 5G:

- 5G technological developments take place including dynamic frequency selection and coordination of base stations which will enable the emergence of self-organised networks;
- The role of vertical industries increases in the 5G eco-system;
- Economic and commercial changes take place in the market resulting from the way 5G technology operates (compared to 3G or 4G);
- Operators' (and regulators') are willing to adopt new techniques for 5G architecture including shared infrastructure (heterogeneous networks, SDN/NFV, edge computing architecture);
- Operators and service providers need access to a new mix of spectrum bands by 2020[41] to ensure 5G becomes available across the EU in a timely manner.

3.2.1 Optimum approaches to spectrum access for use in 5G

The mobile industry[42] has indicated that a fundamental enabler for 5G is appropriate and timely access to spectrum. Therefore, clear, flexible and transparent regulatory decisions for access to new and existing spectrum bands will be fundamental for the successful roll out of 5G.These decisions should consider all possible use-cases, from the very high user throughputs of enhanced mobile broadband to the sub 5ms latency of ultra-reliable communications and the potential to connect billions of IoT devices. See Figure 5 below for the three future IMT-2020 groups.

[41] This includes the pioneer bands but perhaps other bands that have become available as a consequence of internal policy decisions such as release of public sector spectrum or refarming

[42] 5G Spectrum Public Policy Position, GSMA Nov 2016 https://www.gsma.com/spectrum/wp-content/uploads/2016/06/GSMA-5G-Spectrum-PPP.pdf

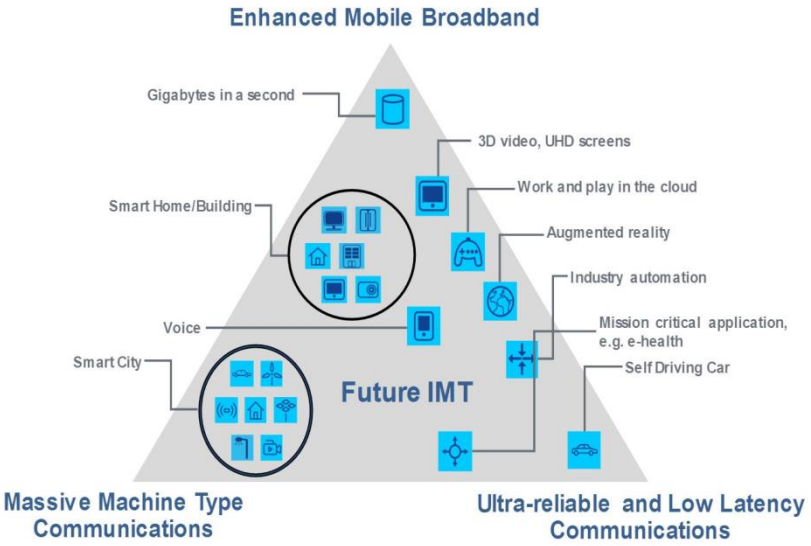


Figure 5: ITU vision of 5G IMT2020. Source: ITU[43]

It is clear from the stakeholder interviews that authorisation approaches differ significantly across Member States. For 5G, identifying which is most adequate amongst the choice of different authorisation approaches is dependent on the varying technical/physical characteristics and conditions for the type of usage.

We provide some further evidence below of how the characteristics of 5G will need to be considered when making decisions for spectrum authorisations among Member States. A summary of these findings is given below.

- MNOs will continue to need exclusive individual rights of use in existing and future bands identified for 5G to enable guaranteed QoS and support global roaming[44]. This is particularly crucial in bands below 1 GHz and up to 6 GHz due to the relatively long-range propagation characteristics and the scarcity of available blocks. However, many of the bands are already assigned or already identified for IMT, so sharing blocks in these assigned spectrum bands might be required to yield the benefits of 5G or enhance mobile coverage to the widest possible extent.
- Time to market of services is linked to technology development, commercial availability of equipment (infrastructure and handsets), harmonised spectrum availability and adequately enabled infrastructure. In particular, Figure 6 shows the evolution (actual and estimates) of 4G population covered and 4G connections in Europe in terms of absolute values (in the bars) and percentages (in the trendline) and that there will still be a significant gap in 4G adoption (57%) and 4G network population coverage (93%) by 2020. This means that subscribers could go straight to 5G by this time however operators will no doubt wish to continue to seek return on investment for 4G.

[43] IMT Vision –Framework and overall objectives of the future development of IMT for 2020 and beyond, ITU-R M2083, 2015

[44] 5G White Paper – executive version, NGMN Alliance, December 2014

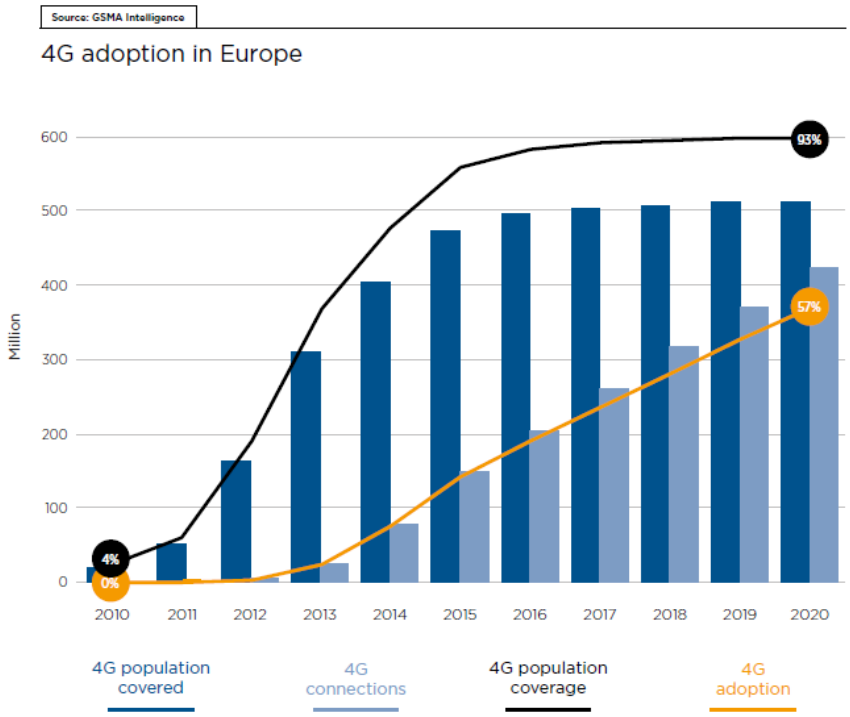


Figure 6: 4G adoption in Europe. Source GSMA Intelligence[45]

Figure 7, shows the timing between technology launch to peak uptake is around 20 years. If this holds for 5G, we will see the peak of uptake by around 2039/2040.

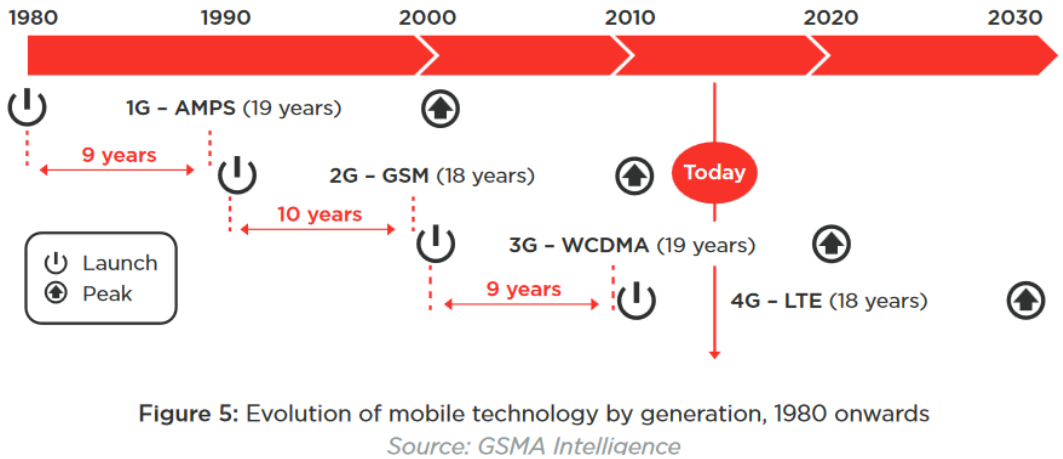


Figure 7: Evolution of mobile technology by generation. Source: GSMA Intelligence[46]

However, proponents of 5G have agreed to accelerate the standards and expect a quicker uptake compared to previous generations[47]. In contrast to previous generations, 5G adoption

[45] The Mobile Economy Europe 2015, GSMA Intelligence, 2015

[46] Understanding 5G: Perspectives on future technological advancements in mobile, GSMA Intelligence, 2014

[47] 3GPP approves 5G NSA standard acceleration, stage set for 2018 deployment push, RCR Wireless, March 2017, http://www.rcrwireless.com/20170315/carriers/3gpp-approves-5g-nsa-standard-acceleration-stage-set-for-2018-deployment-push-tag2

is expected to be led by a leap in connections driven by millions of IoT and other internet enabled devices as 5G networks are being rolled out.

The table below which presents a range of growth forecasts (Cisco, Ericsson, GSMA) which estimate the growth in devices globally and range from 13.7 – 17.6 billion by 2022. In Europe it is estimated by the GSMA that there will be 182 million IoT connections by 2020.

Year	Global connections		European connections
	Ericsson[48]	Cisco[49]	GSMA[45]
2016	5.6 billion	5.8 billion	87.8 million
2020^/2021/2022*	17.6 billion	13.7 billion	182 million

Table 3: Comparison of growth forecast estimates of IoT connections

5GPPP undertook research into spectrum authorisation and access modes. METIS II, in their deliverable D3.1[50], outlines spectrum scenarios and requirements for bands above 6 GHz. In particular, their report highlights how existing spectrum authorisation models (Primary user mode, LSA mode and unlicensed mode) address each of the broad use case families within 5G across both traditional MNO models and verticals. We provide below extracted text from the report in relation to the general conclusions on the suitability of spectrum bands for the three 5G use case families:

- *For Extreme Mobile Broadband (**xMBB),** a mixture of frequency spectrum comprising lower bands for both coverage purposes and data traffic, and higher bands with large contiguous bandwidth to cope with the ever-increasing traffic demand, including wireless backhaul solutions, is required. **Exclusive licensed spectrum is essential** to guarantee the coverage obligation and QoS, supplemented by spectrum authorized by other licensing regimes, e.g. LSA or unlicensed access (e.g. Wi-Fi offload) or new enhanced unlicensed access schemes (e.g. LAA) to increase overall spectrum availability.*
- *For some Massive Machine Type Communications (**mMTC)** applications, frequency spectrum below 6 GHz is more suitable and spectrum below 1 GHz is needed in particular when large coverage areas and good outdoor to indoor penetration are needed. **Exclusive licensed spectrum is the preferred option**. However, other licensing regimes might be considered depending on specific application requirements.*
- ***Licensed spectrum is considered the most appropriate** for Ultra-reliable Machine-Type Communications (**uMTC)**. For safety V2V and V2X communication the frequency band 5875-5925 MHz harmonized for Intelligent Transport Systems (ITS) [ECC08-DEC01] is an option. Another option is the sub-1GHz spectrum, particularly well-suited for high-speed applications and rural environments.*

[48] The Mobility Report, Ericsson, November 2016

[49] Cisco Visual Networking Index, June 2017

[50] Mobile and wireless communications Enablers for the Twenty-twenty Information Society-II Deliverable D3.1 5G spectrum scenarios, requirements and technical aspects for bands above 6 GHz, METIS II, May 2016

The output from METIS research could be argued to be too limited as the approach takes for granted that spectrum assignment will continue to be on the basis of supporting traditional MNOs and does not consider wider utilisation of alternative flexible approaches to assignment. The traditional MNO approach would mean new spectrum bands allocated for 5G should be divided into equal sized blocks and packaged ready to be awarded and assigned on an exclusively licensed basis. The use of 'other licensing' regimes (e.g. LSA or unlicensed access) are considered as supplementary options that could fulfil perceived lower level prioritised access. In other words, mobile operators would require the highest level of access and protection to guarantee quality of service while other operators would need to share under conditions set by the operator and/or the SRA.

The research could go further and consider use cases that may not need exclusively licensed spectrum to operate and could benefit from more flexible authorisation approaches. For example, there is a lack of consideration for use cases that are geographically constrained such as rail and roads that might benefit from access to harmonised bands in a way that does not require individual exclusive access and in turn could deliver benefits to enterprises and consumers.

The METIS-II research primarily considers spectrum access mechanisms for 5G suited to mobile operators, but does not explicitly exclude the possibility of introducing new players and service providers in the market. A flexible approach would be possible through sharing newly allocated bands which could be for new nationwide service providers such as rail/connected car or emergency services authorities. These services however, require greater levels of protection from interference, resilience, high availability and QoS which the MNOs at present either do not deliver or lack the commercial incentive or capability[51]. It is unclear from the METIS work if this would be possible on a licensed shared access basis or concurrent use depending on the frequency band and available bandwidth.

Depending on the geographic extent of the application and its key performance requirements, more flexible authorisation approaches may be more appropriate. IoT for instance is used for a variety of applications across different geographies, local/indoor regional or nationwide. Applications such as smart metering require wide area connectivity (regional or nationwide) but not necessarily on a critical basis. As a result they could be based on "best effort" and use a general authorisation approach. In contrast, safety critical applications of connected cars require individual rights of access to spectrum (not necessarily exclusively) with very low risk of interference. Therefore, a mix of spectrum authorisation approaches will be needed for the different IoT and vertical use cases.

3.2.2 5G use cases and services

Numerous use cases have been developed and considered across a range of different 5G studies and standardization bodies. METIS-II[52] has drawn together a number of these use cases and identified around 81 of them from across eight different EU projects and 84 use

[51] The one exception is in the UK with Government opting to take a more cost effective approach selecting the mobile operator EE as the partner to deliver Mobile Broadband services to all the Emergency Services and replace the existing TETRA network with LTE

[52] 5G use cases from METIS-II project, METIS-II

cases developed across NGMN and 3GPP. The METIS-II project found that most of the use cases are similar in many ways and that some consolidation was needed so that a representative set of uses can be applied to future studies. The basis of the use cases has evolved from a set of user groups which include automotive, energy, factories, media and entertainment, public protection and disaster relief, programme making and special event and private/professional land mobile radio.

Figure 8 shows the five main uses cases that METIS-II collected and which cover each of the three use case families (often more than one) and as such the 5G networks will be able to support other use cases that belong to those categories.

5G Use Cases in METIS-II

	Use case	Scope of Requirements (Network/User Perspective)	Scope of Services (Service Perspective)
xMBB, mMTC	Dense Urban Information Society	Experienced user data rate / Traffic vol. per subscriber / Nb. of users & devices / Energy efficiency	Broad range of communication services covering needs related to both indoor and outdoor urban daily life (excl. office and factory)
xMBB	Virtual Reality Office	Experienced user data rate/Traffic volume per subscriber/ Latency	Broad range of communication services in in the (indoor) office context
xMBB	Broadband Access Everywhere	Experienced user data rate / Availability / Mobility / Energy efficiency	Full coverage topic addressing outdoor/indoor communication needs especially in rural areas
mMTC	Massive Distribution of Sensors and Actuators	Availability / Number of devices / Energy efficiency	Broadest range of IoT services covered
xMBB, uMTC	Connected cars	Latency/ Reliability / Mobility	Strong expectation from the (automotive) industry Belong to the first uMTC services expected to be commercialized

Figure 8: Consolidated set of use cases for 5G

In our analysis we extract a number of the relevant use cases from the above set and a few additional ones to consider the implications of spectrum authorisation and benefits in our scenarios. For example, we have considered in addition smart metering, public transportation and payment services that have also been highlighted as use cases[53] for 5G.

[53] Future Use Cases for Mobile Telecoms in the UK, Real Wireless on behalf of National Infrastructure Commission, Dec 2016 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/581437/Real_Wireless_Future_Use_Cases_for_Mobile_UK.pdf

3.3 Scenarios for testing different spectrum access approaches

3.3.1 Introduction

As we have seen throughout the report, the introduction of 5G could impact the use of spectrum and hence its regulation. In the following chapters, we assess how different authorisation approaches could be implemented against our four future-looking scenarios. The assessment aims to identify what enablers and innovations are possible given use of more flexible approaches to authorisation. The scenarios are not mutually exclusive and it is likely that some elements of all of them will form part of the future 5G landscape. Briefly, the scenarios are as follows:

- '**Mega MVNOs'** – In this scenario overarching MVNOs are established which corral services from a range of suppliers (including, potentially, traditional mobile networks, WiFi providers, IoT service providers and others) to deliver tailored packages to their end users which utilise the most appropriate supplier to meet the end users' needs.
- '**Self-Organising Networks'** – In this scenario, the technology of 5G is designed in such a way (primarily in the higher frequency bands) that it does not require specific frequency planning, but so that each cell site selects the optimum frequency from those available to it, and the network self-organises and self-optimises the use of spectrum as it grows.
- '**Infrastructure Economics'** – In this scenario, the cost of providing the cell sites necessary for the expected densification of mobile networks is not commercially viable such that sharing of sites, and of the RAN are the only way to provide cost-effective services in many areas.
- '**Vertically Driven'** – In this scenario, enhanced 4G networks satiate the vast majority of user demand, and it is therefore the industry verticals (e.g. transport, healthcare, construction) that are the primary drivers for the roll-out of 5G.

The above scenarios are in addition to the 'no change' scenario, in which network operators continue to function as they do today, meaning that each supplies all of the services relevant to its customers using its own network facilities in its own (exclusive) spectrum.

In considering the implications for spectrum of the scenarios, the primary aim is to determine in what manner spectrum will need to be authorised to enable the scenario to materialise and its associated benefits to be delivered. In particular, whether the currently most prominent model of spectrum licensing (e.g. exclusive and individual) is the only method necessary to support the scenario or whether another approach (e.g. collective or general authorisation) would be needed to enable the different envisaged services to develop. The approaches to spectrum authorisation considered in these scenarios can be summarised in the figure below (note that this is a simple extension of the model identified by the RSPG).

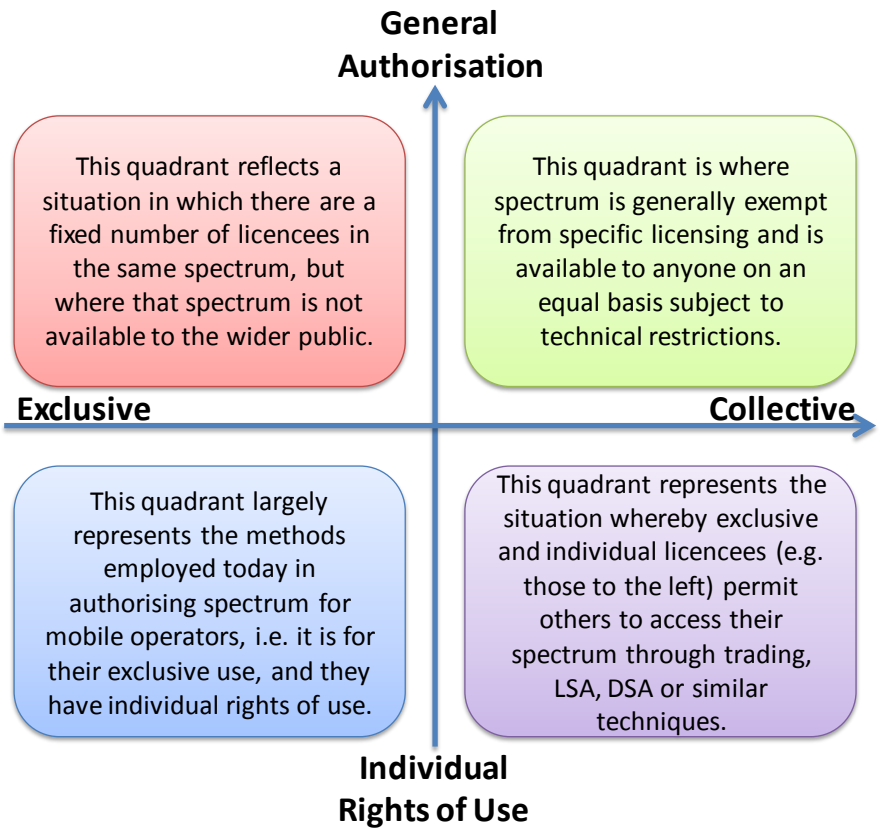


Figure 9: Approaches to spectrum authorisation

The quadrants shown in the diagram reflect different "ideal types" for the purpose of our analysis but they are not discrete spectrum authorisation approaches *per se*. In addition, there are approaches which may straddle the axes and it is equally possible that multiple approaches could be used in the same spectrum band, or by the same licensee. In addition, it is possible that different countries or operators may adopt different approaches to authorisation in an un-coordinated way.

If it is clear, based on the scenario's demands, that any approach other than individual and exclusive is required for the scenario to deliver its envisaged benefits, then there is clearly a need for future authorisation of spectrum to be sufficiently flexible and correctly framed to permit such methods to be used. Similarly, if the scenario demonstrates that there are benefits in a harmonised or consistent approach to authorisation or assignment, or some elements associated with these, this would indicate the need to ensure these aspects will be considered in any future approaches to spectrum award.

In examining each of the scenarios, we have considered what benefits they may offer, over and above the 'no change' case. These benefits, which generally accrue to end users, boil down to a number of specific elements, namely:

- Faster time-to-market
- Wider coverage
- Higher performance (e.g. throughput or availability)
- Lower end-user costs
- Greater reliability

- Provision of specialist services (e.g. high reliability)
- More efficient use of spectrum (though this is not necessarily an end-user benefit, it does imply more or better overall services in the available spectrum).

We have identified cases where a given spectrum authorisation method is the driver for a specific benefit or set of benefits. We have further identified if these benefits are more likely to be enhanced if European harmonisation in spectrum assignment or authorisation were applied.

It is important to clarify that in the context of our analysis harmonisation is meant to be in relation to the criteria and approach rather than a harmonisation of specific conditions. For example, when we address harmonisation of the conditions of the licences (e.g. the coverage), we refer to the harmonisation of the criteria used to define the concrete coverage obligation rather than harmonisation of the coverage objective itself. The same could apply for shared use conditions or for trading or leasing. In this case, for example, the specific coverage conditions should be set by Member States according to their market and economic need and their policy goals decided for the auction and taking into account for example level of service penetration and efficient use of spectrum. But it is feasible to proffer criteria that the MS should use to define the coverage condition such as being ambitious enough to ensure the widest roll-out possible, or to measure coverage obligations.

Therefore, in each of the scenarios, we will analyse 5 levels of harmonization:

- At the most basic level this consists of general conditions of the spectrum allocation approach, the definition of the common bands to implement 5G.
- The next level considers defining the types of service to be provided in such bands (e.g. mobile, PPDR, ITS);
- At the next level, conditions which harmonise the approach to authorisation (e.g. individual, exclusive, shared,);
- Next the mechanism by which the SRAs select the spectrum licensee could be harmonised (e.g. auction, administrative selection, first-come first-served).
- Finally, harmonisation could also be applied to the criteria and approach to defining the conditions of the licence itself (e.g. duration of the licence, coverage obligations and the way sharing, leasing and trading of spectrum is implemented).

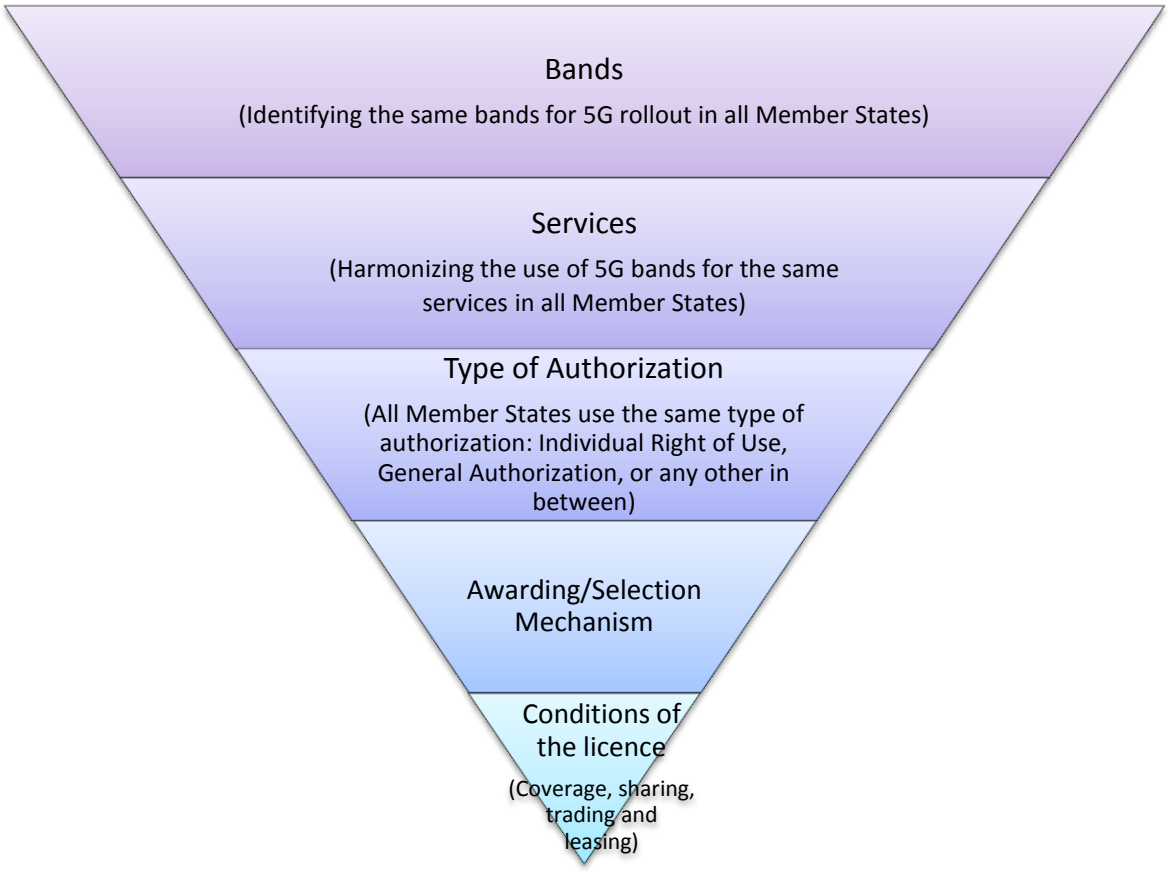


Figure 10: Degrees of harmonisation approach

3.3.2 Mega MVNOs

3.3.2.1 Scenario

Overarching or 'thick' MVNOs are established which aggregate services from a range of wireless network operators (including, potentially, traditional mobile networks, WiFi providers, IoT service providers and others) to deliver tailored packages to their end users, and which utilise the most appropriate supplier to meet the end users' needs. The MVNO handles the interaction with subscribers whereas the network operators provide the underlying technical services. Google's Project Fi is an example of an early form of such a service which provides services to the general public.

The Mega MVNOs may smooth out the cost differentials between services and service providers to provide a more uniformly priced service. The Mega MVNO may offer a number of packages with different service bundles giving end users greater flexibility to buy something that meets their requirements. These bundles may be tailored to specific users such as the general public as well as IoT, PPDR and critical communications. The diagram below[54] illustrates different degrees of MVNO activity relative to the overall service provision chain. The Mega MVNO that we will refer to in this scenario will reflect an operator

[54] Credit to veridian.ro

somewhere between the Enhanced Service Provider and the Full Infrastructure MVNO as illustrated in the figure below.

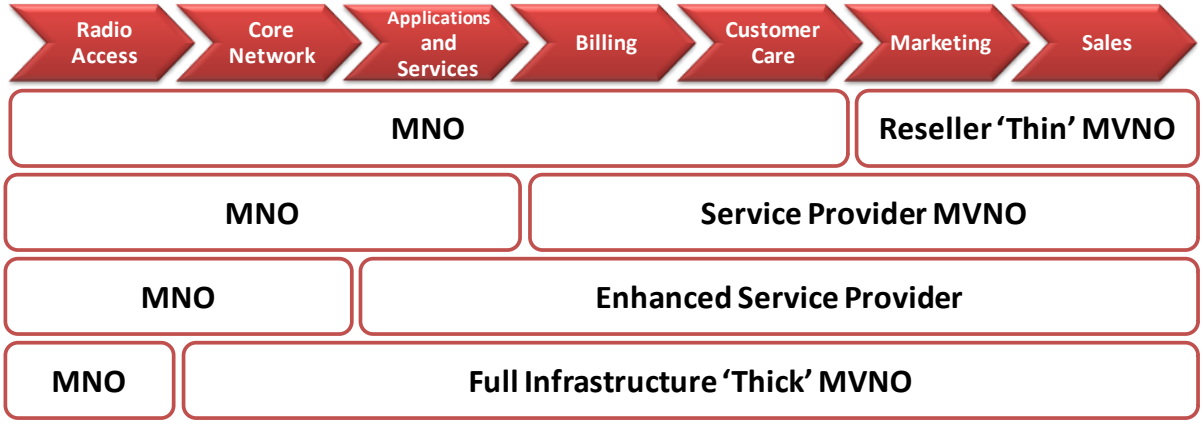


Figure 11: Degrees of MVNO activity

The provision of the MVNO's differentiated services could be achieved either in the network where the Mega MVNO has a significant amount of core network that can route traffic intelligently, or in an application on the user device which deals with handing over traffic based on the type of traffic and available wireless networks (or some balance of the two). Techniques such as LWA (LTE-WLAN Aggregation) already offer the user-based technology solutions to enable this to take place. The end user is oblivious to which wireless network is carrying the traffic.

Such MVNOs could deliver services to the general public (e.g. mobile broadband) but could also be established by industry verticals or other organisations who wish to supply services to a group with a specific performance requirements (e.g. reliability or availability) by aggregating the services of several suppliers. In this way MVNOs could support all of the potential 5G use cases.

We consider the value chain of the Mega-MVNO and the possible approaches to spectrum access for this scenario:

- TOP of the chain is the supplier of connectivity – This is includes the MNO which could hold the individual exclusive rights to spectrum and that can sell capacity to consumers and enterprises. It also includes other wireless broadband providers such as Wi-Fi or wholesale Fixed Wireless Access providers.
- MIDDLE of the chain is the Mega MVNO – This entity procures capacity or access under contract with the supplier (TOP) at wholesale prices given the expected large quantities of capacity to be purchased and for a fixed term contract.
- BOTTOM of the chain is the consumer or enterprise – Purchase of retail or enterprise grade capacity linked to quality of service and type of services

Note that none of the above defines who holds the spectrum rights. Under today's model it would be the MNO (TOP) who would hold the spectrum, however in the future there would be nothing to stop the Mega MVNO holding the spectrum.

3.3.2.2 Changes to Market and Infrastructure

In this situation, wireless network operators or service providers may become increasingly wholesale providers, disconnected from the customer relationship. They may begin to specialise in providing a particular type of service (e.g. voice or IoT) or focus their service only in specific areas (e.g. rural, urban or along rail or road corridors). It is possible that a wholesale wireless network operator may have shared ownership between the different organisations involved in its provision (e.g. a technology supplier, an infrastructure owner and a network operator). Price becomes one of the primary drivers for the success of a wireless network operator as competition for provision to the different MVNOs intensifies.

Wireless network operators with a limited geographic scope become viable, especially if they can provide a service where it may not have otherwise been commercially viable for bigger players, or where they own specific infrastructure that allows them to provide a service cost effectively from their own sites. It is feasible that monopoly operators could corner the market in a particular type, location or variation of service. Specialist and niche operators also become viable.

In this scenario, it is possible that existing, traditional MNOs are the parties who morph into the Mega MVNOs, outsourcing all of the provision of the wireless network itself to third parties and focussing only on the customer relationship and service aggregation. Alternatively, new players (such as Google or Facebook) may enter the market, or industry verticals or groupings of them may form their own MVNOs.

3.3.2.3 Implications for Spectrum

In this scenario, traditional mobile operators would need to be able to continue to provide their services and this is likely to require exclusive, individual licences in many cases for the various business and quality of service reasons they cited in the interview process. However, the scope for niche players opens up a need for other providers to be able to access harmonised mobile spectrum. This spectrum would be both below and above 1 GHz, depending on the type and location of the service that is to be provided.

Under current authorisation regimes, the only way in which new operators would be able to gain access to the majority of the already assigned mobile spectrum would be by reassignment of existing bands or assignment of new bands. Alternatively, if the existing operators were willing to share, trade or lease their spectrum through a variety of techniques such as formal trading, Licence Shared Access or even Dynamic Shared Access. Without access to such spectrum, it is highly unlikely that these niche services would be able to develop fully, as they would have to rely on spectrum available through other methods (e.g. licence exempt) and this is less likely to be harmonised for 5G services. Licence exempt spectrum, for example, may permit development of some services (e.g. IoT, WiFi or WiGIG) but would preclude the niche operators from providing, geographically targeted or high availability and reliability 5G services.

In renewing existing licences in 5G frequency bands, it may be necessary for regulators to introduce stricter ‘use it’ clauses. This means that MNOs would be mandated to provide other interested users access to under-utilised spectrum so that more spectrum becomes available to other service providers to offer new applications and services. These clauses would encourage operators to use spectrum effectively and efficiently and either to provide coverage and services over greater geographic areas, or alternatively, to make spectrum

available in any areas which they do not intend to cover. Whether such rules could be enforced (e.g. getting operators to admit that there were areas they may not cover) is another question (and beyond the scope of this study). Further, regulators could stipulate the conditions for trading, leasing or sharing (e.g. using LSA or DSA) such that there was clarity for the non-incumbent operators concerning where and how they could gain access to the available spectrum.

Whilst geographic coverage is one issue, many verticals commented in the public workshop that it was not coverage that was their issue, but that the operators did not provide the range or scope of services that they required. Again, without access to harmonised spectrum, these verticals would be unable to develop the services with the specific characteristics that they require. This could once again be enabled by a shared, leased or traded approach, but equally setting aside spectrum (that may then be shared) for niche or bespoke services would more rapidly and flexibly open up possibilities for new services.

For new spectrum bands yet to be licensed, there could be a move away from a systematic national authorisation (towards more regional or local authorisation) such that in areas where the bigger operators did not believe they could provide a cost-effective service, the spectrum could be accessed by other providers (e.g. on a restricted geographical basis). Indeed for the higher frequency bands (above 2 GHz) where coverage from any given site is relatively limited in area, such geographic sharing should not significantly impact the performance of operators' networks as interference from other nearby users would be minimal (or could be designed to be minimal through carefully agreed site placement). For instance, we learnt from the public workshop that the Netherlands is planning to make spectrum in the 2.1 GHz band, which was formerly used exclusively by the mobile operators for 3G services, available on a lightly licensed basis, which would open the door to a set of opportunities for other services that are either non-national in coverage or which are focussed on specific use cases.

Even for existing spectrum bands, as in the Netherlands case, it may be that when the time comes for existing licences to be renewed, some spectrum could be made available as a national commons, to encourage new and novel service provision models.

It is also possible that the MVNOs may themselves wish to own spectrum, so that they could sub-lease it to a network operator who then provides a wireless service for them (again this could be to provide services to the wider public, or for a set of specific users with defined performance requirements). The Mega MVNO could then award access to its spectrum to those wireless service providers who would have won some sort of competitive award procedure to provide and operate the radio infrastructure.

The spectrum options foreseen in this scenario are illustrated in the diagram below.

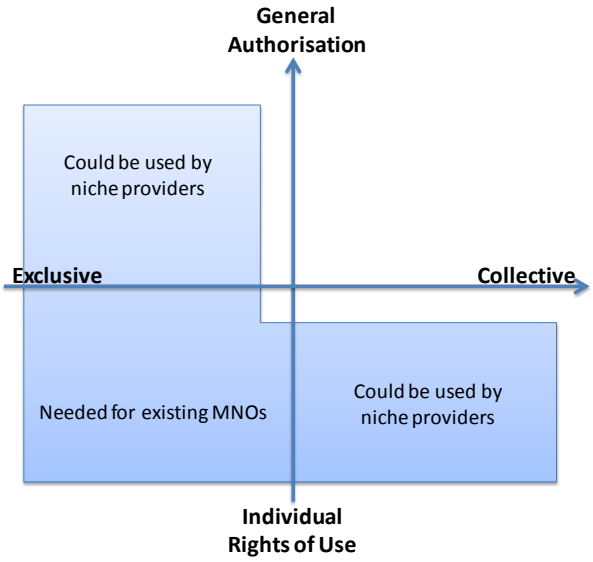


Figure 12: Possible spectrum options for Mega MVNO

3.3.2.4 Benefits arising from the scenario

The primary benefit of the Mega MVNO scenario is to the end users, specifically with respect to the price of services brought about by the optimisation of service selection and the bartering power of the MVNO, as well as wider coverage and the provision of tailored services that could be delivered by niche geographic coverage or specialist suppliers.

The lower cost services require that there is sufficient competition in supply. This means that the MNOs have their own spectrum, as they are likely to provide the core of the services, but also requires that alternative suppliers have access to spectrum. This could be through sharing, trading or leasing from the MNOs, or through a more widespread use of LSA or general authorisation approaches. Under a 'do-nothing' scenario, supply of services to the MVNO would be limited to those from existing MNOs and to those who could develop services in licence-exempt bands (such as Wi-Fi or WiGIG). Whilst this is likely to meet most consumer requirements, there may not be the commercial imperative on the part of the MNOs to provide niche services such as critical communications, or ITS services on the road networks. If alternative means of getting access to harmonised 5G spectrum were available, it would enable specialist providers to deliver these services, potentially in a more cost-effective way, and may even put pressure on the MNOs to up their game and attempt to take more of the market through delivering such services. It may be in higher frequency bands that such approaches will be inherent in the spectrum authorisation, however it is important that some method of accessing existing lower frequency bands is also considered. Requirements for some industry verticals, for example high availability or reliability, are unlikely to be able to be met in licence exempt spectrum (other than existing WiFi and some IoT applications) due to the need for both certainty of supply and low interference if service quality is to be maintained.

The wider coverage which is expected to be provided by niche geographic providers, whether in rural areas or along road or rail tracks, will only be delivered if spectrum can be made available to these providers only for the areas they may be interested in. In lower frequency bands this may be through leasing sharing or trading, in higher frequency bands yet to be licensed, this could be enabled through a general authorisation approach.

Arguably, this scenario improves the efficiency of spectrum use, by ensuring that spectrum that is not being used for one purpose (e.g. by an MNO in a rural area) can be re-used by an alternative provider. However, this is only possible if methods of sharing spectrum are enabled. Furthermore, this flexible access can lead to more rapid access to spectrum and therefore reduce delays to rolling out 5G type services.

Finally, there is potentially an opportunity for specialist services to be delivered, or at least for operators who provide services in a specific market or industry niche. These services could include enhanced Mobile Broadband services as specified by 5G or more niche services such as multimodal transport systems.

This will once again require that those operators have access to appropriate spectrum and this is most likely to occur through some kind of general authorisation or sharing, trading or leasing approach.

3.3.2.5 Benefits of a more harmonised approach of spectrum assignment procedures across the EU

In this scenario, the most significant benefit would be the possibility for users to have greater choice in terms of communication service providers, which in this scenario means that the user may choose from the traditional MNO, the traditional MVNO and now, a Mega MVNO. This scenario also enhances positive conditions for new players like regional or niche market players to enter the market. This improved level of choice will benefit consumers in the form of lower prices and greater service availability. The success of the Mega MVNO scenario will depend on the business models that are created and the bargaining power they have with traditional service providers like MNOs and other licensees, as they are indispensable in the supply chain.

In the scenario portrayed, Mega MVNOs are not initially seen as having rights of access to the spectrum, however they may wish to acquire spectrum at a later date but will not operate the network infrastructure. Their business model is designed to be successful because they will not be responsible by themselves for the functioning of the communications network, but they will only buy in resale capacity from different stakeholders like Wi-Fi hotspots, private wireless networks and MNO's, to then provide the service to the end customer.

The benefits of this scenario may be boosted if there was greater harmonisation in assignment procedures across the EU. This is because there might be room for alternative players in niche markets who might be interested to acquire spectrum to make their business case more successful by providing pan-national services (e.g. on road networks) additionally to the resale capacities they already count on. This would be the case if in the Mega MVNO environment there was room for an alternative player in the supply chain that would provide the Mega MVNO with the radio access. Let's bear in mind that in this scenario, the Mega MVNO does not operate the network, but there is a whole ecosystem of other players that provide radio access based on their own spectrum, or that owned by the MVNO.

This means that these alternative players might be encouraged to enter the market by obtaining frequencies through leasing or sharing in specific regions throughout Europe (i.e. capital cities around Europe), to make their business case successful. This strategy would only make sense if the services provided to the Mega MVNOs used the same frequencies in very similar conditions throughout Europe. Furthermore, this access could have lower transaction costs (i.e. high liabilities and guarantees, complicated mechanisms of auctioning spectrum that would require expensive consultancies to support them at the auction)

because these are reduced when the assignment procedures themselves are harmonised across different European countries. Today MVNOs negotiate with the same operators under the same rules of engagement. They acquire capacities from European operators that can offer services in more than 2 or 3 countries or states. If those operators or resale providers would be able to offer their resale capacities in a more harmonised way, it would pave the way for much greater choice of connectivity for future Mega MVNOs.

If we look more specifically at the benefits of harmonisation it is necessary to distinguish the different levels of harmonization that regulation may encounter, and to what extent should this harmonization criteria be applied in each Member State (end of each sub-section in 3.3). It is important also to recall that when we talk about harmonisation we refer to the harmonisation of the criteria taken into account to define the conditions of an assignment, i.e. harmonisation of the criteria to define the duration of licence, such as taking into account the duration of the amortisation of infrastructure costs.

Below, we identify some of the benefits of further harmonisation in the assignment of spectrum for 3 key services and uses. We also depict in the figure below (and for the other scenarios) which elements of the regulatory framework may benefit 5G technologies if greater harmonisation is adopted. The green shaded cells represent greater benefits when harmonisation is adopted and the blue shaded cells represent aspects of assignment that without further harmonisation might not bring additional benefits.

- **Enhanced Mobile Broadband**: If more harmonisation were to be implemented in the EU under this particular scenario, a number of benefits would boost the chances of success in the adoption of 5G technologies. Once harmonisation has been implemented mobile broadband providers would reduce their costs in the process of obtaining spectrum licences. This results when a mobile broadband provider has the burden of understanding and dealing with only one set of criteria that defines its success in obtaining several spectrum licences throughout the EU.

  Harmonising the criteria for spectrum assignment for enhanced Mobile Broadband services also creates higher legal certainty to providers. Knowing that the regulators in all Member States would apply the same principles when assigning spectrum gives the providers more stability in all their European businesses and reduces the risks of investment decisions.

- **Transpor**t service facilities: In this scenario, the facilities providers (like Bip&Go, Telepeage, Contactless Payment Cards) may also benefit from deeper harmonization in the criteria that defines the conditions to assign spectrum. These providers are now mostly confined to a national operation given, in some level, to the fragmentation in spectrum assignment. If greater harmonization in the criteria to assign spectrum was adopted, these facility providers would then have a chance to overcome the issue of national borders, allowing the users to use the facilities seamlessly thorough Europe. In that sense, their businesses may expand if the conditions to obtain spectrum throughout Europe allow them to produce and operate devices and provide the service without the costs of having to understand and deal with different criteria at the moment of obtaining the spectrum that is vital for their devices and services to operate. This will guarantee a seamless operation without the need to change devices or adjusting frequencies when crossing borders, benefiting consumers.

Service/Use	Level of harmonization that might enhance the benefits of the scenario						
	Bands	Use/Services	Types of Authorization	Awarding/Selection mechanism	Conditions of the licence		
					Coverage conditions	Sharing obligations	Timing obligations
Mobile Broadband	Create economies of scale, reduces production costs for terminals and infrastructure and promotes cross border services and networks.	Create economies of scale, reduces production costs for terminals and infrastructure, and gives legal certainty which promotes investment	Provides legal certainty, guarantees procedures for innovative and new services and providers	Reduces costs for providers to access frequencies, more legal certainty in rules of procedure	Provides legal certainty to promote investment	Promotes competition and innovative services	Provides market certainty and promotes rapid access to new 5G services
Multimodal Transport Services	Create economies of scale, reduces production costs for terminals and infrastructure, and promotes cross border services and networks.	Create economies of scale, reduces production costs for terminals and infrastructure, and gives legal certainty which promotes investment	Provides legal certainty, guarantees procedures for innovative and new services and providers, like a Mega MVNO	Reduces costs for providers to access frequencies, more legal certainty in rules of procedure	Provides legal certainty to promote investment	Given that the service provider is already multimodal, harmonizing sharing obligations for these particular providers might not bring additional benefits, as spectrum will be already used as efficiently as possible.	Creates market certainty and introduces the possibility of EU wide services to be deployed in a time frame known in advance

Table 4: Mega-MVNO benefits of harmonised elements and conditions for authorisation

3.3.3 Self-Organising Networks (SON)

3.3.3.1 Scenario

In this scenario, 5G technology is designed in such a way (primarily in the higher frequency bands) that it does not require specific frequency planning. Instead each cell site selects the optimum frequency from those available to it, and the network self-organises and self-optimises the use of spectrum as it grows. This function has been in the 3GPP standards since Release 8.

Networks would self-organise their own frequency plan, and could potentially co-ordinate with other networks to optimise performance (through minimising interference). Artificial intelligence in the network performs all of the frequency planning which can be done dynamically taking into account, for example, the addition of new sites, or changing seasonal propagation characteristics. Indeed, given the large number of sites needed and the complexity of managing frequencies in such a network, it has been argued that it would be unfeasible for the network to operate in any other way than being self-organising. The advantages of SON include:

- Reduced installation time and therefore cost
- Reduced capex through optimised use of resources
- Reducing human error in network design
- Improved user performance through
  - Load balancing between cells
  - Self-healing in the event of a site failure

In this scenario, we consider the following possible approaches to spectrum access:

- Direct spectrum access, obtained through auction or trading
- Indirect access to spectrum, i.e. shared access through a supplier such as an MNO
- Pool of spectrum accessed on a concurrent basis

The diagram below illustrates the various functions which enable self-organising network technology.

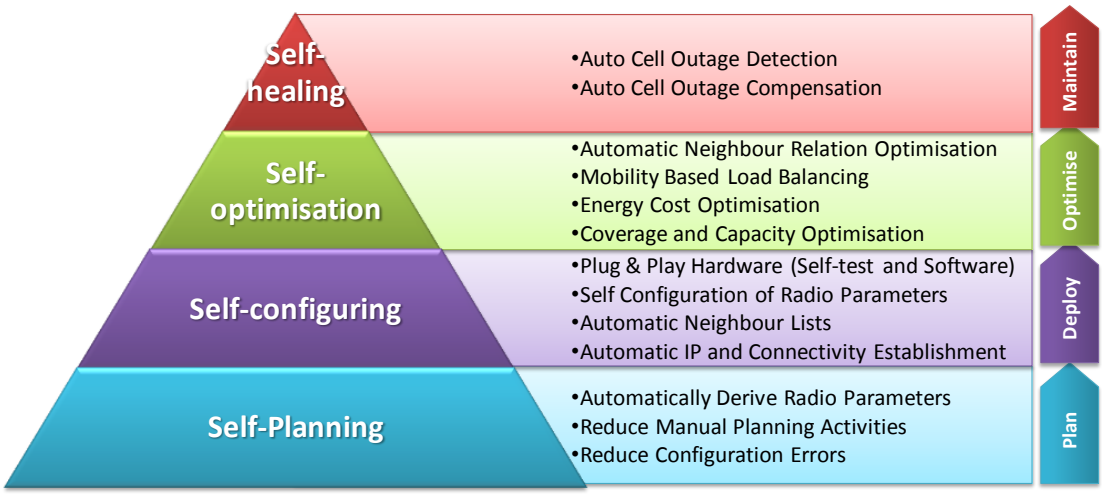


Figure 13: Function which enable SON technologies

3.3.3.2 Changes to Market and Infrastructure

For operators to differentiate themselves from each other, the most likely approach would be to install additional cellular infrastructure to ensure that the number of users in a cell is kept to a sensible value. Maintaining a given quality of service becomes a combination of assessing where demand may justify additional cells, and in the intelligence of the self-organising algorithms to find the optimum frequency from the available channels.

It is worth noting that spectrum is not the only requirement for such a scenario to develop. In addition to rapid and straightforward access to spectrum (i.e. general authorised approach) to support the myriad of cell sites, operators will need a reduction of some of the regulatory hurdles associated with gaining access to potential future cell sites to ensure benefits are produced to their fullest extent and in the most rapid way.

Such networks could also cater for some of the 5G use cases by intelligently allocating resources to a particular user or need based on their performance requirements. Specific cells could be designated as, for example, primarily PPDR cells and have their performance tailored for this purpose in order to optimise this service from amongst the available frequency and network resources.

3.3.3.3 Implications for Spectrum

The more spectrum that is available to each operator, the better cell sites will be able to manage their frequency use to minimise interference and thus improve their quality of service. Take for example the case of 4 operators, each of whom has access to 4 discrete channels. In this case, each operator can only select from its own 4 channels at each site. If all 4 operators pooled all of their channels, each site would be able to choose from 16 channels, and thus the probability of finding a 'clear' channel that allows to minimise interference and improve quality would be increased. This is essentially what a lot of WiFi hotspots already do when selecting the channel to operate on. Similarly, DECT cordless phone technology has access to a pool of 10 channels and each base station selects the frequency, which it believes to have the lowest amount of interference. Anyone using 5G technology, whether an MNO, a niche provider or an industry vertical would be able to take advantage of the self-organising functions of the network if they had access to the 'pool' of spectrum.

Note that the advantages of pooling frequencies only apply if each operator were to use different sites – if there are multiple operators who are sharing the same sites then there would be little difference between the two cases as there would need to be 4 frequencies at each site, reducing the overall flexibility in assignment. Whilst it might be argued that in the case of a single wholesale operator these advantages may not apply, if that operator had access to the whole of the available spectrum (e.g. all 16 channels in the above example), they would then be able to select the most appropriate channel and make best use of the spectrum. Of course, there is a range of scenarios in-between these two extreme options, for example with each operator having a limited number of their own channels (e.g. 2 each) and a pool of shared channels (e.g. 8 in total) also being available to all operators.

The spectrum options foreseen in this scenario are shown in the diagram below.

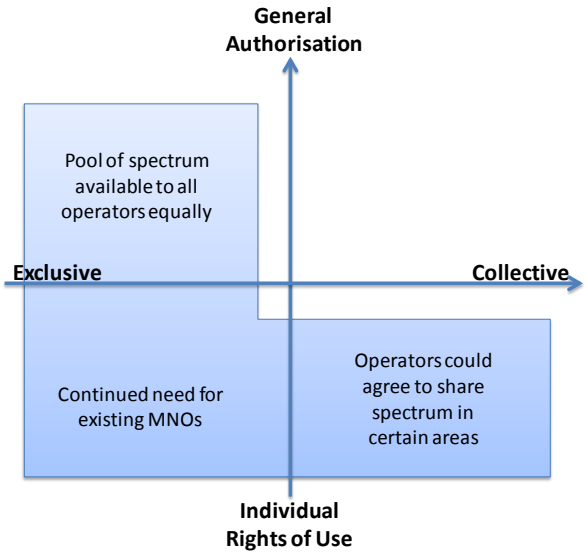


Figure 14: Spectrum options for SON

3.3.3.4 Benefits arising from the scenario

Many of the benefits delivered in this scenario are delivered by the technology changes and the facilitation of rapid deployment of small cells by removing regulatory obstacles, though it clearly requires the necessary spectrum to have been licensed and the associated authorisation measures to be in place. As we will see below, faster time to market and higher reliability are the result of spectrum (and sites) being timely available.

There are, however, benefits which would be enhanced by a move away from the traditional individual and exclusive spectrum authorisation scenario. Higher performance can be delivered through each site having access to a greater amount of spectrum especially if operators are encouraged to share their spectrum. This could be accomplished by having a pool of spectrum that is exclusively used for mobile but accessed in a coordinated way (concurrent access); which means that the frequencies have been authorised without giving an individual right of use to a particular stakeholder, but to any stakeholder that can comply with certain conditions, without identifying the specific frequency each will use or through trading or leasing between operators. The scenario would bring about reductions in the cost of deploying the networks and thus reductions to end-user prices. This could be further enhanced through similar authorisation arrangements.

It could also be argued that this scenario leads to more efficient spectrum use, especially if operators can share spectrum such that each site can select the most optimum frequency. This could be to the extent that less overall spectrum may be needed to deliver the services. For example, having the choice of, say, 12 frequencies at each site that are shared between 4 operators (e.g. using 12 shared channels) may yield a better service than each operator having only 4 frequencies to choose from (e.g. using 16 non-shared channels). It would be important, however, that such access was done in a timely fashion, which is to say that this scenario potentially enables the ability to enhance time to market particularly for newly identified 5G bands such as 26 GHz. An operator that has implemented a SON approach can configure the network such that interference is minimised and managed enabling competing services such as enhanced mobile broadband in distinct locations.

3.3.3.5 Benefits of a more harmonized approach of spectrum assignment procedures across the EU

As said above, the benefits of this scenario will be created by the technology changes, and the ability to rapidly deploy small cells (for example by implementing a light regulatory regime for permitting such deployments). Nevertheless, it is important to point out those strategies such as the example of a pool of frequencies that are accessed in a coordinated way by several licensees but exclusively used for mobile services, may benefit from a harmonized approach. This particular harmonisation approach would generate benefits that rely on the quick and seamless opportunity for operators to gain access to spectrum at a European level, creating economies of scale in the production chain of their products and the speed in which their services might reach the entire internal market.

Below, we identify some of the benefits of further harmonization in the assignment of spectrum for 2 key services and uses:

- **Enhanced Mobile Broadband**: If more harmonisation were to be implemented in the EU in terms of assignment procedures, conditions and timely availability under this particular scenario, enhanced mobile broadband providers would reduce their costs in the process of obtaining spectrum licences, in addition to the reduction of costs that the SON model provides. As an example, harmonizing the criteria regarding assignment procedure and mechanisms (i.e. the use of auction, beauty contest, individual licence or light licensing) or in particular the conditions for shared access and use of spectrum across the MS will result in creating higher legal certainty to providers that can rely on reducing costs when applying to spectrum authorization procedures[55]. In this scenario it is also very important to highlight that if the spectrum assignment procedures are harmonised, the usually high costs incurred when obtaining an individual right of use, might be reduced when using a model in which dynamic assignment, sharing and leasing is not only possible but mandatory, like when the SON model is applied. As a result, it has been argued that "more shared access is equivalent to extra spectrum and it is through exploiting this new spectrum that the major economic benefits of shared spectrum access accrue. The scenario simulations, which assumed allocation increases for wireless broadband of 200 and 400 MHz respectively, yielded estimates of the net economic benefit to the EU of shared spectrum access for wireless broadband and showed significant returns in net increases in GDP over nine years to 2020."[56]
- **Fixed wireless access:** SON deployed as a fixed wireless access service delivers a range of additional benefits to consumers and businesses, such as faster time to market and increased flexibility in deployment. Access to a wide range of frequency bands that can be used for both FWA and eMBB falls precisely into the performance expectations for 5G. Therefore, a consistent approach to spectrum assignment or type of authorisation will provide a degree of market certainty and predictability. It could also enhance and increase the overall ecosystem and the flexibility for the types of use of equipment

[55] "*Spectrum sharing contracts* provide users with legal certainty while creating market-based incentives, including financial compensation, to identify more BSOs in the internal market, if NRAs grant *shared spectrum access rights* to additional users of a frequency band." Communication from the commission to the European Parliament, the council, the European economic and social committee and the Committee of the regions. promoting the shared use of radio spectrum resources in the internal market. Brussels, 3.9.2012 COM (2012) 478 final.

[56] *Perspectives on the value of shared spectrum access*. Final Report. Support for the preparation of an impact assessment to accompany the Commission's Initiative on the Shared Use of Spectrum, SMART 2011/0017. 10 February 2012. Prepared for European Commission, Information Society and Media Directorate-General, Electronic Communications Policy, Radio Spectrum Policy (Unit B4) by Simon Forge, Robert Horvitz and Colin Blackman. Page 10.

across the EU and create new business models with increased regulatory certainty, reduced bureaucracy and reduced costs.

Service/Use	Level of harmonization that might enhance the benefits of the scenario						
	Bands	Use/Services	Types of Authorization	Awarding/Selection mechanism	Conditions of the licence		
					Coverage conditions	Sharing obligations	Facilitation of authorisation for roll out of small cells
Mobile Broadband	Create economies of scale, reduces production costs for terminals and infrastructure and promotes cross border services and networks.	Create economies of scale, reduces production costs for terminals and infrastructure, and gives legal certainty which promotes investment	Reduces costs for providers to access frequencies, more legal certainty in rules of procedure	Given that this scenario involves the adoption of a technical mechanism that will assign the frequencies in the most efficient way, this process has no upfront benefit if harmonised.	Provides legal certainty to promote investment	Promotes competition and innovative services	Promotes rapid roll out of infrastructure and access to 5G services. Reduces costs and timing for accessing infrastructure locations
Fixed Wireless Provider	Create economies of scale, reduces production costs for terminals and infrastructure, and promotes cross border services and	Create economies of scale, reduces production costs for terminals and infrastructure, and gives legal certainty which promotes investment	Provides legal certainty, guarantees procedures for innovative and new services and providers, like a Mega MVNO	Reduces costs for providers to access frequencies, more legal certainty in rules of procedure	Provides legal certainty to promote investment	Given that technically this scenario implies that the spectrum is assigned in the most efficient way to the provider that can make the most of it, further harmonization of these conditions do not imply	Promotes rapid roll out of infrastructure and access to 5G services. Reduces costs and timing for accessing infrastructure locations

	networks.					further benefits.	

Table 5: SON benefits of harmonised elements and conditions for authorisation

3.3.4 Infrastructure Economics

3.3.4.1 Scenario

In this scenario, the assumption is that providing all the cell sites necessary for the expected densification of mobile networks is not commercially viable in many areas. It is even less economically efficient for each operator to cover the same non-commercially viable areas where the number of users per cell is relatively small which may be in rural areas, or in dense urban areas where cells are very close together. This is likely to be particularly the case in higher frequency bands (e.g. mmWave bands) where coverage areas are very small, even in urban and suburban areas. To achieve coverage in these areas, costs can be reduced by sharing of sites and of the RAN itself (e.g. both passive and active sharing) or public money can be injected into the equation to fill the private sector profitability gap.

In addition to spectrum issues, greater focus on the sharing of infrastructure would reduce costs for the deployment of innovative infrastructures that will guarantee larger coverage and more rapid deployment. Such sharing could be undertaken voluntarily, however it may be that in some areas where, for example, infrastructure is held by an operator who sees no commercial benefit in rolling out services, that harsher measures, such as enforced sharing of infrastructure, may benefit coverage and roll-out.

Operators would differentiate their service through having their own dedicated cells in locations where it was economically or commercially beneficial to do so. This could be equally true of those wishing to offer a public, enhanced mobile broadband service, or providing specific, tailored services for other potential 5G use cases with different defined performance requirements. Another way of differentiating their service would be through intelligent network slicing or routing – effectively being smarter with the data once it has arrived in the network (e.g. within the core) rather than being smart with how it arrives to the network (e.g. the RAN).

In this scenario, we consider the following possible approaches to spectrum access:

- Direct spectrum access, obtained through auction or trading
- Indirect access to spectrum, i.e. shared access through a supplier such as an MNO
- Pool of spectrum accessed on a concurrent basis

3.3.4.2 Changes to Market and Infrastructure

Operators would share the RAN in many locations. There are a number of technical methods that could enable this, ranging from Multi-Operator Radio Access Networks (MORAN) where parts of the radio network controller and cell-site (eNode B) are shared but each operator has their own core network and operate on their own frequencies, to Multi-Operator Core Network (MOCN) where frequencies and all cell site equipment is shared, and only the core network itself is different between operators. These differences are illustrated in the diagram below.

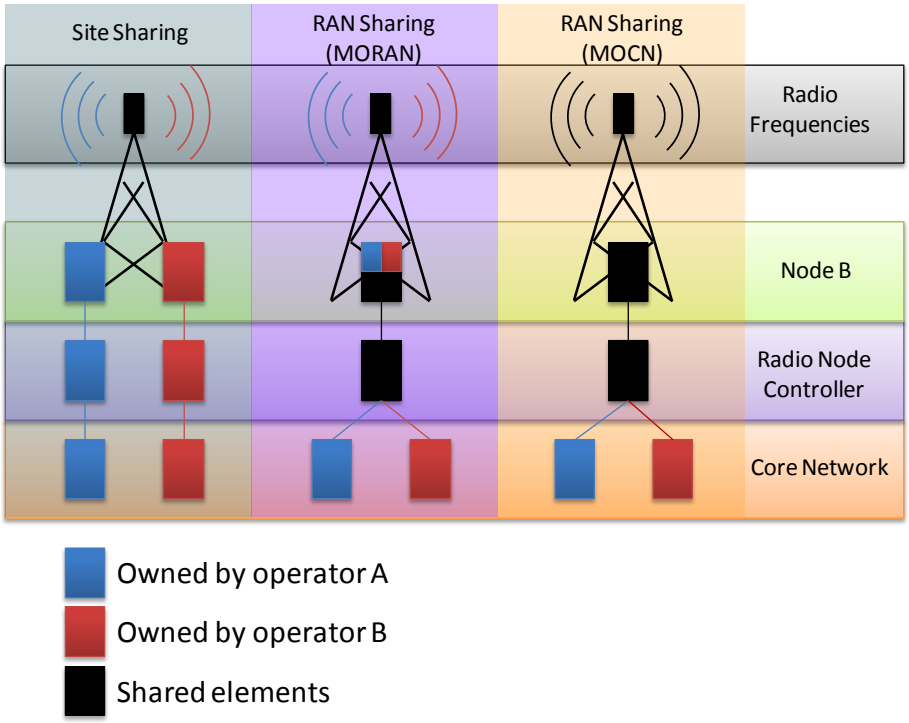


Figure 15: Methods that enable infrastructure sharing

Potentially there may be one overall network (akin to a wholesale network), with only small areas in which operators provided their own cell sites. Though there is one RAN, this may not necessarily belong to one operator or company, and different providers may deliver coverage in different areas or using different technologies and amalgamate these into a single virtual network. Network operators may focus provision in specific areas, with agreement between operators that they share national coverage obligations between them, or may concentrate on providing niche services to specific use cases but allow any spare capacity to be used by other operators.

In such a scenario, it may be the infrastructure owners themselves (e.g. the local council, or highways agency) who roll-out the network on their own sites and then lease the infrastructure to the mobile operators who then operate it in their own spectrum. For Intelligent Transport Systems (ITS) and driverless cars, for example, the owner of the highways could roll-out the necessary infrastructure to provide full coverage and provide connectivity and other services to vehicles on the roads, taking the burden of such costs from the MNOs, and sharing any spare capacity with them. Alternatively the infrastructure builder could operate the service in commonly available (e.g. generally authorised) spectrum and then sell services directly to the MNOs. There is scope for 'RAN operators' with limited geographic coverage: for instance it could be envisaged that a small rural area would install its own network and then connect this to an operator to manage the service. Such operators would essentially be wholesale operators, providing RAN to any of the operators who wished to procure a service.

A single (or low number) of physical networks maximises static economic efficiency insofar as the overall cost of providing the service is minimised, but dynamic economic efficiency caused by operators being able to compete through differentiated services is reduced.

3.3.4.3 Implications for Spectrum and mobile infrastructure

To maximise the performance of the network, each cell-site would require as much capacity as possible and by implication, as much spectrum as possible. Whilst it may be feasible for each operator to use only its own spectrum at each cell site, having access to the spectrum of its competitors (especially if they were sharing the resulting radio access) would ensure that the cell site could provide the best possible quality and throughput. This may be achieved through operators agreeing to share spectrum in certain geographic areas, or a similar approach to that proposed in the self-organising networks scenario, e.g. a combination of exclusive and pooled spectrum.

Infrastructure or often wholesale operators (including tower operators) i.e. those who see an opportunity to develop a business by reselling or leasing their infrastructure, may opt for obtaining spectrum either directly or indirectly (e.g. operating the network on spectrum leased or loaned by the MNOs for whom they are providing a service). It may be that the wholesale operator could use the spectrum belonging to any operator for whom they provide a service. In the case where the infrastructure operator was using the spectrum of a licensed operator (e.g. an MNO), this may require additional regulation to ensure that the MNO's were willing and encouraged to make such arrangements, otherwise there would be no incentive for the infrastructure owner to make the investment. Alternatively, the infrastructure provider sells access to its site portfolio to the MNOs, which is a common approach in the market today. The exception in this scenario would be that the infrastructure provider could go further than just providing passive infrastructure to delivering the overall service, thus requiring more flexible authorisation approaches, to help it meet its own business case needs.

For an infrastructure-based operator (e.g. highway authority) however, some guarantee of access to spectrum would therefore be important before they decide to make the network investment. Such networks may be geographically limited (for example along a rail route, or even as small as a shopping mall) or may be more widespread, they may provide a range of services, or may focus on one specific use case. Potentially these wholesale operators could lease spectrum from an incumbent MNO or they may wish to have access to harmonised 5G spectrum through a general authorisation approach. Without a flexible approach giving multiple parties access to suitable spectrum, many of these options would not be enabled, but instead could only take place if the holders of the spectrum (e.g. the MNOs) decided that they wished to operate such a business model and sought out other providers to help share the costs.

The various spectrum options which are necessary in this scenario are shown in the diagram below.

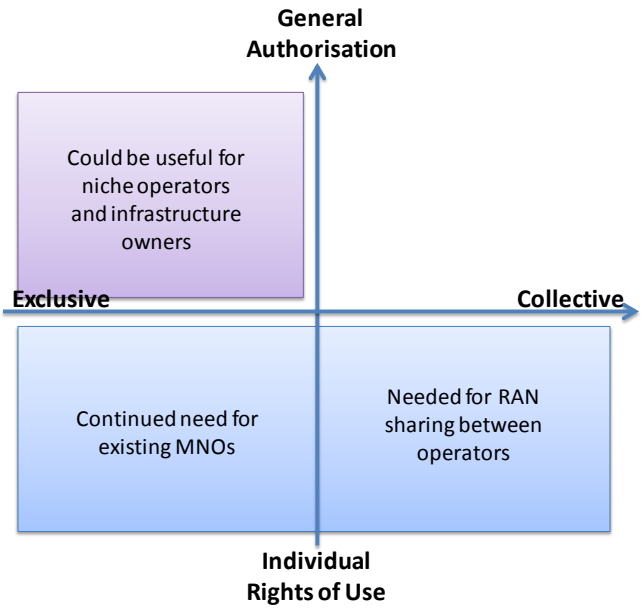


Figure 16: Spectrum options for infrastructure economics

3.3.4.4 Benefits arising from the scenario

There are a number of benefits which occur in this scenario:

- Firstly, there would be a faster time to market for 5G services, as in many cases, once a cell site is placed into use, it would provide many providers with access to the network, regardless of the service or technology. This requires the operators to have exclusive spectrum but it is also enhanced by the ability to use larger channel bandwidths, if some form of sharing is possible.
- Secondly, and as a result of the same processes, coverage may be expected to be wider. Again, shared access to spectrum and/or to mobile infrastructure for those providing the services would enhance this benefit.
- There would almost certainly be a reduction in the cost of the networks, which should lead to a more rapid and cost-efficient roll-out and a reduction in end-user costs ultimately. This does not necessarily require a change in spectrum authorisation, but it would be enhanced if operators could share spectrum.

In addition to the reduction of dynamic economic efficiency identified above, it is worth noting that there is also a potential risk in this scenario, i.e. that of reduced network reliability, even in a scenario where networks are built to be scalable with demand. With only a single network providing connectivity for multiple operators, any failure of that network would lead to outages for all operators. This is not strictly a spectrum issue, however, and the sharing or not of spectrum would not impact this risk. For some 5G services (such as enhanced broadband), this may be less of an issue but clearly in the case of use cases requiring high reliability and high availability (autonomous vehicles), this will require costly back up and additional redundancy.

3.3.4.5 Benefits of a more harmonized approach of spectrum assignment procedures across the EU

In a situation in which the rollout of the network will be less costly, benefits such as wider coverage and lower prices for users may be expected. One key feature for this model to work is that spectrum sharing is not just enabled but is encouraged. If the conditions under which spectrum sharing is possible were harmonised throughout Europe, it would be more likely for infrastructure sharing to be successful. If it was recommended to Member States to include in all spectrum licences such conditions, for example,, it would be possible to quantify the benefits of sharing. This could help identifying what proportion of spectrum and infrastructure sharing would be feasible to maintain a positive return on investment. The evidence from the market study would help to assess whether infrastructure sharing would bring overall net benefits for the particular market and/or location and thus enable an informed decision.

An alternative to this would be to implement a mandate on Member States to establish a set of criteria against which those assignees can measurably demonstrate their ability to share a certain percentage of their network (this percentage to be determined taking into account the specific conditions of service availability and competition conditions in each country). In this case, if operators can reduce the cost of network installation, these reductions may be invested in greater coverage and/or lower prices for consumers. The impact of a harmonised approach to spectrum sharing policies across Europe would create the economies of scale beneficial to the whole mobile sector potentially generating greater investment in a solution that would be useful for a larger portion of their served market.

We look at some of the more specific benefits of harmonisation that demonstrate for different levels of harmonisation, greater benefits may be realised for the infrastructure economics scenario. This is illustrated in the table below, and exemplified with two services or use cases described as follows.

- **Enhanced Mobile Broadband**: Let's recall that in the proposed scenario the primary change to the status quo of communications is that radio access is shared for a vast majority of network deployments. Today, sharing of infrastructure has proven popular and efficient to the point that in most Members States it has become the most used alternative when infrastructure is built. With this scenario, not only the physical sites will be shared, but also the Radio Access Network and the Core Network,. The benefit of harmonisation that is most evident in this case would be the one arising from the possibility of building more cost efficient networks in a larger market, creating economies of scale for the operators that would, at the end of the day, be expected to be reciprocated to users. Another visible benefit of harmonisation in this context would arise from the seamless deployment of networks across the Member States, which guarantee the benefits will also be amply visible in border areas. Additionally, with harmonization, the cost of equipment and devices would also significantly reduce given the larger quantities used throughout the internal single market. All of these financial and economic benefits would also be reflected in the confidence for investors to facilitate the funds necessary for a timely and rapid deployment of 5G networks.

- **Highway infrastructure operator (for connected vehicles)**: As we described in the previous sections of this scenario, there is a potential opportunity for a business case for those players that have traditionally offered site infrastructure to different operators. In this case, it might be plausible for the infrastructure providers to seek spectrum assignment. As a result, they could provide a complete solution to service providers, verticals or other players. We exemplify this case with a highway infrastructure operator, that owns sites along the major highways and is just missing the specific radio access layer. In this case, Harmonization throughout the EU would be beneficial for these potential providers, because they can offer seamless connectivity across borders and wide scale deployment of a common networks to deliver common services to a diverse mix of users.

Service/Use	Level of harmonization that might enhance the benefits of the scenario						
	Bands	Use/Services	Types of Authorization	Awarding/Selection mechanism	Conditions of the licence		
					Coverage conditions	Sharing obligations	infrastructure sharing
Enhanced Mobile Broadband	Create economies of scale, reduces production costs for terminals and infrastructure and promotes cross border services and networks.	Create economies of scale, reduces production costs for terminals and infrastructure, and gives legal certainty which promotes investment	Provides legal certainty, guarantees procedures for innovative and new services and providers	Reduces costs for providers to access frequencies, more legal certainty in rules of procedure	Provides legal certainty to promote investment	Promotes competition and innovative services	Enables differentiation in competition and promotes the most efficient use of spectrum
Highway infrastructure operator	Create economies of scale, reduces production costs for terminals and infrastructur	Create economies of scale, reduces production costs for terminals and infrastructur	Creates seamless connectivity across borders	Creates seamless connectivity across borders	Creates seamless connectivity across borders	Creates seamless connectivity across borders	Creates seamless connectivity across borders

	e, and promotes cross border services and networks. Even if the networks are deployed for local service and local providers, infrastructure and terminals produced in large scale would be beneficial as a result of further harmonization	e, and gives legal certainty which promotes investment. Even if the networks are deployed for local service and local providers, infrastructure and terminals produced in large scale would be beneficial as a result of further harmonization					

Table 6: Infrastructure economic benefits of harmonised elements and conditions for authorisation

3.3.5 Vertically Driven

3.3.5.1 Scenario

In this scenario, enhanced 4G networks (sometimes termed 4.9G) provide sufficient capacity and throughput to satisfy the vast majority of everyday user demand. Ericsson's 2015 Mobility report defined a 5G subscription as:

> "A 5G subscription requires a device capable of supporting LTE Evolved or NX, connected to a 5G-enabled network, supporting new use cases"

This would tend to suggest that the term 5G when viewed from an operator and vendor perspective encompasses advanced LTE networks (e.g. LTE Advanced Pro – 3GPP releases 13 and 14) as well as full 5G New Radio (NR). In this scenario, some 5G NR hotspots do exist, but these are relatively limited in scope and extent. It is therefore the industry verticals (e.g. transport, healthcare, construction) who become the primary driver for the roll-out of 5G.

Different industries develop dedicated 5G networks to provide services specifically for their own purposes, and all have different performance and coverage requirements although these are generally the same for each service or applications in all Member States (the requirements for railway operational communications are, for example, common across all countries). This could happen in any number of vertical industries such as:

- Internet of Things
- Critical Communications (whether PPDR or CNI such as utilities)
- Industrials (e.g. construction, manufacturing, chemical or metal production)
- Transport (i.e. road, rail, sea and air)
- Healthcare

This is not a new idea, some such national networks already exist today across Europe:

- the railways have their own GSM networks, GSM-R, which operates in their own dedicated and harmonised spectrum;
- most public safety agencies have their own radio networks also in their own dedicated and harmonised UHF spectrum (e.g. TETRA in 380-385//390-395 MHz harmonised band);;
- Intelligent Transport Systems (ITS), while yet to be rolled out on a large scale, already have their own dedicated and harmonised spectrum; and
- many utilities have their own radio networks often in their own dedicated spectrum, though the precise frequencies can vary at a national level as there is a lesser requirement for mobility across borders.

The difference is that these networks do not generally use harmonised mobile/IMT spectrum (e.g. that used by MNOs) and equally do not use standard off-the-shelf mobile equipment but use dedicated technologies (which may within themselves be harmonised but which are not compatible with everyday 3G or 4G technology). Whilst services are therefore harmonised across countries, the fact that the equipment is bespoke significantly raises costs, and in addition, does not permit other networks (e.g. existing MNOs) to provide fall-back coverage or capacity in the case of the failure of the dedicated network..

As such we consider the following possible approaches to spectrum access:

- Direct spectrum access, through a range of means including general authorisation but could be through an auction or exclusive licensing (e.g. a regulator allocating portions of mobile allocated band such as 700 MHz for PPDR)
- Indirect access to spectrum, i.e. shared access through a supplier such as an MNO. In addition portions of newly allocated mobile spectrum could be shared instead of exclusively licensed
- Acquire connectivity or access on the basis of meeting vertical requirements for Key Performance Indicators and Service Level Agreements

3.3.5.2 Changes to Market and Infrastructure

Everyday mobile broadband continues to be provided by national operators using their own dedicated infrastructure and spectrum, using mainly advanced 4.9G technology. These operators may also provide some 5G coverage but this will only be in areas where it is

commercially viable to do so, and this may be limited to urban areas or to even smaller hotspots such as railway stations and sporting venues where there is a very high concentration of potential users.

5G networks are established by the various industry verticals and may differentiate themselves in the services, performance and coverage they provide to meet the specific performance requirements of the industry concerned. Many have very specific geographic coverage, targeted only to areas where they require a service (though these areas may be national and straddle urban and rural areas such as for rail or road networks). Spare capacity on these networks may be leased back to the traditional mobile network operators. It is possible that the industry verticals outsource the provision of their network to third parties which may include traditional network operators, or may include innovative new organisations designed to meet their needs.

This is exemplified in the railway sector with a research project in the UK called Project Swift[57] which is seeking to enhance the current in-carriage passenger connectivity by the addition of new technology over the top of existing GSM-R network infrastructure. Depending on the outcome of the trial they may roll out an entirely new network across their own infrastructure. This approach to infrastructure would be highly disruptive and network operation would likely be based on a mix of different spectrum access techniques from using licence exempt or light licensed spectrum (generally authorised), accessing shared spectrum (from MNO or public sector) or buying capacity from an MNO and the rail operator or some other service provider becoming an MVNO.

3.3.5.3 Implications for Spectrum

Whilst traditional mobile operators will continue to need spectrum in which to provide their 4.9G and (limited) 5G services, it will be essential that the industry verticals have the possibility to access spectrum in which to provide their own services too. This may be spectrum dedicated to their usage, or be spectrum which they lease or share with other organisations which in itself may include traditional mobile operators or other verticals. As noted above, many European industries (e.g. rail, public safety) already have their own spectrum, however this tends to be in bands which, though sometimes harmonised at an EU level, are not those in which off-the-shelf mobile equipment operates (GSM-R is just below the normal 900 MHz mobile band and public safety networks operate in spectrum between 380 and 400 MHz that is not a 3GPP mobile band and thus not standardised for traditional mobile networks).

There is one particular example in the utilities sector, from the professional body for the European Network of Transmission system Operators for Electricity (ENTSOE) which provides policy support and development for organisation, that utilise critical national infrastructure. According to a report from the 5GPPP on 5G and energy[58], the sector is seeking to understand the impact of obtaining connectivity through a third party supplier for its network operations so long as the conditions and key performance indicators can be met

[57] SWIFT - Superfast Wi-Fi In-carriage for Future Travel, Innovate UK, http://gtr.rcuk.ac.uk/projects?ref=102485

[58] 5G and Energy, 5G Infrastructure Association, September 2015

by the supplier. It states in the report that "*due to the criticality of some Smart Grid applications and the respective communication solutions 5G needs to foresee appropriate SLA monitoring and management, when the communication solutions are (partially) provided by a third party. Provider and user need to be enabled to verify and monitor the communication solution".*

In this scenario, therefore, it would be important that the verticals have access to harmonised 5G bands at the required quality of service which would be the same bands sought by the traditional mobile operators. This is because, arguably without accessing harmonised bands and without the required quality of service they would:

- not be able to benefit from economies of scale in the manufacture of mobile infrastructure and user devices
- may not gain the full potential benefits offered by the 5G equipment ecosystem (e.g. in terms of broadband, reliability or massive connectivity);
- require specially modified equipment which history (e.g. GSM-R) has shown to be both more expensive and be more difficult to maintain;
- potentially end up in a situation where cross-border spectrum use for similar services was different, reducing the possibility of inter-country roaming;
- be required to deal with different regulatory regimes in each country to enable their services;
- may not get the security of tenure they would wish in order to enable long-term investment.

Access to harmonised 5G bands could be through direct ownership of the spectrum rights by the vertical, or through a contracted service provider who holds the spectrum (bespoke connectivity to meet the verticals' quality of service requirements or similar) or by leasing, trading or sharing spectrum with MNOs and may be in very restricted geographic areas or may be nationwide. For instance, in the UK, the government's Emergency Service Network (ESN) will provide critical communications through a contracted delivery partner (one of the MNOs) but as a result, this may require changes to the licence of the MNO as described in Ofcom's statement to vary EE's licence[59] in order to deliver the specificities of the service that the government requires.

Mobile operators will continue to need access to 5G spectrum on a traditional exclusive, individually licensed basis, and potentially on one of the more sharing based, pooled approaches already identified (e.g. due to the need for more integrated networks sharing to make services economically viable). However, the amount which they need may be less as they will only be concentrating on serving one group within the overall 5G stakeholder ecosystem, leaving some available for the verticals.

[59] EE licence variation statement, Ofcom Jan 2017
https://www.ofcom.org.uk/__data/assets/pdf_file/0032/96566/Statement-EE-application-for-licence-variations-in-support-of-enhanced-mobile-communications-for-the-emergency-services.pdf

For example, according to Huawei[60], spectrum available to operators below 6 GHz, is adequate to offer peak throughput of 10 Gbps (downlink) using 5G technology. Higher frequencies (e.g. above 24 GHz) would only be needed in dense urban or indoor hotspots where each operator may require 2.5 GHz of spectrum to deliver a user experience data rate of 1 Gbps (downlink). It can be argued that given their geographically limited areas, such hotspots would not require exclusive nation-wide use of these millimetre wave frequency bands but could share them with other users in other areas of the country.

New 5G spectrum could be, therefore divided up by user or industry rather than by operator or service provider. Some verticals may wish to be assigned spectrum on a shared basis amongst several industry groupings oran individual right of use on a national or European level, whereas others may be happy to leave the spectrum rights and network operation to third parties who could provide them with the bespoke services they need based on their performance requirements. These third parties may include the traditional operators or new specialist operators established to meet the specific needs of the verticals and thus may mean that some 'vertical' spectrum is shared with mobile operators or used by these new specialist operators.

A final point relates to the fact that within the same industry vertical, different applications often have strongly differing requirements in terms of Quality of Service and other Key Performance Indicators (KPI); such KPI's however tend to remain consistent across multiple Member States. A utility, for instance, may need more exclusivity for critical aspects of their communications such as the monitoring of power networks or fault detection applications, but may be willing to engage in a collective approach for applications characterised by less demanding performance requirements such as smart meter reading.

In cases where services and products are mission-critical, greater exclusivity is generally required. These different requirements will be the same across Member States for the same applications.

There is therefore a sliding scale of requirements for spectrum from within the verticals, that may be necessary depending on the application. This scenario also strongly suits the general authorisation and collective use of spectrum approach given the diverse and varying need for a range of different types of spectrum in order to meet the different KPIs.

3.3.5.4 Benefits arising from the scenario

This scenario is relatively unique in delivering highly specific services tailored to the needs of industry verticals. This will only be achieved if these industries, or the networks designed to supply services to them (by the industries themselves or by other operators), have access to suitable connectivity services (which in turn rely on access to spectrum from suppliers) or to spectrum itself through an appropriate authorisation process. This means there is a large degree of flexibility in how the regulator can approach the spectrum assignment to allow for numerous types of services. As mentioned above, depending on the specific KPIs of the industry, this may require many types of authorisation ranging from individual, exclusive rights for services that require high quality of service, to a general authorisation for services

[60] "Requirements on 5G Development – Device manufacturer's perspective", ECC 5G Mobile Communications Workshop, Mainz, Nov. 2016

which can tolerate delay and occasional loss of data. Without access to spectrum through a full range of these authorisation processes, fewer of the benefits would be fully realised.

Faster time to market is enabled through 'faster time to spectrum' insofar as the various industry verticals need access to spectrum to roll-out their services. Once, however, such access is granted, the time required for them to obtain services is determined only by their own investment profiles and demands. Access to spectrum for the verticals whether on an individual or general authorisation approach, could therefore enable much quicker time to market (i.e. time before the service is available).

One of our identified benefits is wider coverage, however in this scenario it is not necessarily the extent of the coverage which is important, but the fact that the coverage and the other quality of service elements are tailored to the needs of the industry vertical in question. As such, this benefit is enabled by providing access to spectrum to a right holder that can provide access with the relevant different quality requirements and scope of the different services. With respect to high reliability, necessary for some vertical use-cases, it is unlikely that it could be provided through spectrum that is not exclusively and individually assigned to the network operator, in the same way that such spectrum is needed for standard MNOs to provide an appropriate quality of service.

The specialist services necessary for the verticals are enabled through them having access to spectrum authorised in an appropriate way to meet their KPIs and this is likely to require a mix of different kinds of spectrum authorisation approaches.

3.3.5.5 Benefits of a more harmonized approach of spectrum assignment procedures across the EU

Out of the four scenarios described, this one would reap most benefits from a harmonised approach to spectrum assignment across Europe. As said earlier, the key element for this scenario to be successful is guaranteeing spectrum access to vertical stakeholders. If such access were guaranteed at a European level, then benefits accrue from economies of scale both for the equipment using the spectrum, and the associated infrastructure elements (e.g. meters, train radios, transport cards). When spectrum licences are available for vertical stakeholders in the same bands and under the same conditions (meaning individual rights of use or general authorisation), the innovation process and market access will improve, allowing them to invest / focus on improving their products better, rather than securing assignments in all Member States.

Therefore, in a scenario of harmonised spectrum assignment approach through Europe, the vertical industries will have a greater ability to utilise 5G services to the benefit of their services. . Furthermore, a harmonised approach would allow all vertical industries to choose between general authorization spectrum that may be quicker and cheaper to access for products that will not be too connected-dependent, or frequencies with higher quality of service conditions for critical services.

If we look more specifically at the benefits of harmonisation we may find that for different levels of harmonisation, greater benefits may be realised for the vertically driven scenario. We have chosen two use cases to elaborate on the different benefits that further harmonization in authorizations across the EU might bring as illustrated in the table and paragraphs below.

- **Utilities**: The utilities sector would be one of the big beneficiaries of further harmonization in spectrum authorization. Every European household depends on utility companies to provide energy, gas and water, amongst others. Devices that are equipped with communications systems using spectrum have been widely deployed in recent years[61]. If harmonization across the EU for the authorization of spectrum were to be widely used, then the economies of scale that this would create would be large, as the mass deployment of smart metering and other utilities devices would create a larger market in Europe, benefiting from lower prices and faster times to market across the EU. The costs of customising the devices would be avoided and the benefits could be transferred to users. For example, the different providers of some of the current smart meter devices are unable to effectively offer service in every EU Member State as the regulations affecting their access to spectrum differ. A harmonised approach would mean that they would be able to offer their technologies across the EU without having to examine the regulatory situation in each country on a piecemeal basis.
- **E-health**: As in the previous example, e-health and medical devices would also benefit from further harmonization in the authorization process across the EU. The larger the market for a product that needs no further harmonization or customization for each Member State will definitely impact the price and availability of the products and devices, which at the same time can also result on greater uses and modernization of other sectors. As an example, range-health and medical devices used across all EU (i.e. implantable devices to monitor real time health) could save thousands of lives with rapid access to a patients' healthcare programme anywhere in the EU. This means specific targeted care could be administered no matter the location of the patient. Devices production costs could be reduced by producing larger amounts of standard items which do not require further customization as for example, frequency tuning for each country.

Service/Use	Level of harmonization that might enhance the benefits of the scenario						
	Bands	Use/Services	Types of Authorization	Awarding/Selection mechanism	Conditions of the licence		
					Coverage conditions	Sharing obligations	Trading and Leasing obligations
Utilities	Create economies of scale, reduces production costs for	Create economies of scale, reduces production costs for	Provides legal certainty, guarantees procedures for innovative	Reduces costs for providers to access frequencies, more legal	Provides legal certainty to promote investment, as well as may benefit	Promotes competition and innovative services, and given the low	Promotes competition and innovative services, and given the low

[61] As an example, the Netherlands has established as a public policy goal that all households and small businesses have to have the possibility to obtain a smart meter over the next few years. www.government.nl/topics/smart-meters

	terminals and infrastructure and promotes cross border services and networks.	terminals and infrastructure, and gives legal certainty which promotes investment	and new services and providers	certainty in rules of procedure	consumer from lower prices in utilities bills	latency these services imply, technically the spectrum would be used more efficiently when actively shared.	latency these services imply, technically the spectrum would be used more efficiently when actively leasing.
E-health and medical devices	Create economies of scale, reduces production costs for terminals and infrastructure, and promotes cross border services and networks. Even if the networks are deployed for local service and local providers, infrastructure and terminals produced in large scale would be beneficial as a result of further harmonization	Create economies of scale, reduces production costs for terminals and infrastructure, and gives legal certainty which promotes investment. Even if the networks are deployed for local service and local providers, infrastructure and terminals produced in large scale would be beneficial as a result of further harmonization	Provides legal certainty, guarantees procedures for innovative and new services and providers, promoting investment in research and production for a larger market.	Reduces costs for providers to access frequencies, more legal certainty in rules of procedure	Creates EU wide connectivity regardless of patients; location or residence and provides cross border harmonisation.	This critical applications requires exclusive access to spectrum which should be harmonised across all EU and thus cannot be shared with other users	Creates EU wide connectivity regardless of patients; location or residence

Table 7: Vertically driven benefits of harmonised elements and conditions for authorisation

3.4 Summary of approaches to authorisation

The following table summarises the outcome of the analysis. We consider which type of spectrum authorisation regime delivers the various benefits, where such a connection can be made. The term 'shared' has been used in the table below to reflect both the case of operators sharing their own spectrum via some form of LSA or DSA, and where a pool of spectrum is shared between operators on a coordinated basis.

Scenario	Faster time-to-market	Wider coverage	Higher performance	Lower end-user costs	Greater reliability	Specialist services	More efficient spectrum use
Mega MVNO		Enabled through individual exclusive plus shared		Enabled through individual exclusive plus shared		Enabled through access to appropriately authorized spectrum	Enabled via shared use spectrum
SON			Enhanced through shared use spectrum	Enhanced through individual exclusive plus shared			Enabled via shared use spectrum
Infrastructure Economic	Enabled through individual exclusive plus shared	Enabled through individual exclusive plus shared		Enhanced through individual exclusive plus shared			
Verticals Driving	Enabled through access to appropriately authorized spectrum		Enabled through access to appropriately authorized spectrum		Enabled through individual exclusive	Enabled through access to appropriately authorized spectrum	

Table 8: Overview of approaches to authorisation across scenarios

The figure below summarises the extent to which each authorisation approach delivers benefits in each of the scenarios. It is clear that the 'vertically driven' scenario benefits the most from having a range of different authorization approaches whereas the 'SON' scenario benefits least from having spectrum available through a variety of authorisation methods. It is also clear that individual exclusive assignments remain very important across most scenarios, but that Generally Authorised Exclusive spectrum and Individually Authorised Collective spectrum (which are both methods for accessing spectrum by different incumbents) are highly important in a number of cases. Although typically this is for the MNOs, in some cases (e.g. in the vertically driven scenario) this is also for other users such as the industry verticals.

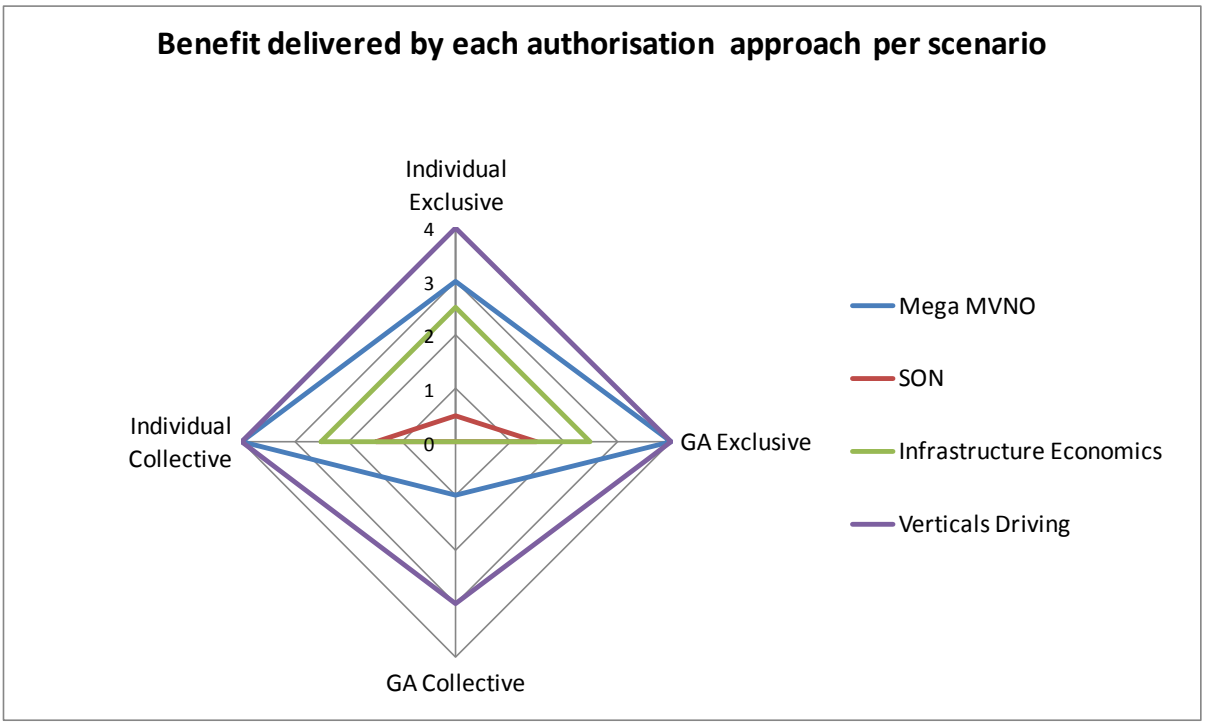


Figure 17: Summary of extent of benefit provided by each authorisation method

It is difficult to distinguish the different benefits provided under exclusive but generally authorized spectrum (e.g. a pool available to multiple parties, but limited in number) or individual but collective (e.g. sharing between operators through LSA). In essence, these two have similar characteristics, but they are different in terms of the regulatory approach. In the first case (a pool of spectrum), it is the regulator who would take the decision that spectrum is shared between operators and thus provide certainty to the market. In the second, the operators themselves agree to share and thus offer increased flexibility of access in the market.

Only in the case of the verticals-driving scenario (and to a lesser extent in the Mega MVNO scenario) there is any significant need for spectrum that is both collective and generally authorized (such as licence-exempt spectrum).

3.5 Summary findings

5G requires access to multiple bands supporting multiple bandwidths simultaneously to dynamically adapt and support the multiple services and use cases. We have found from the scenario analysis that there are authorisation approaches that support these type of spectrum requirements. We acknowledge that the EU has a framework in place today that will allow 5G services to be deployed in all Member States given:

5G requires both:

- Guaranteed quality of service – individual rights of use
- Straightforward, quick and cost effective access – general authorization

Although the framework that is in place today allows industry to access spectrum to achieve technical efficiency and achieve commercially viable roll-out, the scenarios have demonstrated the benefits of a more flexible and harmonised approach to spectrum authorisation. In essence, more flexibility and harmonisation might boost or enhance the rollout of 5G technology and possibly introduce new services that might not be realised if SRAs and operators continue to use the same traditional approaches. At the same time, increased utility of the approaches within the authorisation framework can promote a rapid and efficient deployment of the required infrastructure. This may also open access to specific niche services in sectors such as agriculture or utilities (typically in remote area) that may never be deployed given continued use of current approaches.

The results from the scenario analysis have demonstrated the benefits a more flexible and harmonised approach can bring to the regulatory environment. Wireless industry could deliver more new and innovative services whilst reducing administrative costs, reduce delays in deployment, potentially introduce new services quicker, and create a favourable assignment framework in their country, leading to better market outcomes.

Furthermore, mandating effective sharing may:

- result in lower roll-out costs, thus enabling investment in wider coverage and ;
- generate economies of scale in the production of user and network equipment;
- lead to lower prices for services that directly benefit consumers;

Existing approaches to authorisation are adequate for classic MNO models in which operators value the spectrum accordingly and are willing to pay for access to limited blocks within a competitive environment. This applies to spectrum up to around 6 GHz where block sizes range from 5 MHz to 100 MHz and can still support multiple operators without sharing.

However, as shown in our scenarios such as the Mega MVNO this could enable new services using licensed shared approaches. In particular, in bands below 6 GHz sharing offers increased flexibility and since the available bandwidth is relatively scarce more spectrum could become available in areas that MNOs currently consider to be uneconomical to serve.

General authorisation is an adequate approach when quality of service is not fundamental to spectrum users, and where willingness to invest in infrastructure is driven by the use case need (i.e. applications within IoT) and there is a level of tolerance to interference. Overall general authorisation is not necessarily more adequate than individual rights of use and vice versa unless it is linked to a particular type of usage and/or frequency band.

Based on the 5G spectrum usages, we have determined that both individual rights of use and general authorisation will be needed but that a fragmented approach where each Member States chooses a different authorisation regime would not be beneficial even if based on national circumstances. Depending on the band, type of usage and technical conditions required it is more beneficial to have a choice of authorisation models. QoS guarantees and interference management can justify exclusive individual rights of use. A need to share, wider choice and flexibility would mean that general authorisations are more adequate.

3.6 Impact of elements and conditions of mobile spectrum assignments on market outcomes

In the following sub sections, we have examined the impact of elements and conditions for mobile spectrum assignments on market outcomes and on operators' network investment decisions. We have also examined the impact of a consistent approach to assignment procedures and usage conditions in the EU on the same market outcomes and business decisions.

3.6.1 Spectrum usage in EU Member States

We address in this section “to what extent elements and conditions of spectrum assignment procedures and spectrum usage conditions will have an impact on the assignment results and on mobile markets”. To do this we have used data from the PolicyTracker Spectrum Database (PSD)[62] and other sources.

For elements and conditions of spectrum assignment procedures, we consider the following:

- Type of assignment procedure
- License length
- Coverage requirements
- Reserve prices

For the impact on assignment results and mobile markets we have focused on:

- Price paid for spectrum,
- Dynamics of mobile markets e.g.Number of players
- Price to consumers
- Take-up of mobile broadband services
- Deployment of 4G networks
- Network coverage

[62] The PolicyTracker Spectrum Database is the ultimate reference source for mobile and wireless broadband frequencies, which have been auctioned by regulators and identifies the bands won by mobile network operators. Data typically includes frequency band, bandwidth, prices paid, licence length and inclusions of coverage obligations

We conducted extensive analysis to determine if there were distinct relationships between a number of the elements such as bands auctioned, licence length and number of operators and bandwidths assigned in each Member State. However, the analysis, detailed in appendix A, revealed that for a majority of the combination of elements there were no clear relationships.

3.6.2 Methodology

This study has used two approaches to compare spectrum assignment procedures with their impact on mobile markets. The first is to examine whether individual elements and conditions have an impact, and the second is a grouping approach. Under this latter approach, we first categorised Member States into three groups based on their approach to assignment, then categorised Member States into another three groups based on assignment results and mobile market indicators. We then examine whether there is any matching between:

- the input categories: the elements and conditions of spectrum assignment; and
- the outcomes: the assignment results and mobile market indicators.

The individual approach has produced some helpful insights, but the number of links between inputs and outputs is fewer than might be expected. This is because there are some inputs and external factors influencing the mobile market, not all of which are within the scope of spectrum policy. For example, the ITU report on "Exploring the value and economic valuation of spectrum"[63] identifies extrinsic factors that influence the value of spectrum such as:

- Physical characteristics of the market;
- Socio-economic and political characteristics of the market;
- Policy and regulatory governance of the market.

This are characteristic to each Member State and could skew any potential relationships. Furthermore, the grouping approach is more helpful in drawing general conclusions, as explained in the second part of this section.

3.6.3 The individual approach to comparing inputs with outcomes

The first of our outputs, the price paid for spectrum during assignment procedures, is an objective, numerical measure which can be converted into price per MHz per population ($/MHz/pop) to facilitate direct comparison between Member States. We tested its relationship to several input measures but found no direct link.

We believe that one of the reasons for this is that many other factors can potentially influence prices paid in assignment procedures. These include:

[63] Exploring the Value and Economic Valuation of Spectrum, ITU-T, April 2012

- The design of the assignment mechanism (e.g. a single round sealed bid differs from a combinatorial clock auction in terms of price discovery) [64];
- The level of national competition (number of players in the market and/or reservation for new entrant);
- Level of competition within an auction;
- The relative scarcity of spectrum with similar physical characteristics;
- Reserve prices;
- Licence duration;
- Coverage requirements;
- ARPUs;
- Operators' strategic plans;
- Operators' financial resources and related costs of borrowing money if needed;
- Global, regional or national economic trends.

Some of these are related to the assignment procedures or are elements of the rights of use, such as auction design[65] or reserve price, but some are not, such as ARPUs, economic trends or operators' budgets. The potential impact of these extraneous factors appears to limit our ability to make direct linkages between auction price and market outcomes.

3.6.3.1 Auction prices and wider economic trends

The influence of global economic trends becomes clear when comparing the rise and fall of the technology-heavy NASDAQ stock market index against the prices paid in the 3G spectrum auctions held in Europe over a period that includes the bursting of the telecoms bubble in mid-2000, as illustrated in the figure below.

[64] Guidelines for the Review OF SPECTRUM PRICING METHO-DOLOGIES AND THE PREPARATION OF SPECTRUM FEES SCHEDULES, ITU-D, 2016 https://www.itu.int/en/ITU-D/Spectrum-Broadcasting/Documents/Publications/Guidelines_SpectrumFees_Final_E.pdf

[65] "Spectrum auction design affects prices paid, study finds". PolicyTracker, May 2017

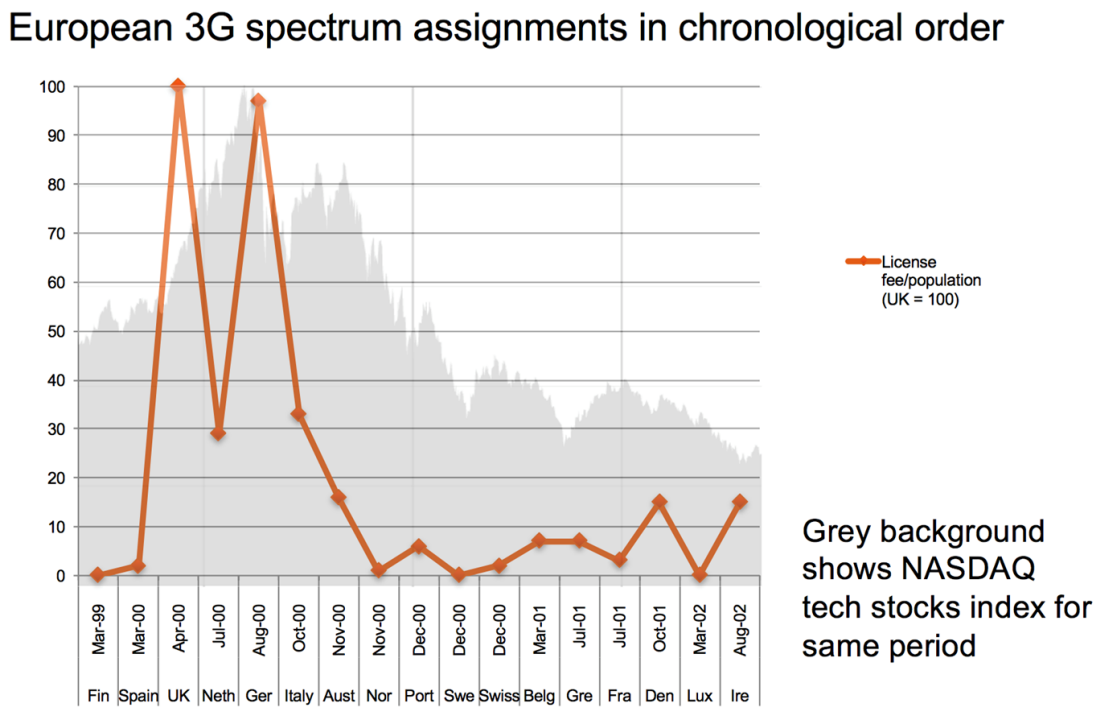


Figure 18: European 3G spectrum assignments

It would appear that a licence with restrictive conditions sold during a stock market boom might realise a higher selling price than a licence in the same band with no conditions during a recession.

3.6.3.2 ARPUs and auction prices

The graph below is based on EU data for ARPUs[66] and PSD auction prices in EU countries from 2010-2014. We divided the countries into quartiles based on their average ARPU for this period and plotted the average auction price of each quartile for four different frequency bands. The chart shows that operators on average pay more for licences in countries with higher ARPUs.

[66] *Average Revenue per User (ARPU) in the Retail Mobile Market* Published by Directorate-General for Communications Networks, Content and Technology, 2014 http://semantic.digital-agenda-data.eu/codelist/indicator/mob_arpu

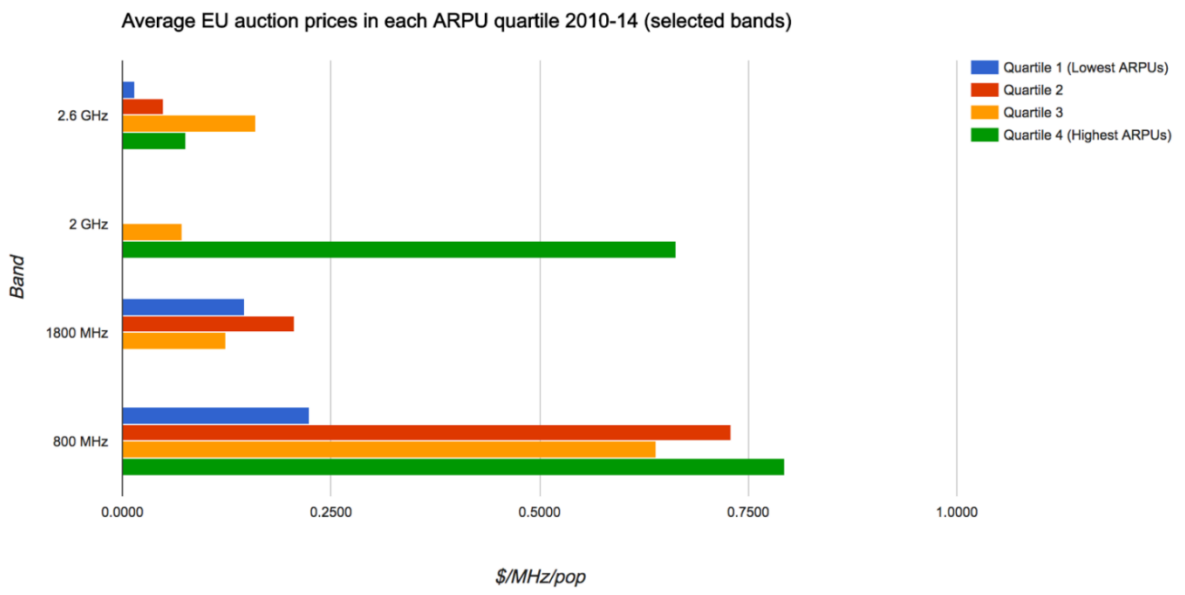


Figure 19: Average EU auction prices in each ARPU quartile 2010-14 (selected bands)[67]

The graph shows bands where auctions have been carried out in countries that cover at least two ARPU quartiles. The 2.6 GHz and 800 MHz bands provide the best indication because auctions have been held in countries that cover each of the four ARPU quartiles. The 700 MHz band is probably not a good reference as the auctions in, for example, France and Germany had different policy objectives, which drove the different price results. For this reason, we omitted the 700 MHz band auctions from the results depicted in Figure 23.

The bars represent the average price paid for the relevant band by all operators in the quartile from 2010-2014. Considering the number of factors that can influence auction pricing, **the relationship between ARPU and pricing in 2.6 GHz, 2 GHz and 800 MHz is persuasive**. It also reflects industry practice as operators often use ARPUs when modelling the enterprise value of a licence.

[67] Source: PSD and EU data shown in footnote below.

3.6.4 Evidence for assignment procedures influencing prices in spectrum auctions

3.6.4.1 Type of assignment procedure

Auctions are the most commonly used assignment types in Member States in bands harmonised for wireless broadband, as shown in the graph below. There have been so few trades or administrative assignments that it is not possible to establish any direct link between these and price paid for spectrum, so we have based our subsequent analysis on a comparison of the amount paid in auctions and in beauty contests. The analysis also examines individual bands rather than national averages because the results would be distorted by the large price differentials between bands[68].

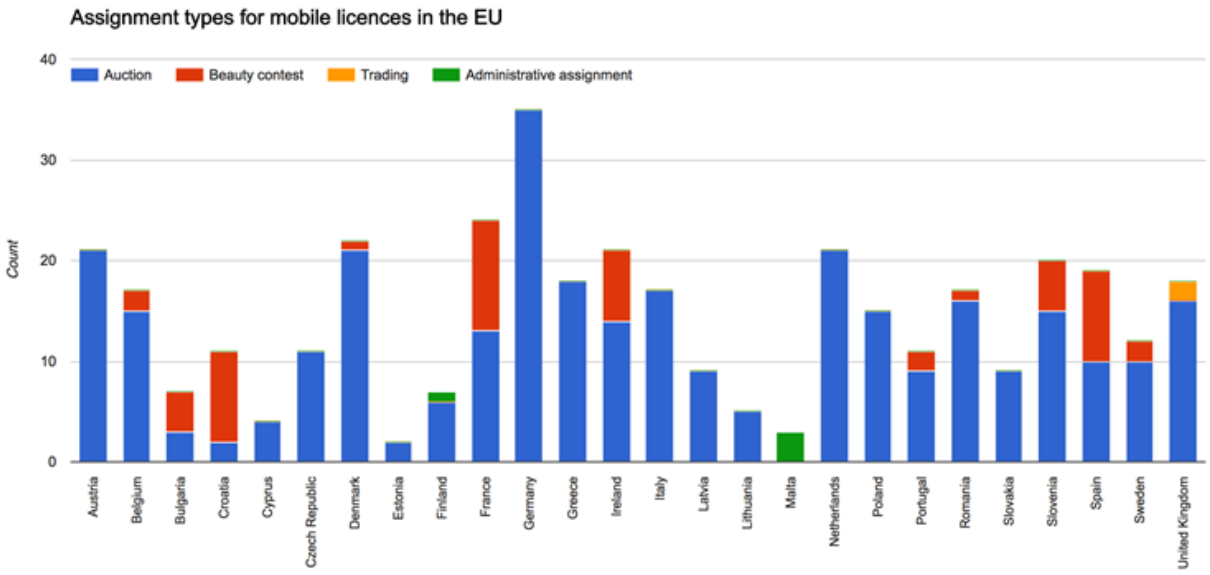


Figure 20: Assignment types for mobile licences in the EU

In most bands there is a lack of sufficient data, for example we are not aware of any beauty contests in the 1800 MHz or 2.6 GHz bands in the EU since 2000. In 800 MHz and 3.5 GHz there have been one each, but this is not sufficient data to draw conclusions.

The 2 GHz band would have been our best hope of establishing whether assignment type influenced prices paid for spectrum, as this offers the longest chronological range and the largest number of data points but the results are skewed by the telecoms bubble of 2000 and there seems no discernible pattern in the remaining data. Overall the PSD analysis does not suggest any relationship between spectrum prices and assignment types.

[68] 800 MHz is typically five times more expensive than 2.6 GHz, for example

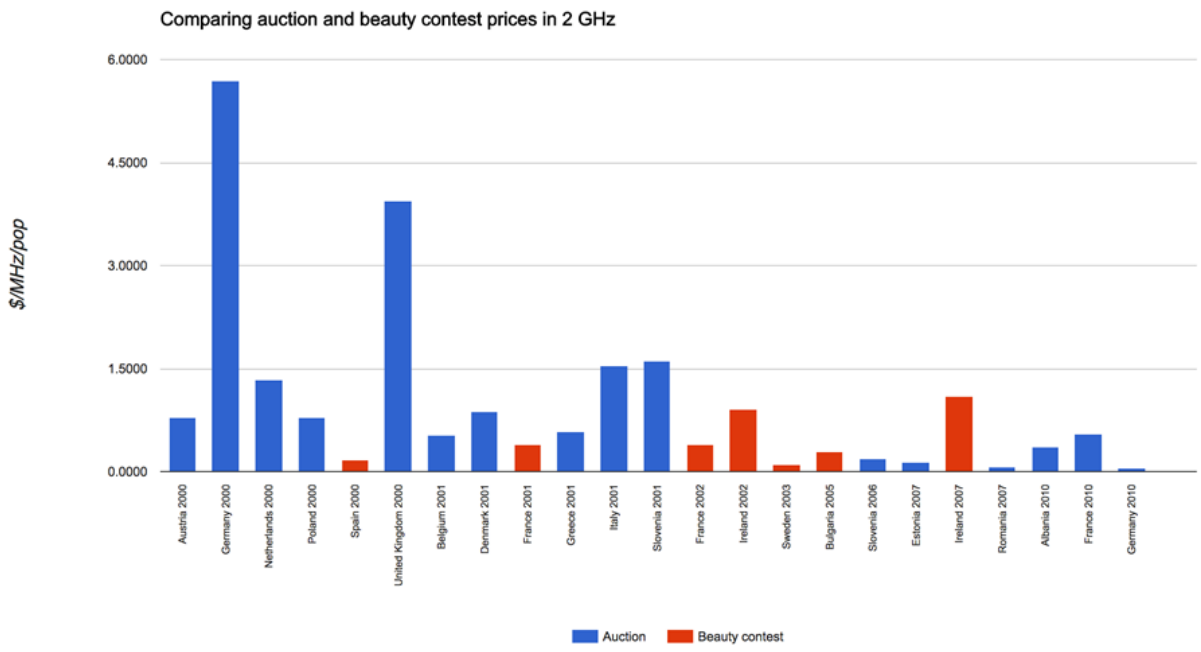


Figure 21: Comparing auction and beauty contest prices in 2 GHz

3.6.4.2 Licence length

3.6.4.2.1 Impact of licence length on auction prices

One might assume that bidders would be prepared to pay more for longer licences because of the longer return period. The diagram below illustrates the Discounted Cash Flow technique for gauging the value of a spectrum licence. Had the licence gone on for longer the terminal value would have been higher because profits would have continued to accrue. Surprisingly, therefore, the data does not display any obvious link between licence length and pricing (as also shown by graphs in appendix A).

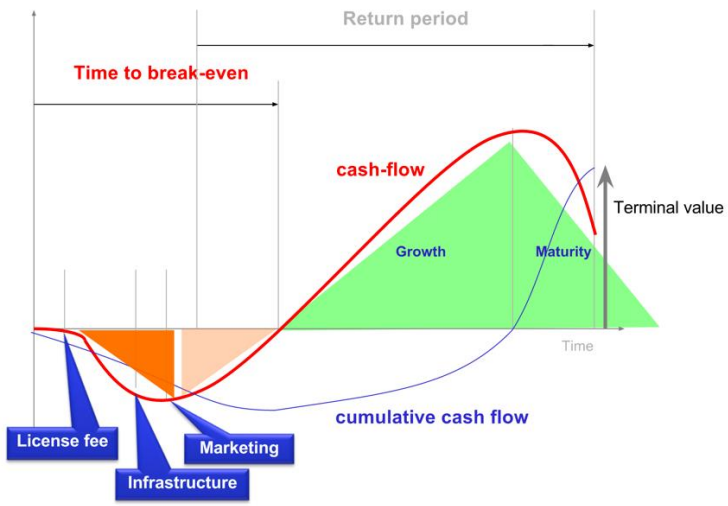


Figure 22: Using cash flows to calculate the value of a spectrum licence

Because of the problems caused by the telecoms bubble in making price comparisons in 2 GHz, we compared prices paid for licences in the following bands:

- 2.6 GHz (variety of licence lengths from 15-20 years)
- 1800 MHz (variety of licence lengths from 12-25 years)
- 800 MHz (variety of licence lengths from 11-24 years)

In order to eliminate the varying values of bands, we have only examined auctions where the same band was assigned with differing licence lengths.

As discussed previously so many other factors can potentially influence auction prices that the available data, despite being extensive, is not comprehensive enough to isolate this single determinant. The ideal like-for-like comparison of countries selling a short licence then a long licence in the same band a few months later is highly unlikely. Most often and especially for 4G multiple bands tend to be sold to all operators at once and not resold for many years.

Cross country comparisons are fraught with difficulty: if a 15 year 900 MHz licence were to be sold in country A in one year, then an identical 900 MHz licence with a 20 year duration sold in country B a few months later, then operators would probably be prepared to pay more, *if the circumstances were also identical.* This never happens though – countries have varying levels of competition, different GDPs and ARPUs and operators do not all have the same need for a particular spectrum band at a particular moment.

Another factor which may reduce price differentials is the accounting practice of amortising intangible assets such as spectrum licences over a fixed period (typically 15 years, as we will see further in Chapter "Trends in licences"). This means that the cost of the licence would disappear as an asset from companies' balance sheets after this time, even if the spectrum license lasted longer. This accounting convention may lead to an undervaluation of longer licences whilst there is no doubt that they offer the potential to generate higher returns.

3.6.4.3 Trends in licence lengths

Our existing data displays the variation in licence lengths in EU countries (see below). Considering all the mobile licences awarded in the EU since 1990 (Count), the figure shows that licence lengths of 15 and 20 years are the most common, accounting for 190 and 160 respectively even if there is considerable variation, with some licences lasting less than ten years. These shorter licences are of concern to mobile operators because they limit investment time horizons and potential return on investment of the licence[69].

[69] The impact of licensed shared use of spectrum, Deloitte on behalf of GSMA, Jan 2014

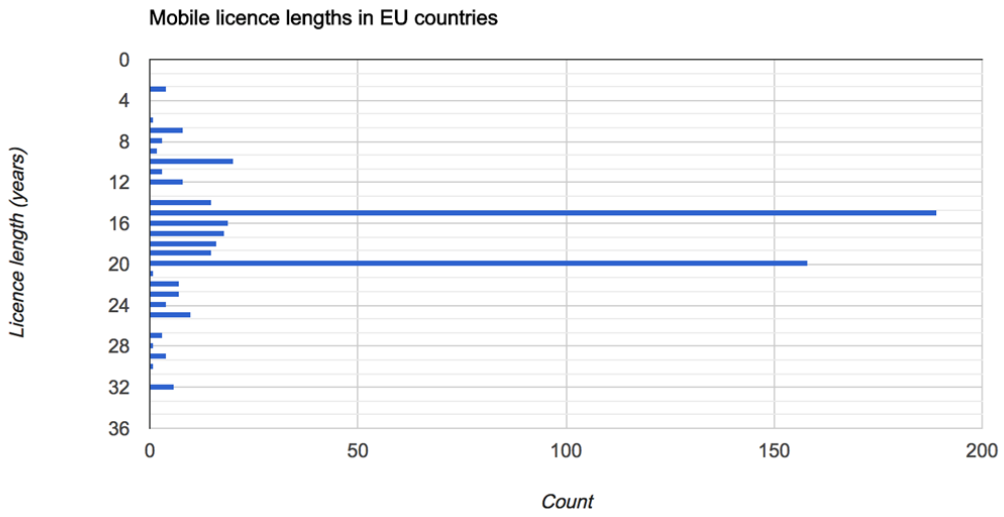


Figure 23: Mobile licence lengths in EU countries

We note that overall, licence length has been declining, as shown in the graph and table below. The lower average figures in recent years are not driven by large numbers of very short (likely temporary) licences, say of two or three years duration. As the table below shows, it is rather that licences of 11-15 years duration, unknown in the early years of mobile, have become increasingly popular.

One explanation may be that after the first mobile licences were issued, administrations have had the option to issue subsequent licences so that their expiry would be aligned with those of the existing licences. In this case, such new licences would hence necessarily be of shorter duration. Another possible explanation is that in the early years of mobile there was less certainty about the long-term profitability of the industry. As this market became more established, administrations may have wished to exert more control over its competitive structure, so came to favour shorter licence lengths.

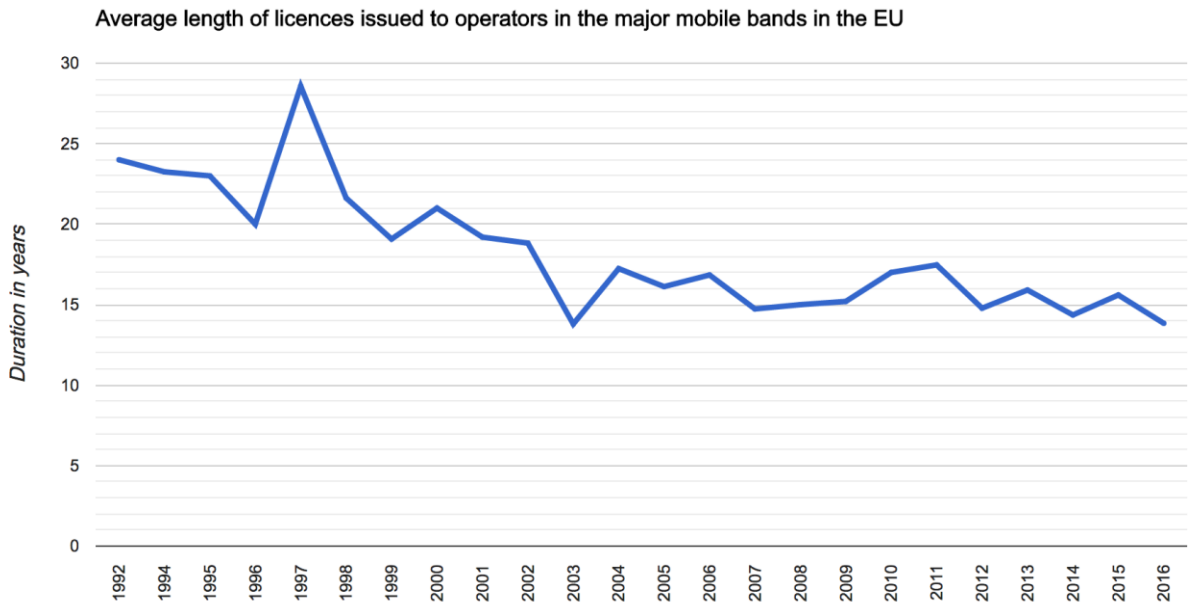


Figure 24: Average length of licences issued to operators in the major mobile bands in the EU

	<=5 years	6-10 years	11-15 years	16-20 years	21-25 years	26-30 years	31-35 years	Most used licence length
1992					1			21-25 years
1994					3	1		21-25 years
1995				5	3	2		16-20 years
1996				2				16-20 years
1997				1	1	1	4	31-35 years
1998			3	2	1		2	11-15 years
1999			1	12				16-20 years
2000			2	36	11	2		16-20 years
2001			5	26				16-20 years
2002			4	13				16-20 years
2003			5					11-15 years
2004		1	11	13				16-20 years
2005		2	16	15				11-15 years
2006		4	12	16				16-20 years
2007		2	11	2				11-15 years
2008		1	12	2				11-15 years
2009		3	3	9				16-20 years
2010		1	15	12	1			11-15 years
2011		5	5	18	4			16-20 years
2012		4	40	6				11-15 years
2013	4	5	9	30	4	3		16-20 years
2014		2	37					11-15 years
2015			10	5				11-15 years
2016		4	14	1				11-15 years

Figure 25: Number of mobile licences issued in EU, categorised by length

3.6.4.3.1 Do longer licences encourage network investment?

In general, the mobile industry considers that shorter licences have decreased the incentive for network investment [70] [71] and this study examines the evidence for this as part of our goal of examining how approaches to assignment can affect the mobile market. To do this we compare average licence lengths and mobile CAPEX[72] in national markets in the EU.

[70] *Licensing to support the mobile broadband revolution* A report for the GSM Association, CEG, May 2012 Ch 7 Section 7.1 Licence duration

[71] See also ETNO's comment here http://www.businessinsider.com/r-eu-states-push-back-against-25-year-wireless-spectrum-licenses-2017-4?IR=T

[72] The definition of CAPEX and the values that are included as such, correspond to the definition used in the Digital Single Market Reports available in **https://ec.europa.eu/digital-single-market/en/connectivity which is the Electronic communications sector network investment:** All telecommunications network investment (both tangible and intangible) excluding license fees.

Mobile CAPEX data is available from 2009 – 2015 [73] and we compared this with average licences lengths for the previous 10 years. The result shown below indicates a tendency for higher investment levels in countries that have awarded longer licences. Data omissions mean that not all Member States are included and we chose the metric of CAPEX per head to recognise that costs are higher in countries with larger populations. Details on the methodology are available in the appendix.

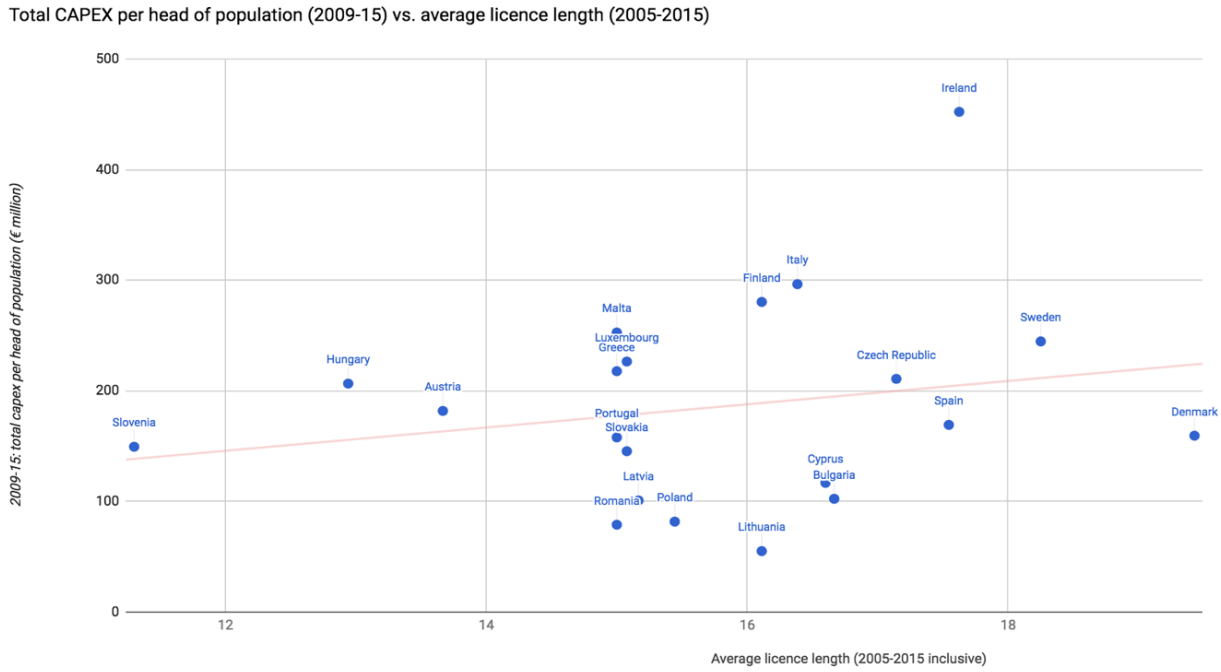


Figure 26 Capex per head of population compared with average licence length

This evidence of an association between licence length and investment levels is a further reason for policy-makers to be concerned about the trend of a reduction in licence durations.

3.6.4.4 The relationship between reserve prices and final auction prices

Many factors can influence the final price paid following an auction, from wider economic trends to the strength of competition for the bands on offer. Nonetheless, it is clear that while a low reserve price can allow the auction to determine the market price for the spectrum on offer, high reserve prices can lead to nothing other than high final prices (or unsold spectrum). Our research confirmed this, underlining the importance of sound methodologies (e.g. benchmarking, business modelling and/or technical modelling) for the setting of reserve prices. In recent years, regulators have rarely been able to rely on new entrants to create the competition which pushes up a low reserve price to a realistic market rate, so there is pressure to set higher starting prices to ensure a fair return for a public asset. If these are too high, though, there is a danger that the operator may be unable to make a profit and invest in greater and/or more advanced networks.

The scatter chart below is based on EU auctions' reserve and final prices since 2007. It shows a strong association between reserve prices and final prices paid. Three example

[73] Figures supplied by the European Commission

spectrum auctions are shown on the chart to help identify low, medium and high auction prices across the range.

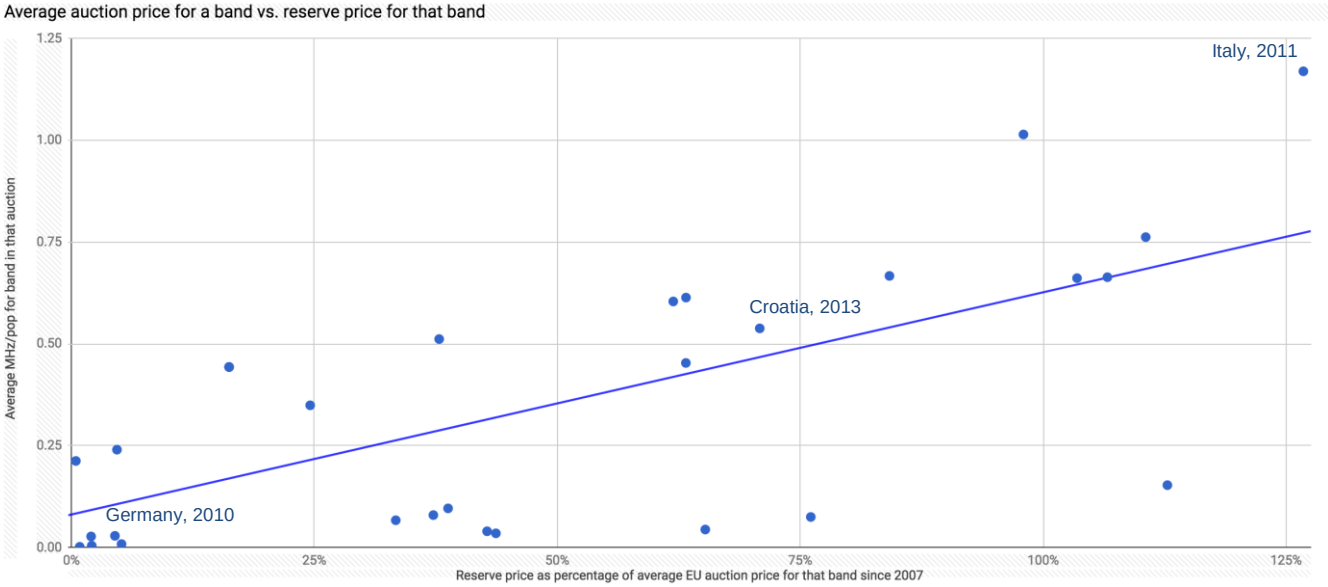


Figure 27: Comparing reserve prices and final prices paid in spectrum auctions

In order to show how relatively expensive the reserve prices are, they are shown on the horizontal axis as a percentage of the average price paid for that band in all EU auctions since 2007. The vertical axis shows the average MHz/pop paid by all bidders who won lots in that band in this particular auction. The table below shows the auctions represented in the chart, moving from bottom left to top right.

Auction	Reserve price as % of average price for that in EU since 2007	Average MHz/pop for band in that auction	Auction	Reserve price as % of average price for that in EU since 2007	Average MHz/pop for band in that auction
Poland 2008 900 MHz	0%	0.24	**Czech Republic 2013 2.6 GHz**	43%	0.04
Denmark 2010 2.6 GHz	0%	0.21	**Portugal 2012 2.6 GHz**	44%	0.03
Netherlands 2010 2.6 GHz	1%	0.00	**Czech Republic 2013 800 MHz**	62%	0.60
Latvia 2015 800 MHz	2%	0.03	**Finland 2013 800 MHz**	63%	0.45
Finland 2009 2.6 GHz	2%	0.00	**Portugal 2012 800 MHz**	63%	0.61
Germany 2010 2.6 GHz	4%	0.03	**Greece 2014 2.6 GHz**	65%	0.04
Sweden 2008 2.6 GHz	5%	0.24	**Croatia 2013 800 MHz**	71%	0.54
Latvia 2013 2.6 GHz	5%	0.01	**Italy 2012 2.6 GHz**	76%	0.07
Spain 2011 2.6 GHz	16%	0.44	**United Kingdom 2013 800 MHz**	84%	0.67
Spain 2011 2.6 GHz	16%	0.44	**France 2012 800 MHz**	98%	1.01
Spain 2011 2.6 GHz	16%	0.44	**Greece 2014 800 MHz**	103%	0.66
Denmark 2013 800 MHz	25%	0.35	**France 2010 2 GHz**	107%	0.66
Belgium 2012 2.6 GHz	33%	0.07	**Belgium 2013 800 MHz**	111%	0.76
Czech Republic 2013 1800 MHz	37%	0.08	**France 2011 2.6 GHz**	113%	0.15
Sweden 2011 800 MHz	38%	0.51	**Italy 2011 800 MHz**	127%	1.17
United Kingdom 2013 2.6 GHz	39%	0.10			

Table 9: List of EU auctions for mobile bands from 2009 to 2014

3.6.5 Do auction prices have a direct effect on other market outcomes?

While auction prices are one of the results of an assignment procedure, they are also an input to the operator's business model which may influence the wider mobile market. Industry representatives have often claimed that high auction prices have a negative impact on investment, as noted, for example in the ITU's spectrum valuation report[63]. We have

tested this thesis using data available on network coverage as this seems a reasonable proxy for network investment[74].

3.6.5.1 The relationship between auction prices and network coverage

As a substitute for a network roll-out metric, we have used data produced by a private company, Open Signal, which uses a mobile phone app to collect data about which services customers are able to access[75]. The app provides a 'percentage of network availability' figure for 79 countries, including 26 EU member states[76]. For example, if a country is listed as having 50% 4G availability, then on average that country's 4G users are able to find an LTE signal half of the time. This is a good indication of national network rollout: if a user cannot access a 4G network the most likely explanation is that the service has not been deployed in that area. It also has the advantage of being objective, rather than relying on operators' own claims about their network reach. Since typically, most people live in urban areas where roll-out is hence a priority, the figures might show an overly positive result.

EU countries were ranked based on the Open Signal data on 4G availability and on auction prices based on GSD data, as shown in appendix A section 5.7134.

We compared the ranking of 4G availability with the ranking for auction prices [77] restricting the auctions considered to commonly used 4G bands[78] and the date to the past 10 years as this is the timescale most likely to have affected 4G investments.

Those countries where operators have paid the most for spectrum over the past decade showed the worst 4G network availability. In the UK, Italy and France, auction prices were in the top 5 for this sample but network availability was in the bottom 5, with access to 4G available between 57% and 49% of the time. Conversely, the countries with the lowest auction prices, Lithuania and the Netherlands, had the highest network availability: 84%.

As a cross check we compared the 4G network availability figures with average 4G auction prices in each country, these latter figures being equalised to take account of the relative values of the bands.[79] The results shown in the scatter diagram below demonstrate an inverse relationship between prices paid and network availability.

---

[74] This seemed a more likely causal relationship that the other outputs measured, namely number of operators, price to consumers and take-up of mobile broadband services.

[75] See https://opensignal.com/reports/2016/11/state-of-lte for more details

[76] No data was available on Cyprus and Malta

[77] The methodological challenge here is comparing one unified data set – network availability – with a dataset containing a range of values – auction prices. Prices paid for 4G bands vary considerably, with the lower bands being valued more highly. So if country A had only spectrum in the 2.6 GHz band and country B had only sold 800 MHz we might falsely conclude that auction prices in B were much higher than A. Table 2 addresses this by ranking how much a country paid for each individually band, averaging these figures, then creating a new ranking based on this average.

[78] i.e. 1800 MHz, 800 MHz, 2.6 GHz, 700 MHz and L-Band

[79] The equalisation was done by creating a multiplier based on the average prices for each band in all EU countries since 2007. 800 MHz, being the most expensive, was take as the baseline and the other bands were multiplied by the following factors to

Figure 28: Comparison of auction prices and 4G network availability in the EU

While a comparison does not prove a causal relationship, there is strong statistical evidence that high spectrum prices can be associated with lower 4G availability. If it is more difficult to get a strong 4G signal, it is less likely that the customer will use high speed mobile data and less likely that the country will experience the associated economic benefits.

Some caution should be exercised when considering these figures. Mobile market outcomes can be affected by many variables, some of which are outside the scope of this study. For example, Lithuania and the Netherlands, which had the highest 4G network availability are both small and flat, making it easier to deliver wide geographical coverage. There is also only a single auction price available for both Lithuania and Spain. However, we consider that when taken together the individual comparisons and grouping approach gives useful insights.

3.6.6 Comparing spectrum auction prices across the Member States

The available data was analysed to see if some Member States consistently achieved higher or lower prices at auctions.

The graph below ranks the $/MHz/pop prices paid for each band across the Member States since 2000. The ranking is based on percentage terms with 100% representing the highest price paid for a band and 0% the lowest[80]. The Member States with the lowest average ranking appear on the left of the graph and those with the highest on the right. To ensure

give parity: 1800 MHz: 4.0586; 2.6 GHz: 6.8900; L-Band: 5.6053; 700 MHz: 2.7688. The 4G auction price for each country is an average of these equalised figures.

[80] Percentage ranking was used to prevent the distortion which would have been caused by numerical ranking e.g. the top rank for a widely sold band might be 50 but for a less popular band it might only be 5, giving an inappropriate weighting to the most used bands. Percentage ranking shows the highest ranking as 100%, whether the band had been sold 50 or 5 times.

sufficient data points the graph only shows those bands where we have data on more than five auctioned licences.[81]

If one Member State had consistently sold spectrum at the highest price then the bars for that country would all reach to the top of the axis, indicating a score of 100%. Conversely, if it had always sold for the lowest price no bars would appear at all because they would be at the lowest rank i.e. 0%.

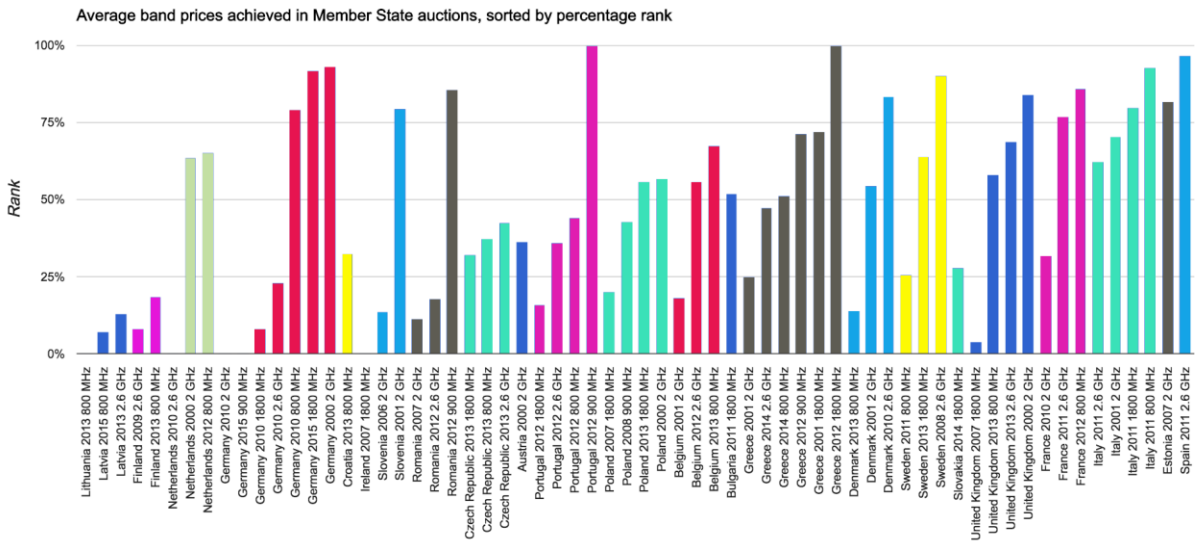


Figure 29: Average band prices achieved in Member State auctions, sorted by percentage rank

Several points can be noted from interpreting this graph. First, we should be aware of the lack of data in some circumstances, for example in Lithuania, which had a very low ranking, or Estonia and Spain, which had the two highest rankings[82], data is only available for a single auction. However, firmer conclusions can be drawn from the other results.

Considering those Member States where data is available for three bands or more, several of them show a reasonable spread in their rankings. In Germany, for example, the prices achieved for 2 GHz in 2010 and for 900 MHz in 2015 were relatively low while those for 2GHz in 2000 and for 1800 MHz in 2015 had comparatively high prices. A similar spread can be observed in Romania, Czech Republic, Portugal, Denmark and Sweden. If these countries' practices generate both relatively high and low prices, this suggests that their procedures do not have an inherent proclivity towards maximising or minimising revenues.

This leaves the UK, France and Italy, the three countries with sufficient data that had the highest rankings. Both the UK and France can claim a significant spread, with one band price that counted as one of the cheapest. Italy is the only country with all rankings above 50%. This seems significant because there are between 26 and 62 data points for each of the bands involved: 2.6 GHz, 800 MHz, 1800 MHz and 2 GHz, it is therefore not an aberration caused by coming top of the rankings in bands that have only been sold a handful of times.

[81] This excluded infrequently auctioned bands like 700 MHz, L-band, 450 MHz and 3.7 MHz. Included in the dataset is 900 MHz, where data is available on 8 licences. In all the other bands data is available on at xxx 26 licences have been sold , with the maximum being 62 licences in 2.6 GHz.

[82] Lithuania, Austria, Croatia Ireland and Bulgaria also have available data on only one auction.

On the other hand, Italy's rankings depend on the results of two auctions in 2000 and 2011. As we have seen earlier there is a multiplicity of factors that can affect auction prices. In this case the timings – during the 2000 telecoms bubble and coinciding with the smart phone data crunch – are likely to have been influential.

The infrequency of spectrum auctions restricts the conclusions one could draw about assignment practices from this ranking exercise. However, it is worth mentioning the two countries that have shown relatively low rankings in the widely sold 800 MHz and 2.6 GHz bands: Latvia and Finland. Again, we are only talking about two auctions in each country – and many factors could have caused this - but for them both to be consistently in the lowest eighth is noteworthy. Furthermore, both Finland and Latvia ranked first and second respectively in a Swedish analysis by The Internet Foundation in Sweden in 2013[83] for mobile broadband subscription uptake per capita in the Nordic and Baltic states. It could be argued that the low prices paid at auction in these countries has enabled more funds to be invested to extend the networks quicker relative to other Nordic and Baltic countries thus leading to increased uptake in mobile broadband subscribers in Finland and Latvia.

For further detail and information about the approach to grouping of the Member States with the aim to correlate the inputs and the outcomes, please refer to Appendix A, 7.14.

3.7 Overview of findings

3.7.1 Individual comparisons

In terms of the wide range of factors that can influence auction prices we produced evidence for:

- **A comparison between wider economic trends and auction prices**, as evidenced by the close relationship between the NASDAQ index and auction prices during the telecoms bubble of 2000
- **A comparison between ARPUs and auction prices**, as shown by an analysis of ARPU quartiles and average auction prices

Regarding the influence of elements and conditions of assignment procedures we *have not* found a link between auction prices and licence length or between auction prices and assignment type.

Regarding individual comparisons between assignment procedures and market indicators we found **a positive association between high auction prices and low network availability**.

We also found a positive association between **longer licence lengths and higher mobile CAPEX**.

Our study also found that it was possible to identify countries where spectrum was consistently sold at high prices. Italy was the one country where prices were consistently high, other countries such as the UK and France had some high prices but some low ones. Conversely, Latvia and Finland had consistently low prices.

[83] Telecommunication Markets in the Nordic and Baltic Countries, The Internet Foundation in Sweden, 2013

However, these examples are not widespread enough to draw strong conclusions.

3.7.2 Grouping analysis

We found that two countries, Finland and Denmark, which were in the highest groupings in the input categories, were also in the highest categories in the market indicators. This suggests a positive link between market-led assignment procedures and competitive markets with low prices and good consumer choice. However as this is based on only two countries, it is not fully conclusive.

Regarding aspects of the assignment process that are not welcomed by industry – high reserve prices and auction prices; short licences and onerous coverage obligations - we did not find a link between those countries which are most likely to display those characteristics and poor market outcomes. One reason is that the countries we assessed only tended to have one or two industry-unfriendly aspects to their assignment process, diluting any negative effects.

3.7.3 Implications of the research

3.7.3.1 The complexity of the mobile ecosystem

Before drawing conclusions, we should consider the complexity of the issue we are addressing. We are trying to ascertain whether specific elements of spectrum assignments have an impact on mobile market outcomes, and if so what they are. The aim is to draw lessons from the 4G experience and apply this to 5G.

The problem is threefold:

- First, extraneous factors influence both assignment characteristics and mobile market outcomes. We have seen the effect of stock market bubbles on auction prices but we should also note the influence of political pressures on competition. For example, the Netherlands had a fifth 4G operator because political pressure from the Dutch parliament[84] forced the 2010 2.6 GHz auction rules to include strict limits on the amount of spectrum that could be bought by incumbents. A market merger subsequently reduced the number of operators back to four. Had these spectrum caps not existed the band might have sold to the incumbents at a lower price (due to less competition) and the number of 4G operators would have remained stable at 4.
- Second, the factors we have identified as inputs (i.e. characteristics of spectrum assignments) may in some circumstances influence each other. Regulators could compensate for onerous coverage obligations by offering longer licence lengths, for example. In addition, mobile market outcomes are potentially interrelated, low take up of mobile broadband is likely to be influenced by high consumer prices, and in our grouping analysis Hungary, Bulgaria, Czech Republic, Greece and Slovakia appear in both categories. Good network roll-out and high network speeds may also lead to high

[84] T-Mobile was restricted to 10 MHz and KPN and Vodafone had a 20 MHz limit. New operators were allowed up to 40 MHz. See https://www.policytracker.com/headlines/dutch-2.6-ghz-auction-only-fdd-licenses-sold and https://www.dotecon.com/assets/images/dp1001.pdf p20

broadband take-up and Denmark, Finland and the Netherlands are all in the highest categories in our groupings.

- Third, is it a one-way process or a two-way process? For example, are high auction prices a cause or an effect of intense competition? Both could be true: the more operators seeking spectrum at an auction, the higher prices are likely to be but also, the more operators have paid the more they may need to bring down prices to attract customers to recoup their investment, hence stimulating competition. Does network quality stimulate take-up or vice versa? Or are they in a symbiotic relationship?

It seems reasonable to conclude that the area we are studying is a complex web of multi-dimensional relationships and in that context we are highly unlikely to find evidence for simple causation – "magic bullets" where a single factor is having an overwhelming effect on a single outcome. This makes the evidence we have uncovered all the more significant. In an environment with so many variables the relationships must be particularly strong to establish associations.

3.7.4 Summary of spectrum assignment outcomes analysis

Our study indicates an individual comparison between high auction prices and poor 4G network availability, which we regard as a good proxy for network rollout. The data does not tell us why this happens but operators say that high auction prices reduce the amount they can spend on networks.

The grouping study reinforces this conclusion by taking a wider approach. It posits an answer to the question: do approaches generally welcomed by operators – namely low auction prices and low reserve prices; long licence lengths and market-led coverage obligations - lead to positive outcomes in the mobile market? The evidence suggests that they do: Denmark and Finland, two of the three countries that have the largest number of these features, also have mobile markets with the most positive characteristics, namely high levels of competition; network roll-out; take-up; and quality and choice of services. Given the many factors at play in the mobile market, we regard this as strong evidence.

What policies could we adopt in the 5G era to prevent those assignment characteristics that seem to have a negative effect on the market? It is reasonable to assume that high reserve prices are likely to lead to high auction prices and there is good match for this in our grouping analysis? Italy and France were in the highest grouping for both[85].

The forthcoming 700 MHz auctions in most European countries are an opportunity to consider approaches for more ambitious coverage obligations. In the case these are set out, their impact has to be taken into account when setting the reserve price or the assignment price (for other selection procedures which do not rely on reserve prices). Our study indicates that the least onerous obligations are part of a package of policies that has positive market outcomes. Furthermore, our study suggests that greater freedom to operate some bands as purely commercial enterprises brings greater benefits. If a coverage obligation is needed, it may not need to apply to all operators. The social policy objective of widespread coverage could potentially be achieved at less damage to the market through a single

[85] Intense competition within the auction will also lead to high prices: Sweden and Spain both had low reserve prices but high auction prices.

coverage obligation band and national roaming agreements. Circumstances will vary from country to country but our study points to the benefits of a market-led approach.

There is a further need for policymakers to re-think coverage obligations because technology neutrality means that existing mobile bands can be re-purposed for 5G, raising the question of whether an existing coverage obligation should still apply once the band is put to a new use. If, for example, 700 MHz band-specific coverage obligation on voice or data services were set in some member states but not in others, that could restrict EU harmonisation and inhibit potential economic benefits by stopping the widespread deployment of 5G. Having coverage obligations attached to specific bands could restrict the deployment of the best technologies in those bands. It may be preferable to attach coverage obligations in different ways, allowing operators flexibility to meet this obligation across a wide portfolio of bands, technologies and services. It might also be appropriate to start thinking about coverage obligations in terms of service, i.e. X Mbps available to Y% of population or in terms of temporal rather than geographic availability.

Our other finding about declining licence lengths is also significant here. As this is one of the factors that can have a negative impact on market outcomes, the tendency towards shorter licences is a matter of concern. It does not seem to have been a deliberate policy choice, rather a set of decisions of which this was an unintended consequence. Reversing this could have a positive impact on 5G.

3.8 Identification and analysis of the impacts that the selection of an assignment approach might have on the Member States

Based on the findings from section 3.6 and the summary of the feedback from the stakeholder interviews, we address the specific questions in relation to the impact selection procedures and conditions of spectrum usage have and which include:

- Impact of spectrum assignment on business investment. Notably investment in network deployments by operators, provision of future electronic communications services envisioned within the auspices of 5G;
- Impact of a consistent approach to spectrum assignments comparing assignment procedures and spectrum usage conditions;
- Specific aspects that would most benefit from secondary policy development.

Furthermore, we identify how these approaches can alleviate specific problems and deliver more timely availability and appropriate access to spectrum envisioned within the auspices of 5G.

3.8.1 Impact of spectrum assignments on business decisions and network investment

New networks will be required for 5G that will expand the capabilities and resources of traditional MNOs and new service providers. For example, software defined networking and network function virtualisation will form part of the delivery platforms for 5G which are usually provided by fixed telecoms operators meaning 5G networks will be much more converged with fixed networks than earlier wireless networks.

Since new use cases such as connected cars and health care will require infrastructure along highways and within hospitals and other medical establishments access to this infrastructure and availability of services will differ from today.

Mobile operators and other service providers will need to consider the new 5G business models and make decisions based on new approaches to service delivery to ensure network investments fulfil the requirements and performance expectations of 5G.

Some examples of the types of business decisions taken by MNOs and other electronic communications service providers are given below:

- Build and invest in infrastructure to deliver core services;
- How to ensure customer retention and growth;
- Choice of particular harmonised frequency bands;
- Equipment, device and technology choice – not if but when;
- Participation in future spectrum auctions, which bands and how much spectrum is available/needed;
- How to streamline particular processes (OSS/BSS) and where to make cost savings;
- Decision to share spectrum or infrastructure;
- Decision on selling capacity on a wholesale market basis;
- When and where to invest in infrastructure to alleviate congestion on the network;
- Decision on specialised coverage projects such as along rail routes, in building such as enterprises and shopping malls.

More specifically, this study focuses on investment by MNOs and the balance between investment in spectrum and infrastructure. This is a critical aspect of a mobile operator's business and is increasingly linked to competition aspects of the market. We have found from both talking to MNO stakeholders and feedback from the public workshop that high spectrum fees will limit the available investment in infrastructure. As we have seen, this may be caused by the link between high reserve prices and high final auction prices, which ultimately limit the amount of capital available to MNOs for investment in infrastructure.

Also, studies from the GSMA[86] and analysts have found that more expensive spectrum can lead to:

- Reduced quality of networks and thus reduced uptake of mobile services
- Higher consumer prices for mobile broadband data
- Lost consumer welfare and lack of purchasing power

This may become a vicious cycle in which, overall, consumers and society lose out as network operators wrestle with increased costs and flat/declining revenues ultimately leading to poor user experience. Spectrum fees are often predominantly required upfront, and these are hence one of the primary cost factors MNOs will consider when making business decisions. However, these business decisions will only be finalised once spectrum is made available by the SRA and will be affected by the auction design (i.e. decisions on elements and conditions) and the final price, which could result in the MNO cancelling certain investment plans or cutting costs elsewhere.

There will be a need for SRAs to make more spectrum available more quickly (as identified in section 2.2) which will likely include a mix of individual exclusive licensing (such as for 700 MHz and 3.4 – 3.8 GHz) and general authorisation or hybrid approach such as light licensing. Therefore, mobile operators in the EU will need to prepare for more auctions but also potentially new (often currently under-utilised) approaches for accessing mobile allocated spectrum. This may trigger a change in the way future business decisions are taken that will ensure the availability of 5G services.

We examine to what extent the elements and conditions of spectrum assignment procedures and spectrum usage conditions will have an impact on mobile operators' business decisions regarding investments in network deployment and provision of electronic communications services.

Impact of assignment procedures on business decisions

We have already examined (see section 3.6) the elements that lead operators to make decisions on accessing spectrum on an individual exclusive licensed basis. The most common approach to making mobile assignment by SRAs in the EU is via auctions. Thus, MNOs are geared up for when more spectrum is identified by SRAs for release to the market. However, in each case and with every frequency band identified, MNO conduct an extensive assessment on whether to bid for the spectrum or not and up to what price.

Investment in new networks and upgrade to existing networks and passive infrastructure will be vital to enabling 5G. A study by the UK Government on Connected Future[87]

86 Effective Spectrum Pricing: Supporting better quality and more affordable mobile services, NERA on behalf of GSMA, Feb 2017

87 Connected Future, National Infrastructure Commission, December 2016

demonstrated the gap in capability of existing network infrastructure and the need for 'vast levels of investment' to deliver the required coverage, reliability and high data speeds. Furthermore, the European Commission study on "Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe"[88] found deployment costs of €56.6 billion in 2020 and €58 billion in 2025 will be needed for 5G. We have identified below the particular elements and conditions for assignment that will impact business decisions based on those found in section 3.6.

- Reserve prices (as opposed to the final auction price which is determined by the market and also the strategy and maximum fee an MNO would pay for spectrum and as a consequence of the reserve price and the other conditions);
- Coverage obligations,
- Length of licence,
- "Use it or lose it" clauses,
- Frequency bands covered, packaging and lots, and
- Award rules and procedures.

We have also taken into account the existing infrastructure and new network architecture expected for future networks in 5G. There will be a mix of ultra-dense heterogeneous networks (using small cells), expanded rural network to cover the last few percentages of the population, and networks to cover specific verticals such as connected cars and emergency services. This requires access to a mix of sub 1 GHz spectrum and mmWave bands.

The types of architecture proposed for 5G have attempted to cover each of the three main areas:

- Enhanced Mobile Broadband,
- Ultra-Reliable Low Latency Communications, and
- Massive Machine Type Communications.

The diagram below is an extract from the 5G PPP METIS project which outlines each of the key network architecture characteristics to address the major 5G use cases.

[88] Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe, tech4i2 et al on behalf of European Commission, 2015

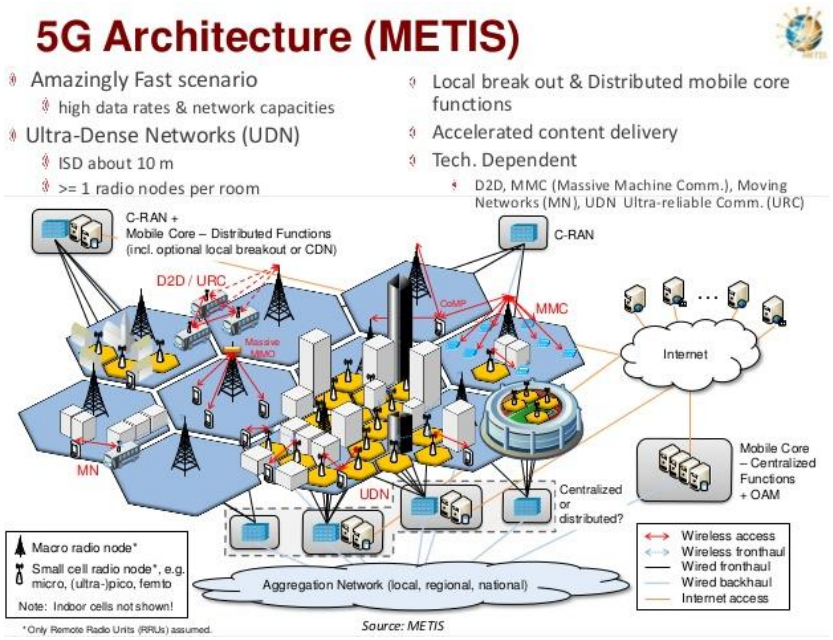


Figure 30: 5G architecture according to 5G PPP METIS project. Source: METIS[89]

A selection of example network architectures is shown in the diagram to highlight the mix of infrastructure site types, nodes, cabling and locations expected for deployment. There are also considerations for site location as many rooftops in major urban areas are already occupied by macro/micro 3G and 4G base stations. The new infrastructure will be deployed closer to users (particularly in urban and suburban areas) and will include lampposts, signs, bridges and other passive infrastructure that will play a role in enabling 5G.

In essence, given the need for further investment in network infrastructure, there is a trade-off between the amount of money spent on spectrum and the amount available for network roll out.

In the table below, we show how each of the elements - if set by the SRA - leads to a positive or negative impact on MNOs business decisions and ultimately lead to network investment or not.

[89] Exploring 5G: Performance Targets, Technologies & Timelines, Gabriel Brown and Sharhram Niri

Elements	Leads to positive business outcome	Leads to negative business outcome	Impact to potential network investment
Reserve prices	Low	Too high	Delays in investment if high reserve prices
Coverage obligations	None or market driven	Restrictive and significant capital burden	Coverage obligations guarantee network investment
Length of licence	Long 20 – 25 years	Too short 10 -15 years	Long licences guarantee investment
Use it or lose it	Market friendly	Short term and restrictive	Ensures willing parties can invest to provide a network and use the spectrum.
Frequency bands covered, packaging and lots	Decision made on a fair, transparent and non-discriminatory basis	Limited quantity, non-typical lot structure and short notice	Sub 1 GHz bands would not need investment
Award rules and procedures	Fair, transparent and non-discriminatory	Complex, lengthy, anti-competitive or poor design	Complex rules could lead to flawed auction results or delay roll out

Table 10: Spectrum assignment elements leading to positive or negative business outcomes

We observe which choice of input leads to a positive or negative business outcome. However, what does this mean in terms of fostering availability of 5G services? Using our future scenarios, we examine which of the elements is subject to a positive or negative business decision. In each case, we explain what decisions may limit investment in network deployment in the future and whom they impact.

Mega MVNO

The elements that impact the business decisions for a Mega MVNO include:

- **Reserve Prices**: The effect of low reserve prices is that MNOs have available funds to invest in infrastructure and this can lead to enhanced coverage and capacity serving more customers. MNOs might be reluctant to invest in spectrum access in a scenario in which a Mega MVNO is having a successful case by deterring the number of subscribers of the MNOs.
- **Coverage obligations:** Indirect benefit to Mega MVNO based on expected expansion of the MNOs network to areas with potential new customers but not too restrictive that it limits availability of investment.
- **Licence length:** Long-duration leads to certainty for return on investment and access to MNOs resources. This would help the MVNOs investment decision to select the appropriate connectivity partner.

- **Use it or lose it:** No real impact to Mega MVNO in this scenario. Unless they can gain direct access to the spectrum in case the MNO is not using it
- **Frequency bands covered, packaging and lots:** No direct impact on this scenario but must be sufficient bandwidth to offer MVNO capacity.
- **Award rules and procedures:** No impact to the Mega MVNO in this scenario.

SON

The elements that impact the business decisions for a SON scenario include:

- **Reserve Prices**: This has a direct impact on the ability for MNOs to deploy SON. Low reserve prices will be essential in order to fund future HetNet architectures for 5G and ultra-dense networks.
- **Coverage obligations:** Not specifically coverage obligations but if there were service performance obligations (i.e. 10 Mbps indoor coverage to 100% of the population) this would have a detrimental impact on the speed at which consumers would access services. This is because investment would be directed to those areas in which the obligation is targeted and not the most profitable areas that would typically be served first. .
- **Licence length:** Long-term certainty of access to the spectrum by MNOs is essential for investment payback particularly if revenues for mobile data continue to decline. However, SON will rely on access to multiple bands including many incumbent bands so there is a dependence on long licence durations or perpetual licensed access
- **Use it or lose it:** MNOs in this scenario will be able to utilise the spectrum quickly and more efficiently so there is limited risk of MNOs losing spectrum because it is left unused.
- **Frequency bands covered, packaging and lots:** It is vital that the available frequency bands are harmonised and standardised with sufficiently wide bandwidths to support a minimum of 20 MHz channels and up to 100 MHz, more particularly for the high capacity areas and where SON will be deployed.
- **Award rules and procedures:** MNOs rely on clear, open, fair and non-discriminatory award procedures that are not complex and seek to find fair value of the spectrum. Rapid access to spectrum will be key to ensure efficient use.

Infrastructure Economics

The elements that impact the business decisions for an infrastructure economics scenario include:

- **Reserve Prices**: This has a direct impact on the ability for MNOs and other network providers to deploy new small cells (additionally to other elements of the network). Low reserve prices will be essential in order to fund future HetNet architectures for 5G and ultra-dense networks.
- **Coverage obligations:** In some cases a coverage obligation would be necessary such as to serve transport routes and thus introduces additional cost requirements. However, for enhanced mobile broadband, and similar to SON, a coverage obligation would not be necessary, but if there were service performance obligations (i.e. 100 Mbps indoor coverage to 100% of the population for a given area) this may have a detrimental impact on the speed at which consumers would access services. This is because investment would be directed to those areas in which the obligation is targeted and not the most profitable areas that would typically be served otherwise.

- **Licence length:** Long-term certainty of access to the spectrum by MNOs is essential for investment payback particularly if revenues for mobile data continue to decline. In this scenario, MNOs will rely on access to new mmWave bands which may also include some degree of general authorisation, in this cases licence length is not an issue as general authorization typically have no end date. However, providing long-term legal certainty in terms of the possibilities of accessing spectrum pursuant to general authorisations continues to be relevant in this scenario too.
- **Use it or lose it:** Similarly to the above element, if authorisation is by GA then use it or lose it is not relevant. However, in exclusively licensed bands, efficient use of the spectrum will be key and rapid access will be necessary.
- **Frequency bands covered, packaging and lots:** It is vital that the available frequency bands are harmonised and standardised, with sufficiently wide bandwidths to support a minimum of 20 MHz channels and up to 100 MHz or more particularly for the high capacity areas. These bands will need to be available everywhere to make the infrastructure economics case viable.
- **Award rules and procedures:** MNOs rely on clear, open, fair and non-discriminatory award procedures that are not complex and seek to find fair value of the spectrum. Rapid access to spectrum will be key to ensure efficient use.

Vertically Driven

The elements that impact the business decisions for a vertically driven scenario include:

- **Reserve Prices**: Assuming verticals will require access to MNO networks, low reserve prices for spectrum will mean that the investment can be made in infrastructure and thus services can be delivered to verticals quicker and more widely across the country. It will also mean wider choice and better competition.
- **Coverage obligations:** Coverage obligations would help verticals as they often operate in areas that currently lack sufficient coverage. 100% geographic coverage for example would mean the likes of PPDR and other critical services could be fully supported over MNOs networks. Alternatively, the verticals could invest in the network themselves to ensure their own requirements and the licence obligations are met.
- **Licence length:** Verticals' investment horizon extends well beyond that of a mobile operator (i.e. utilities, nuclear power stations) therefore, both long licences and perpetual licences would be critical to serve verticals.
- **Use it or lose it:** No real direct impact to verticals in this scenario since the MNOs can demonstrate more efficient use of spectrum if they use it for supporting vertical use cases.
- **Frequency bands covered, packaging and lots:** Currently, many verticals rely on access to their own spectrum on an individual exclusive basis (i.e. railways, utilities and PPDR). In the future 5G eco-system, as long as the KPIs and SLAs can be supported by the MNOs (e.g. Emergency Services Network in the UK using a public cellular operator EE) then harmonised, and standardized frequencies with globally accepted band plans will be important.
- **Award rules and procedures:** No impact in this scenario.

We summarise the findings from the above analysis.

Summary

It is clear that a fundamental impact on MNOs business decisions is the price paid for spectrum and a key element that drives this is setting the reserve price. The GSMA study on spectrum pricing has shown that low reserve prices generally lead to greater network investment and better quality of service and price for consumers. However, our earlier analysis in section 3.6 found that other elements can drive the price up. In a 5G world in which the business models will be more varied and wide reaching, we have found that improvements to the assignment procedures and usage conditions will bring a positive impact on business decisions. This is largely focused on the spectrum fees and particularly deployment/coverage conditions, which in turn impact the speed and geographical nature of the physical deployments.

For example, if low reserve prices lead to more investment for better and quicker network rollout then this is a positive impact on the business decision. This will not necessarily lead to a better performing 5G network because the investment from MNOs is typically directed to the most profitable areas/services which for some of the future scenarios (e.g. Mega MVNO) might not be case. Coverage obligations would suit some verticals particularly on a geographical basis but can be a burden to MNOs if not carefully defined. However, they will bring the benefit of spectrum access for the verticals consequently opening up new revenue streams for MNOs. Also, investment in extended coverage could be (at least partly) paid by the verticals; there is one such example in UK where the Government is paying for the extended coverage to EE's network for the provision of emergency services.

Furthermore, if a specified coverage obligation leads to rollout of infrastructure in the SON case, then MNOs customers benefit from an enhanced and dedicated deployment in areas targeted by MNOs. In the vertically driven case, if there were coverage obligations along roads and rail this would support those specific vertical cases and guarantee network investment. However, there is a dependence on the commercial relationship between the transport authority and the network operator. For example, in the case of rail, collaboration with the rail infrastructure manager and the MNOs will be necessary to ensure network rollout is conducted to meet requirements of both operators.

This would likely be similar for roads, where the highways authority would need to be directly involved in the network deployment.

The investment and thus rollout of 5G networks (including our scenarios) could potentially be delayed or limited in some way if spectrum is withheld for too long once identified, if reserve prices are above fair market value and if non-harmonised bands are considered. Coverage obligations, although they lead to guaranteed network rollout in locations currently underserved, may impact business decisions since it is often harder, more time-consuming and more expensive to deploy in underserved, typically rural areas.

3.8.2 Impact of a consistent approach to spectrum assignments

The EU is seeking, as part of its proposal for a revised European Electronic Communications Code, to ensure consistent and predictable application of the rules throughout the Digital Single Market (DSM). Furthermore, a consistent approach to the elements of spectrum assignment and usage conditions could lead to major benefits in access to spectrum for consumers and other market players such as MVNOs across the EU.

For example, a set of common rules on the elements for spectrum assignment will provide the mobile market greater certainty and clarity on aspects such as timing of assignments, licence length and renewal conditions.

Feedback gathered from the public workshop participants supported this indicating that a consistent approach to certain elements for assignment, such as long licence duration, low reserve prices and network coverage would lead to more security and thus a greater likelihood of more network investment.

However, it was also mentioned at the workshop that to achieve the benefits of a consistent approach, like longer licence lengths and coverage conditions in the EU, may require some form of binding guidance from the European Commission. This would limit to some extent Member States´ flexibility to decide on the specific elements to be applied in their market while at the same time achieving better results in terms of best assignment practice. It was further noted that Member States may also need to fulfil other objectives of general interest, which would mean certain elements or conditions (as mandated within a more consistent approach) could not be implemented if they were to conflict with any such general interest objectives. We learned from the public workshop, notably from Member State´s representatives, that broadly non-binding approaches are preferred to allow each market to decide the best method with the possibility of introducing regulatory innovations.

In all our data gathering from Member States there was 'no evidence' that indicated specific national circumstances that justifies the need for 'consistent' approaches across each Member States when setting license conditions and assignment rules for 5G. However, according to analysis of our scenarios, consistency would enable a number of benefits to be realised. In particular, to achieve consistent levels of connectivity and quality of service across Member States that in turn support new services and applications. This suggests that greater consistency, beyond what is currently achieved in terms of spectrum assignment, would be necessary to deliver against the requirements of 5G services.

A consistent approach across the EU would require all Member States to follow the same principles of assignment procedures such as consistent conditions and elements of assignment that achieve positive market outcomes. . However, it seems, based on past experience, that without some form of binding measure regarding certain elements of the selection process, many of the approaches could become fragmented leading to some EU citizens being unable to access new 5G services at the same point in time.

This raises issues of Member States flexibility reflected in views from RSPG in its February 2017 Opinion[90] states; "*need to maintain an appropriate balance of competencies. Effective spectrum management is an intricate balance of competencies and responsibilities and any attempts to change such balance have to be closely scrutinised to ensure full respect of subsidiarity*."

Nevertheless, below we examine how a consistent approach within the EU, with regards to assignment procedures, could alleviate specific problems and potentially promote the successful rollout of 5G.

[90] RSPG Opinion on Spectrum issues in the Proposal for a Directive of the European Parliament and of the Council establishing the European Electronic Communications Framework, RSPG, February 2017

Given the current lack of EU-wide consistency in the elements and conditions of spectrum assignment, we identify below the elements that can have greatest impact on MNOs and other market players:

- Licence length varies from MS to MS, which impacts predictability to MNOs
- Reserve prices vary and can be above fair market value
- Delays in releasing spectrum by regulators, and thus delays in operators' access to spectrum
- Complex award processes differ from country to country including reservations for new entrants
- Reserving spectrum for future use or other services
- Timing and conditions of licence renewals vary
- Coverage obligations vary between bands
- Use of different authorisation approaches for the same system that crosses country borders

One argument for the rationale of a consistent approach across the EU is the way 4G spectrum, predominantly the 800 MHz and 2.6 GHz bands, were awarded across the EU, and how this process can be improved in time for the introduction of 5G. The table in appendix C shows the awards' dates for each and the wide variations with some long delays. The adoption of 5G presents an opportunity for Member States to reform and improve this aspect of spectrum management with careful and due consideration of the elements (licence length, reserve prices not set above fair market value and consistent coverage obligations) that impact access to spectrum and availability of services. A consistent approach to defining these elements (and others) may deliver the services promised by 5G in a timely and cost effective manner across all EU to the benefit of all citizens.

However, the right balance between well-justified intervention from the Commission and the competencies and formal cooperation between Member States to ensure harmonisation of availability of 5G services across Europe will ultimately benefit consumers and citizens.

We determine below how a more consistent approach in the EU concerning assignment procedures and spectrum usage conditions contribute most significantly to alleviating specifically identified problems and timely access to spectrum to foster the availability of 5G.

In particular, we examine how the current assignment approach has created situations and assess whether a consistent approach would alleviate them.

Current approach situation across MSs	Consistent approach	How does this alleviate the problem and foster 5G
Licence lengths vary	Licence length fixed for appropriate duration i.e. 25 years for all bands awarded via auction	Enhances certainty of security to spectrum all MSs in EU lengths across MSs
Reserve prices vary	Guidance on reserve prices to be set below true value	More chance of increased competition and network investment
Complex spectrum award / poor design	Starting point to be most common or simple design of award unless necessary for more complexity and peer review to build on best practices	Reduces costs to operators, encourages new entrants to participate, potentially unlocks new business models
Efficient use of spectrum varies	Encourage flexible usage to maximise efficient use of spectrum	Quicker access to larger range of spectrum bands enhancing roaming options, unlocks new business models

Table 11: Comparison of consistent elements of assignment to alleviate problems

The table above indicates that a consistent approach could alleviate some problems and create new opportunities for new entrants by unlocking access to spectrum. However, consistency in a number of these cases would mean Member States lose their right/ability to choose their own approach to the assignment procedures that may fit better with their internal market conditions. Furthermore, the EC found from its consultation[91] on the evaluation and review of the regulatory framework for electronic communications that licensing is a matter of national consideration.

In the table below we determine how a consistent approach to some elements across the EU provides more timely availability of spectrum to the market.

Current approach across MSs	Consistent approach	Leads to timely availability of spectrum
Identification of frequency bands and packaging and roadmap to make	Same bands, same band plan available within a common timeframe across the EU	Provides certainty to the market of bands and bandwidths enabling sufficiently early

[91] Consultation on the evaluation and review of the regulatory framework for electronic communications

spectrum available		preparations
Timescales of award processes taking place differ	Common timeframe for undertaking awards. Take place in a fixed and limited time period	The same bands become available on the market within similar timescales creating harmonised access EU wide use
Delays in assigning spectrum	Set timescales that minimise delays in assigning spectrum, like maximum deadlines for assignment	Quicker access to larger range of spectrum bands enhancing roaming conditions
Complex spectrum award / poor design	Starting point to be most common or simple design of award unless necessary for more complexity and peer review to build on best practices	Simple design should aim to reduce auction duration
Addressing cross border interference (between different technologies and services)	Common EU framework for enhancing the method to solve cross border interference	Definitive and more realistic timescales set for reaching agreement, aligned to specific border scenarios.

Table 12: Comparison of consistent elements of assignment for timely availability

The table above indicates that a consistent approach could lead to timely and appropriately available spectrum and support the rapid deployment of new bands for 5G. However, similar to the previous analysis for a consistent approach to alleviate problems, forms of systematic binding mechanisms or binding guidance may be beneficial to ensure that the consistent approach is applied across all EU Member States.

In this case, most of the elements relate to timing of awards and identification of spectrum. Furthermore, if a simple award design was used as a common starting point this could lead to improved timescales of spectrum availability. However, even with the most flexible, transparent and fair award processes, sometimes not all operators are satisfied. For example, in the UK legal threats from the mobile operators[92] to stall the auction, given concerns for the proposed spectrum floors and competition, resulted in a four year delay in awarding the spectrum. Thus, it could be argued that the market was not mature enough to commence the assignment process.

The first fully harmonised frequency band, which could be deployed across the EU for 5G within the EU's 2020 timeframe, is most likely to come from one of the mmWave bands (i.e. 26 GHz). This is because the technical and physical propagation characteristics suit local dense urban areas and indoor coverage and limit their ability to cause widespread interference to other services in other geographical areas. Furthermore, the two other

[92] Threat of 4G lawsuits is over: UK telecoms watchdog, ZDNet.com, Oct 2012 http://www.zdnet.com/article/threat-of-4g-lawsuits-is-over-uk-telecoms-watchdog/

pioneer bands (700 MHz and 3.4 – 3.8 GHz) identified for 5G, have extensive incumbent use, or have already been awarded via auctions (France and Germany) or auctions are planned to award them. In some countries the 3.4 – 3.8 GHz band is highly fragmented with multiple assignments to many different licensees with varying terms and conditions including licence length and therefore commencing a realignment exercise of licence expiry dates today (2017) would result in the band not being fully aligned before 2020. This is based on our assumption that realignment can take many years to fully realise[93] given the time operators need to re-plan and re-engineer their networks. There are plans within CEPT to help those Member States that have fragmented assignments in mobile bands to realign the band, so that it can be fully utilised in 5G networks. Given the extent of fragmented assignments across the EU in the 3.5 GHz band it is unlikely all Member States will utilise this band for 5G by the 2020 timeframe.

Furthermore, the EC has issued a mandate to CEPT to "harmonise technical conditions for the development of EU-wide 5G equipment." in the 24.25 – 27.5 GHz band. The next logical step is for the Commission to implement the CEPT's proposals so that Member States can make decisions on the elements and conditions for assignment in a timely way thus minimising delays and maximising spectrum availability for 5G across the EU.

In the next chapter, based on the analysis and findings from the study, we make some policy recommendations for the newly identified bands for electronic communications services to be made available in a timely and appropriate way while avoiding potential problems.

Summary

We found that certain problems arise with respect to the consistency of the elements of assignment, particularly due to decisions made by SRAs that impact MNOs and their ability to deliver services to the market. Elements such as licence length, reserve prices and reserving spectrum for new entrants directly impact the market; poor decisions by SRAs can lead to uncertainty and unpredictability for the market.

Evidence from previous spectrum awarded by Member States has shown that an inconsistent approach to some of the elements (such as timing of award or setting of high reserve prices) has led to slow uptake and growth of 4G services across Europe. The impact of a more consistent approach to these regulatory and market elements could mean a more rapid start to 5G and availability of key services to the market, including coverage along roads for connected cars and rail corridors for enhanced mobile broadband for passengers of trains.

In the next chapter, we draw some conclusions across each of the key areas of the study.

[93] EU sets 2020 deadline for freeing up 700 MHz band for mobile broadband, FierceWireless, May 2016, http://www.fiercewireless.com/europe/eu-sets-2020-deadline-for-freeing-up-700-mhz-band-for-mobile-broadband

4 Conclusions

We draw together the findings from all aspects of the study into a set of conclusions which describe how each of the specific areas has been addressed with respect to the study requirements.

4.1 Status of general authorisation and individual rights of use across Member States

4.1.1 Existing approaches to authorisation will not impede 5G roll out but could delay it

In the stakeholder engagement exercise, 25 SRAs stressed they do not anticipate an end of the Individual Licensing regime for wireless broadband spectrum bands in the foreseeable future.

Although, mobile operators favoured exclusive individual licensing the introduction of 5G presents new opportunities to enhance approaches to assignment that could speed up availability and access to spectrum across all EU.

Verticals on the other hand, rely on a number of different authorisation conditions some similar to MNOs, such as quality of service and wide area coverage but also reliability, and high levels of availability. It is not so much the authorisation approach that is the problem but access to harmonised spectrum and standardised equipment for verticals, which in certain bands has been limited to MNOs. Thus some of the new use cases and service requirements of 5G will depend on greater flexibility and shared access to exclusively licensed spectrum and in the case of connected cars and e-health also require a consistent regulatory framework across Europe. The issue here is with timing and market demand such that if Member States do not coordinate or help facilitate this type of access roll out of these new services could be delayed across all EU Member States.

Moreover, even though other authorisation approaches are available, such as light licensing regimes, and licensed shared access, there seems to be little demand from industry to take up these approaches. The general perception is that the methods that are in use today are sufficient.

For example, Licensed Shared Access is not widely used by Member States at present and there is scepticism with regard to its future usefulness. However, there are some studies (as identified in section 2.1.1.1) underway in Europe particularly in the 2.3 GHz band to examine the benefits and performance of this approach. Findings from these trials have shown successful implementations of LSA each using their own individual approach in terms of authorisation techniques and technical coexistence requirements.

Although, the current framework may not impede the roll out of 5G it could certainly delay it. Furthermore, we found the adoption of more flexible approaches to authorisation will enable specific use cases to emerge more rapidly such as the Mega MVNO scenario.

4.1.2 Wider adoption of available authorisation choices will help enable access to spectrum for 5G for non-traditional operators

Stakeholders' feedback and the scenario analysis found that the current authorisation framework is generally fit for purpose (for wireless broadband applications). Member States choose the most appropriate authorisation and assignment approach that suit their market conditions and type of spectrum usage. The lack of diversity in assignment mechanisms for wireless broadband systems that are actually used by Member States comes from the fact that in almost all cases Member States have found little or no demand for using light licensing, trading or leasing. This is because the majority of the bands coming to the market will be used for mobile broadband services and there is a well-established approach for these assignments.

However, 5G will lead to significant changes in this respect since 5G use cases extend beyond traditional mobile broadband into internet of things, Vehicle-to-Vehicle communications, healthcare, utilities and more. The multiplication of use cases increases the likelihood that other authorisation approaches and more a flexible access will be required because they enable more rapid access to spectrum, and bring benefits from sharing, or light licensing or a commons approach. Therefore, we might expect that stakeholders would be interested in such spectrum assignment approaches and hence for them to lead the change and apply some pressure to SRAs and in public consultation processes to encourage the use of leasing, trading and light licensing approaches.

The four future scenarios developed in the context of the study illustrate how wider adoption of available authorisation choices could potentially create new business models, introduce new services in areas and markets that are not traditionally targeted by mobile operators and achieve EU policy goals with respect to the Digital Single Market.

4.1.3 Would a more convergent and consistent approach to authorisation, or rights of use deliver more timely availability of spectrum for 5G

The timing for making new and existing spectrum available for new 5G services will be critical. Some Member States have already started assigning spectrum for 5G in the 700 MHz and 3.6 GHz bands which greatly reduces the possibility of adopting consistent approaches to assignment in these bands across all Member States. There is a dependence therefore on swift yet careful decisions from the Commission on how a consistent approach can be implemented to ensure the benefits of timely availability of spectrum can be realised. We found that a consistent approach to authorisation and in some cases assignment and usage among Member States could unlock timely access to spectrum and investment in infrastructure for 5G use cases across the EU. For example, we found that harmonisation of key elements such as type of authorisation would bring lots of useful benefits for the likes of enhanced mobile broadband and transport use cases. We found that most important was that Member States adopt a consistent approach and use the same authorisation regime when deciding on a specific band or part of a band which will support specific 5G services and applications. These, in terms of connectivity and access to spectrum are likely to be the same regardless of the Member State.

Furthermore, a consistent approach to authorisation and assignment would enable harmonised frequencies to be accessed in a consistent way across the EU thus minimising the delay in access and supporting the multiple use cases that depend on movement of

devices across borders. Therefore, regardless of the scenario we conclude that consistency across certain elements will bring additional benefits.

In addition, without a consistent approach to some elements of authorisation, some applications could be delayed for many years, particularly in countries that adopt their own authorisation approaches and therefore cannot react quickly to the changes in market conditions that will be generated from the internal market policies to guarantee the provision of services throughout Europe.

4.2 Impact to assignment procedures and conditions attached to the rights of use for spectrum

4.2.1 Which spectrum assignment procedures and usage conditions have the greatest impact on mobile market outcomes and business decisions

We found that SRAs typically consult industry about their approach to decision making for mobile spectrum awards in an effort to ensure a fair, reasonable, transparent and non-discriminatory approach.

MNOs consider minimalistic and lean policy objectives are helpful for making awards for exclusively licensed spectrum. Verticals think policy objectives should take into account applications with much longer lifecycles as their businesses tend to operate over lifetimes greater than mobile operators (i.e. 30 years or more for the likes of utilities).

As maybe expected, there are differences between the way Member States' approach decision making for the elements and conditions of assignments (i.e. auction formats, packaging, timing, entities involved and responsible entities). For instance, there are differences in the time lags between the allocation of spectrum and deployment of services, which are a concern for licensees. This can impact the availability of new services but is dependent on the specific market conditions. For example, in some bands there might be extensive deployment of incumbent services (i.e. Digital TV) that may take longer to refarm in some countries compared to others. This could affect the timely availability of new services across the internal market.

There is, however an opportunity for the Commission to set out a fresh approach to the spectrum authorisation procedures and also the assignment conditions in the 26 GHz band for introducing 5G into the band. This is because there is some fragmentation amongst Member States with regard to already awarding other pioneer bands (700 MHz and 3.6 GHz). Germany and France have already awarded 700 MHz and some Member States have also reassigned 3.6 GHz with a view to use them initially for 4G and ultimately migrate to 5G. Therefore, the Commission can define a new coordinated approach for 26 GHz before any Member States take any action in this band which could have a positive impact on the availability of 5G services and yield the benefits identified in this study within the recently proposed 2020 EU-wide timeframe.

We considered whether the elements and conditions of assignment procedures influence assignment results and market outcomes. Our study indicates an individual association between high auction prices and poor 4G network availability, which we regard as a good proxy for network rollout. The data does not tell us why this happens but operators say that

high auction prices reduce the amount they can spend on networks. Figure 28 in section 3.6.5 shows with lower average auction prices typically have higher network availability.

We found that low auction prices and low reserve prices; long licence lengths and market-led coverage lead to positive outcomes in the mobile market. The evidence indicates that Denmark and Finland for instance, two of the three countries which have the largest number of these features, also have mobile markets with the most positive characteristics, namely high levels of competition; network roll-out; take-up; and quality and choice of services.

We found that high reserve prices are likely to lead to high auction prices and there is good match for this: Italy and France were in the highest grouping for both[94].

Our study also suggests that greater freedom to operate some bands as purely commercial enterprises brings greater benefits. However, if a coverage obligation is needed, it may not need to apply to all operators but to specific targeted coverage areas such as along road/rail routes. The social policy objective of widespread coverage could potentially be achieved at less damage to the market through a single coverage obligation band and national roaming agreements. Furthermore, other vertical segments could invest in increased roll out to meet other public policy objectives such as Government investing in extra coverage to meet emergency service requirements. Circumstances will vary from country to country but our study points to the benefits of a market-led approach.

Our other finding about declining licence lengths is also significant. As this is one of the factors which can have a negative outcome on market outcomes, the tendency towards shorter licences is a matter of concern. It does not seem to have been a deliberate policy choice, rather a set of decisions of which this was an unintended consequence. Reversing this could have a positive impact on 5G.

4.2.2 Would a consistent approach to spectrum assignment procedures and spectrum usage conditions across the EU resolve specific problems and deliver more timely availability of spectrum for 5G

We have found that a consistent choice of criteria for elements of assignment across Member States can deliver more timely availability of spectrum for 5G. This is based on the ability of Member States and the Commission establishing the right balance of EU binding measures and decisions at a national level to the common benefit of the internal market and digital single market.

In particular, we found little evidence to suggest there is a need for national divergences when setting licence conditions and assignment rules for 5G. We recognise for example, that the topography and geography of some countries are different and therefore it is easier and possibly cheaper to deliver coverage obligations in the Netherlands for example compared to Slovenia. However, when setting licence conditions and assignments rules we do not see major differences in the criteria. This is because 5G services will require similar levels of coverage, maximum levels of quality of service and accessibility in terms of connectivity across the EU in order to deliver the diverse range of services and applications promised by 5G. Thus, greater consistency in spectrum assignment is needed to ensure that such

[94] Intense competition within the auction will also lead to high prices: Sweden and Spain both had low reserve prices but high auction prices.

services can be adequately delivered and reduces burdens on regulators to develop their own individual criteria.

In addition, a consistent approach to assignment can alleviate specific problems. More specifically, newly identified frequency bands such as those in mmWave bands (e.g. 26 GHz) could be used to introduce new 5G services, such as enhanced Mobile Broadband but in a way that is more flexible and the flexibility to offer new innovative service in areas that previously would not have normally been provided by traditional mobile operators.

5 Appendix A – Mobile assignments data

5.1 Introduction

In this appendix, we present a variety of data that has been used in the analysis of the various input and output parameters of spectrum licences across different EU Member States.

5.2 Overview of spectrum assignments in Member States

The table below shows the bands assigned in EU member states, the date of assignment, the licence durations and bandwidths. We consider this to be a useful high level overview.

The bandwidth and duration data is presented in order of size. (All EU countries have 2G, 3G and 4G services)

Member State	No. of national mobile network operators	Licence durations (sorted by year)	Date of awards	Bands assigned	Paired bandwidths assigned (x2)	Unpaired bandwidths assigned
Austria	3	9, 15, 16, 18, 19, 20	1995, 1998, 2000, 2004, 2008, 2016,	1800 MHz, 2 GHz, 2.6 GHz, 3.5 GHz, 450 MHz, 800 MHz, 900 MHz,	0.8, 1.9, 2.5, 3, 5, 8, 9, 10, 10.2, 15, 15, 15, 20, 21, 42	5, 5, 10, 25
Belgium	3	10, 15, 20,	1995, 1998, 2001, 2009, 2011, 2013,	1800 MHz, 2 GHz, 2.6 GHz, 3.5 GHz, 800 MHz, 900 MHz,	0.8, 10, 14.8, 15, 20, 25, 50	5, 5, 45, 50
Bulgaria	5	10, 20,	1994, 2001, 2004, 2005, 2011,	1800 MHz, 2 GHz, 3.5 GHz, 900 MHz,	5, 8, 10, 11	5, 42
Croatia	3	11, 12, 16, 20,	2004, 2007, 2008, 2009, 2012,	1800 MHz, 2 GHz, 3.5 GHz, 800 MHz, 900 MHz,	4.8, 5, 7, 10, 14, 15, 20, 21	5
Cyprus	3	15, 19, 29,	1995, 2004, 2005, 2014,	1800 MHz, 2 GHz, 900 MHz,	10, 12.2, 15, 25	5
Czech	3	16, 20,	2001,	1800 MHz, 2	1, 2, 4, 4, 7,	5

Republic			2004, 2005, 2013,	GHz, 2.6 GHz, 3.5 GHz, 450 MHz, 800 MHz,	10, 18, 19.8, 19.8, 20	
Denmark	5	15, 16, 20, 22, 23,	1997, 2001, 2005, 2007, 2010, 2013,	1800 MHz, 2 GHz, 2.6 GHz, 3.7 GHz, 420 MHz, 450 MHz, 800 MHz, 900 MHz,	3, 3.1, 4, 5, 9, 10, 12, 11.8, 12.2, 15, 20, 23.6, 28	5, 10, 15, 25
Estonia	3	14,	1995, 2003, 2007, 2010, 2013,	1800 MHz, 2 GHz, 2.3 GHz, 2.6 GHz, 3.5 GHz, 3.7 GHz, 800 MHz, 900 MHz,	10, 11.4, 14, 15, 15, 20, 21, 24.8, 24.8, 42	5, 5, 30
Finland	5	8, 9, 20,	1999, 2006, 2007, 2009, 2013,	1800 MHz, 2 GHz, 2.6 GHz, 3.5 GHz, 800 MHz, 900 MHz,	10, 10.6, 13.2, 20, 19.8, 20, 20, 24, 24.8, 25, 28	5, 15, 50
France	4	15, 16, 20,	2001, 2002, 2006, 2009, 2010, 2012, 2015,	1800 MHz, 2 GHz, 2.6 GHz, 3.5 GHz, 700 MHz, 800 MHz, 900 MHz,	4.8, 5, 9.8, 10, 14.8, 15, 20, 21.6, 23.8	5
Germany	3	15, 20, 24,	1992, 2000, 2006, 2010, 2016,	1800 MHz, 2 GHz, 2.6 GHz, 3.5 GHz, 700 MHz, 800 MHz, 900 MHz, L-Band,	5, 5, 9.9, 10, 10, 15, 20, 21, 25, 42	5, 10, 14, 20, 25
Greece	4	15, 20, 25,	1995, 2001, 2012, 2014,	1800 MHz, 2 GHz, 2.6 GHz, 3.5 GHz, 800 MHz, 900 MHz,	5, 10, 14, 15, 20, 21, 25, 28, 30	5, 20
Hungary	4	6, 7, 10, 15, 28,	1994, 1999, 2000, 2004, 2010, 2014,	1800 MHz, 2 GHz, 2.6 GHz, 800 MHz, 900 MHz,	1, 1.8, 2, 5, 8, 9, 10, 15, 20, 30	5, 25

Ireland	3	10, 15, 17, 20, 27,	2002, 2006, 2007, 2013, 2015,	1800 MHz, 2 GHz, 3.5 GHz, 3.7 GHz, 420 MHz, 800 MHz, 870 MHz, 900 MHz,	4, 5, 10, 11, 14, 15, 20, 25	5, 10, 20, 25, 35
Italy	4	8, 14, 17, 18, 19, 20	1995, 1998, 1999, 2001, 2011, 2013, 2015,	1800 MHz, 2 GHz, 2.6 GHz, 3.5 GHz, 800 MHz, 900 MHz, L-Band,	5, 9.6, 9.6, 10, 10, 15, 20	5, 20, 21
Latvia	4	11, 12, 15, 18, 20, 22	1994, 1996, 2005, 2009, 2012, 2015,	1800 MHz, 2 GHz, 2.3 GHz, 2.6 GHz, 3.5 GHz, 450 MHz, 800 MHz, 900 MHz,	0.8, 1, 4.5, 8, 9.6, 10, 10, 13.2, 20, 25, 25, 25, 28	5, 30, 50
Lithuania	5	10, 12, 17, 18, 20, 22	1995, 1999, 2005, 2006, 2009, 2013,	1800 MHz, 2 GHz, 2.6 GHz, 3.5 GHz, 800 MHz, 900 MHz,	2.6, 3.2, 3.2, 10, 15.2, 17, 18, 19.8, 19.8, 20, 28	0
Luxembourg	4	15, 16,	2002, 2003, 2005, 2008, 2012,	1800 MHz, 2 GHz, 2.6 GHz, 800 MHz, 900 MHz,	5, 9.6, 9.8, 10, 14.8, 15, 15, 20, 25	5, 5, 40
Malta	3	15,	2005, 2007, 2011,	1800 MHz, 2 GHz, 3.5 GHz, 900 MHz,	2.8, 4.6, 5, 20, 19.8, 20, 21, 24.8	5
Netherlands	4	7, 12, 17, 20,	2000, 2003, 2010, 2013,	1800 MHz, 2 GHz, 2.6 GHz, 3.5 GHz, 800 MHz, 900 MHz,	5, 10, 14.6, 15, 15, 20, 30	5, 5, 5, 10, 25, 30, 80
Poland	4	14, 15, 18, 23, 30,	1997, 2000, 2003, 2005, 2007, 2009, 2013,	1800 MHz, 2 GHz, 2.6 GHz, 800 MHz, 900 MHz,	5, 9.6, 9.8, 10, 14.8, 15, 15	5, 50
Portugal	3	15,	2001, 2006, 2007,	1800 MHz, 2 GHz, 2.6 GHz, 800	5, 7.8, 8, 10, 19.8, 20, 20	25

			2012,	MHz, 900 MHz,		
Romania	4	10, 15, 29, 32,	1997, 2000, 2005, 2007, 2008, 2012, 2016,	1800 MHz, 2 GHz, 2.6 GHz, 3.5 GHz, 3.7 GHz, 800 MHz, 900 MHz,	5, 10, 14.8, 15, 15, 20, 25, 28, 30	5, 15, 30, 45, 50
Slovakia	4	10, 12, 14, 20,	2002, 2005, 2006, 2008, 2014,	1800 MHz, 2 GHz, 2.6 GHz, 3.5 GHz, 3.7 GHz, 800 MHz, 870 MHz,	0.6, 4, 10, 14, 15.2, 17, 20, 30, 40	5, 40, 50
Slovenia	4	3, 7, 10, 15,	2001, 2004, 2006, 2008, 2011, 2014,	1800 MHz, 2 GHz, 2.6 GHz, 3.5 GHz, 800 MHz, 900 MHz,	5, 9.8, 10, 12, 15, 21, 25, 30, 35	5, 15, 25
Spain	4	15, 19, 20, 25, 32,	1995, 1998, 2000, 2005, 2011,	1800 MHz, 2 GHz, 2.6 GHz, 3.5 GHz, 800 MHz, 900 MHz,	10, 11, 13.8, 15, 14.8, 20	5, 10, 20
Sweden	4	12, 15, 16, 24, 25,	2000, 2003, 2005, 2008, 2009, 2013,	1800 MHz, 2 GHz, 2.6 GHz, 3.5 GHz, 450 MHz, 800 MHz, 900 MHz,	5, 6, 9, 10, 19.8, 20, 20, 28, 35	5, 50
United Kingdom	4	20, 21, Perpetual	1992, 1993, 1994, 1995, 2000, 2006, 2007, 2013, 2015	1800 MHz, 2 GHz, 2.6 GHz, 3.5 GHz, 3.6 - 4.2 GHz, 420 MHz, 800 MHz, 900 MHz, L-Band	2, 5, 5.8, 6, 10, 15, 20, 35, 36, 45	5, 10, 20, 25

Table 13: Overview of spectrum assignment data across all EU 28 Member States

5.3 Member States divided into quartiles based on ARPUs

Country	Average ARPU 2010-14	Quartile
Latvia	53	1
Romania	54	1
Lithuania	57	1
Bulgaria	66	1
Poland	96	1
Estonia	104	1
Croatia	110	1
Hungary	128	2
Portugal	132	2
Italy	152	2
Czech Republic	157	2
Finland	167	2
Greece	167	2
Slovakia	171	2

Country	Average ARPU 2010-14	Quartile
Malta	180	3
Germany	184	3
Austria	189	3
Slovenia	207	3
Spain	218	3
Denmark	226	3
Sweden	227	3
Belgium	228	4
United Kingdom	236	4
Cyprus	236	4
Netherlands	243	4
France	256	4
Luxembourg	271	4
Ireland	278	4

Table 14: EU 27 subdivided into quartiles based in mobile ARPU 2010-14

5.4 Prices paid for various licence lengths in selected spectrum bands

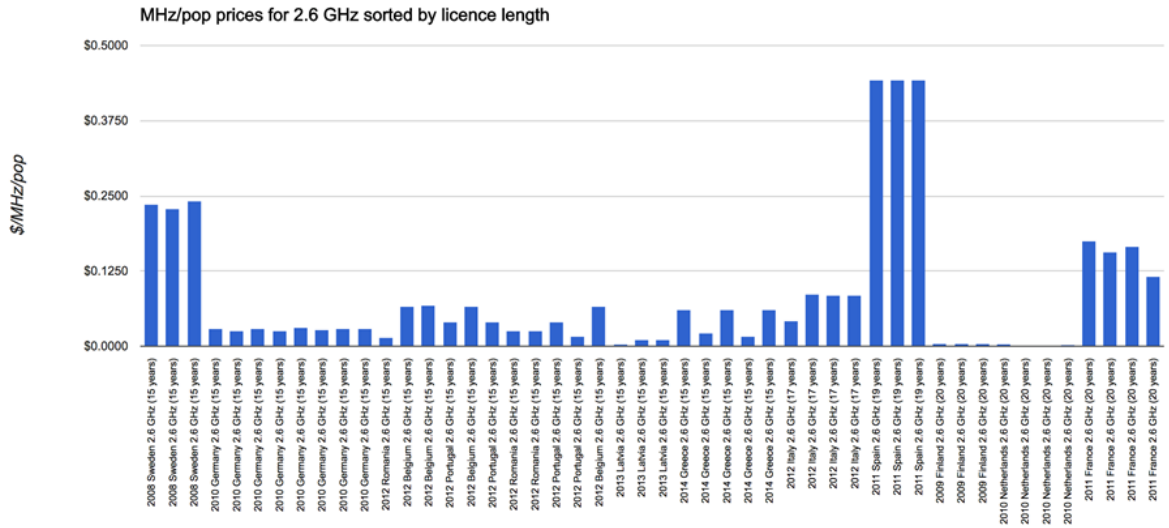


Figure 31: MHz/pop prices for 2.6 GHz sorted by licence length

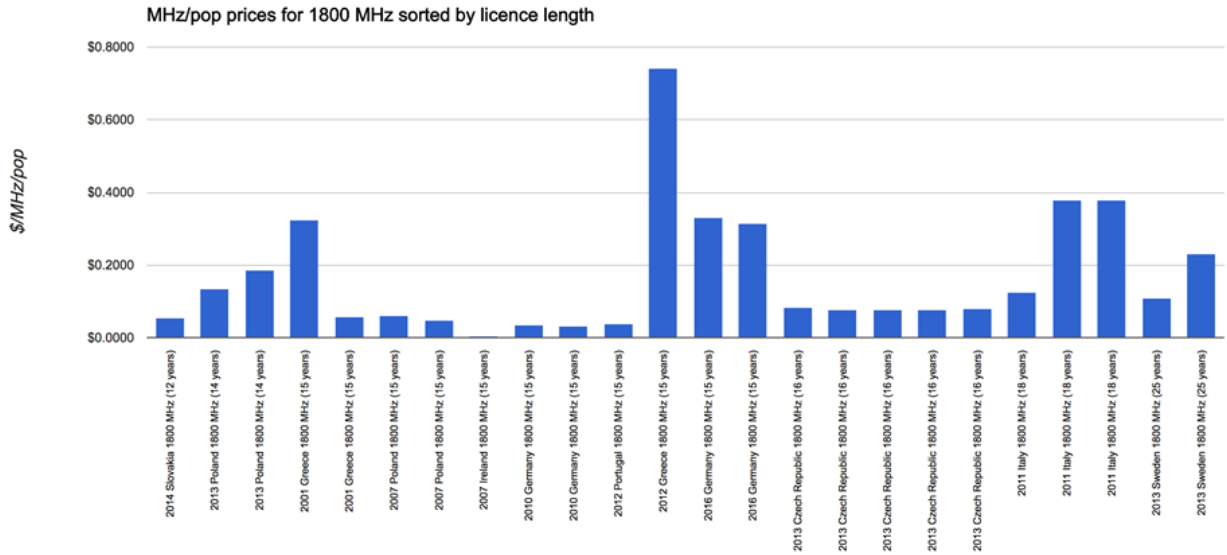


Figure 32: MHz/pop prices for 1800 MHz sorted by licence length

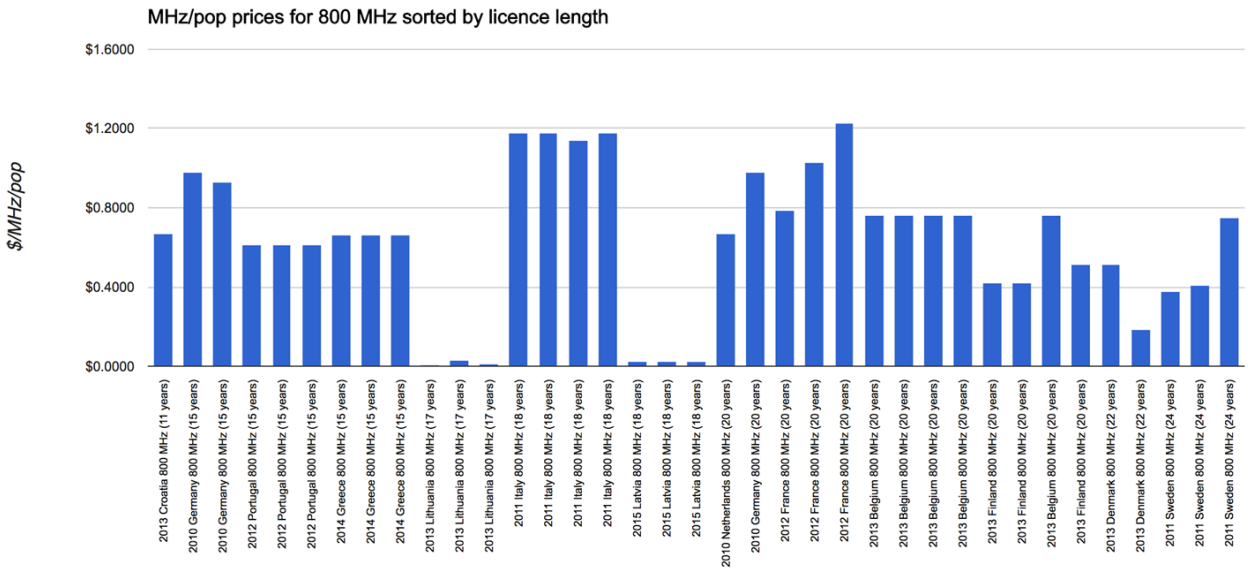


Figure 33: MHz/pop prices for 800 MHz sorted by licence length

5.5 Ranking of spectrum auction prices since 2007

Country	Auction price ranking (where 1 is the lowest)	Grouping
Netherlands	1	Low
Lithuania	1	Low
Latvia	3	Low
Finland	4	Low
Romania	5	Low
Germany	6	Low
Croatia	7	Medium
Czech Republic	8	Medium
Portugal	9	Medium
Poland	10	Medium
Denmark	11	Medium
Greece	12	Medium
Sweden	13	High
Belgium	14	High
United Kingdom	15	High
Italy	16	High
France	17	High
Spain	18	High

Table 15: Ranking of spectrum auction prices since 2007 Source: PSD

Please note we do not have available data on the following: Slovenia, Bulgaria, Hungary, Estonia, Slovakia, Austria, Cyprus, Luxembourg, Malta, Ireland

5.6 Licence length since 2007

Country	Average licence length	Numerical rank	Grouping
Bulgaria	10.0	1	Short
Slovenia	10.4	2	Short
Hungary	12.9	3	Short
Croatia	13.0	4	Short
Romania	13.8	5	Short
Estonia	14.0	6	Short
Slovakia	14.5	7	Short
Poland	14.7	8	Short
Austria	14.8	9	Short
Cyprus	15.0	10	Medium
Greece	15.0	10	Medium
Luxembourg	15.0	10	Medium
Malta	15.0	10	Medium
Portugal	15.0	10	Medium
Lithuania	15.3	15	Medium
Germany	15.5	16	Medium
Latvia	15.5	17	Medium
Belgium	15.8	18	Medium
Netherlands	15.8	19	Medium
Czech Republic	16.0	20	Long
Italy	16.4	21	Long
Finland	17.0	22	Long
Spain	17.8	23	Long
Sweden	18.5	24	Long
Ireland	18.7	25	Long
France	19.3	26	Long
Denmark	20.8	27	Long
United Kingdom95	See footnote	28	Long

Table 16: Licence length since 2007

[95] Since 2013 the UK has issued perpetual licences: we have therefore included it in the "Long" category

5.7 4G availability across EU Member State and auction price ranking

EU member state	4G availability	4 G availability Rank	Auction price ranking (where available)
Lithuania	84.73%	1	1
Netherlands	84.10%	2	2
Sweden	81.37%	3	13
Hungary	79.77%	4	-
Finland	76.36%	5	4
Estonia	75.11%	6	-
Slovenia	73.66%	7	-
Czech Republic	72.96%	8	8
Latvia	72.80%	9	3
Denmark	71.17%	10	11
Belgium	70.14%	11	14
Spain	67.16%	12	18
Austria	66.39%	13	-
Portugal	65.75%	14	9
Luxembourg	64.94%	15	-
Slovakia	63.95%	16	-
Bulgaria	62.73%	17	-
Croatia	62.56%	18	7
Greece	59.79%	19	12
Romania	58.13%	20	5
United Kingdom	57.94%	21	15
Germany	57.12%	22	6
Poland	57.11%	23	10
Italy	54.16%	24	16
France	49.44%	25	17
Ireland	43.45%	26	-

Table 17: EU Member State 4G availability and auction price ranking

5.8 Coverage requirements

Country	Coverage target can be achieved through more than one licence? (Yes= 1/ 0 =no)	Coverage obligation on 2.6 GHz and above? (Yes=0/ no=1)	Within a single band do some licences have coverage obligations and some not? (Yes=0/ no=1)	Different coverage obligations for different operators? (Yes/no)	How many bands do not have coverage requirements?	Overall, how market-led is the approach to coverage? (0= xxx, 6 = most)	Grouping
Austria	1	0	0	0	0	1	Medium
Belgium	1	1	0	0	1	3	Most market-led
Croatia	1	1	0	1	0	3	Most market-led
Cyprus	0	1	0	1	0	2	Medium
Czech Republic	0	0	0	0	0	0	Least market-led
Denmark	0	1	1	0	1	3	Most market-led
Estonia	0	0	1	0	0	1	Medium
Finland	0	1	0	1	4	6	Most market-led
France	1	0	0	0	0	1	Medium
Germany	0	0	0	0	0	0	Least market-led
Greece	0	1	0	0	0	1	Medium
Hungary	0	0	0	1	0	1	Medium
Ireland	0	1	0	0	0	1	Medium
Italy	1	0	0	1	0	2	Medium
Latvia	0	0	0	0	0	0	Least market-led
Lithuania	0	0	0	0	0	0	Least market-led
Luxembourg	0	1	0	0	5	6	Most market-led
Malta	0	1	0	0	0	1	Medium
Netherlands	0	0	0	0	0	0	Least market-led
Poland	0	0	0	0	0	0	Least market-led

Romania	1	0	0	1	0	2	Medium
Portugal	0	0	0	0	0	0	Least market-led
Slovak Republic	0	0	0	0	0	0	Least market-led
Slovenia	0	0	0	1	0	1	Medium
Spain	0	1	0	1	0	2	Medium
Sweden	1	1	1	0	0	3	Most market-led
United Kingdom	1	1	1	0	0	3	Most market-led

Table 18: Coverage requirements for EU Member States. Source: PSD and ECC and RSPG reports[96]

[96] ECC REPORT 231 *Mobile Coverage Obligations* March 2015 and RSPG *Report on Improving Broadband Coverage* (RSPG11-393) November 2011

5.9 Reserve prices since 2007

Country	Reserve price as a % of average band price[97]	Ranking (where 1 = most expensive)	Grouping
Poland	0.2%	17	Low
Netherlands	0.9%	16	Low
Latvia	3.6%	15	Low
Denmark	12.5%	14	Low
Spain	16.2%	13	Low
Sweden	21.3%	12	Low
Romania	30.3%	11	Medium
Finland	32.7%	10	Medium
Germany	39.7%	9	Medium
Czech Republic	47.3%	8	Medium
Portugal	53.5%	7	Medium
United Kingdom	61.5%	6	Medium
Croatia	70.8%	5	High
Belgium	72.0%	4	High
Greece	84.4%	3	High
France	105.8%	2	High
Italy	142.4%	1	High

Table 19: Reserve Prices since 2007. Source: PolicyTracker from regulator's websites

[97] This figure is calculated by taking the reserve price for a particular national auction in $/MHz/pop then dividing that by the average final sale price for the relevant band in all EU auctions since 2007. These figures are then averaged to give a mean percentage for each country.

5.10 Data on network availability and network speed

EU member state	4G availability (%)	4G availability ranking	4G availability grouping	4G speed (Mbps)	4G speed ranking	4G speed grouping
Slovenia	73.66%	20	High	20.03	1	Low
Germany	57.12%	5	Low	20.30	2	Low
Poland	57.11%	4	Low	20.79	3	Low
United Kingdom	57.94%	6	Low	21.16	4	Low
Estonia	75.11%	21	High	21.47	5	Low
Portugal	65.75%	13	Medium	22.27	6	Low
Ireland	43.45%	1	Low	22.49	7	Low
Czech Republic	72.96%	19	High	22.65	8	Low
Sweden	81.37%	24	High	23.06	9	Medium
France	49.44%	2	Low	24.28	10	Medium
Finland	76.36%	22	High	24.34	11	Medium
Slovakia	63.95%	11	Medium	25.82	12	Medium
Italy	54.16%	3	Low	26.41	13	Medium
Greece	59.79%	8	Low	26.46	14	Medium
Belgium	70.14%	16	Medium	26.59	15	Medium
Austria	66.39%	14	Medium	26.73	16	Medium
Latvia	72.80%	18	Medium	27.64	17	Medium
Spain	67.16%	15	Medium	28.32	18	Medium
Croatia	62.56%	9	Medium	28.66	19	High
Lithuania	84.73%	26	High	28.73	20	High
Denmark	71.17%	17	Medium	31.20	21	High
Luxembourg	64.94%	12	Medium	31.70	22	High
Netherlands	84.10%	25	High	33.84	23	High
Bulgaria	62.73%	10	Medium	34.26	24	High
Romania	58.13%	7	Low	35.61	25	High
Hungary	79.77%	23	High	40.61	26	High

Table 20: Data on network availability and network speed. NB: No data available for Malta or Cyprus Source: Open Signal's *State of LTE 2016* report[98]

[98] See https://opensignal.com/reports/2016/11/state-of-lte

5.11 Total number of national operators and number of operators offering 4G networks

Country	No of national operators	No of 4G licence holders[99]
Malta	3	1
Sweden	4	3
Lithuania	5	2
Portugal	3	3
Czech Republic	3	4
Croatia	3	3
Estonia	3	3
Germany	3	3
Ireland	3	3
Luxembourg	4	3
Hungary	4	4
Greece	4	3
Slovenia	4	3
Latvia	4	3
Austria	3	4
Belgium	3	4
Cyprus	3	4
United Kingdom	4	4
Slovakia	4	4
Spain	4	4
Italy	4	4
France	4	4
Denmark	5	5
Netherlands	4	5
Poland	4	5
Bulgaria	5	5
Romania	4	5
Finland	5	6

Table 21: Total number of national operators and number of operators offering 4G networks Source: PSD

[99] This includes licences in 3.5 GHz where the operator may be offering a fixed mobile service rather than a mobile service.

5.12 Proportion of users subscribing to mobile broadband services

EU member state	% of mobile broadband subscribers	Ranking	Grouping
Slovakia	52%	1	Low
Bulgaria	53%	2	Low
Croatia	53%	2	Low
Czech Republic	54%	4	Low
Hungary	56%	5	Low
Romania	56%	5	Low
Greece	59%	7	Low
Slovenia	60%	8	Low
Belgium	64%	9	Low
Latvia	64%	9	Medium
Poland	65%	11	Medium
Estonia	69%	12	Medium
Italy	70%	13	Medium
Germany	71%	14	Medium
France	73%	15	Medium
Ireland	73%	15	Medium
Spain	74%	17	Medium
Lithuania	74%	17	Medium
Netherlands	75%	19	High
Finland	77%	20	High
Luxembourg	78%	21	High
United Kingdom	79%	22	High
Portugal	82%	23	High
Denmark	84%	24	High
Austria	86%	25	High
Sweden	90%	26	High

Table 22: Proportion of users subscribing to mobile broadband services NB: No data available for Malta or Cyprus

Source: GSMA Intelligence

5.13 Consumer prices

Country	Price (€) for 1 Gb data and 600 voice minutes	Rank	Grouping
Estonia	10.07	1	Low
Austria	14.17	2	Low
Latvia	14.33	3	Low
Denmark	15.03	4	Low
Croatia	15.86	5	Low
Lithuania	16.1	6	Low
Italy	16.87	7	Low
Poland	17.46	8	Low
United Kingdom	17.53	9	Low
Slovenia	17.92	10	Middle
Finland	18.51	11	Middle
Sweden	18.9	12	Middle
Romania	19.03	13	Middle
Luxembourg	19.19	14	Middle
France	20.29	15	Middle
Belgium	25.76	16	Middle
Germany	26.57	17	Middle
Netherlands	28.2	18	Middle
Ireland	29.39	19	Middle
Cyprus	35.83	20	High
Spain	39.44	21	High
Portugal	41.76	22	High
Slovakia	43.78	23	High
Czech Republic	46.05	24	High
Bulgaria	59.67	25	High
Greece	60.77	26	High
Malta	64.57	27	High
Hungary	78.57	28	High

Table 23: Consumer prices Source: *Mobile Broadband Prices in Europe 2016*

5.14 Spectrum award dates across EU for 800 MHz and 2600 MHz

EU Member State				EU Member State		
Date	**800 MHz**	**2600 MHz**		**Date**	**800 MHz**	**2600 MHz**
2008		Sweden		2012		Netherlands
2009		Finland		2012	Romania	Romania
2010		Austria		2013	Austria	
2010		Denmark		2013	Belgium	Finland
2010		Estonia		2013	Cyprus	Cyprus
2010	Germany	Germany		2013	Czech Rep.	Czech Rep.
2010	Netherlands	Netherlands		2013	Estonia	
2011		Belgium		2013	Finland	
2011	France	France		2013	Greece	
2011	Italy	Italy		2013	Lithuania	
2011	Portugal	Portugal		2013	Latvia	
2011	Spain	Spain		2013		Luxembourg
2011	Sweden			2013	Poland	Poland
2012	Czech Rep.	Czech Rep.		2013	Slovakia	Slovakia
2012	Denmark			2013		Slovenia
2012	Ireland			2013	UK	UK
2012		Lithuania		2014	Estonia	
2012		Latvia		2014	Hungary	
2012	Luxembourg	Luxembourg		2014	Slovenia	Slovenia

Table 24: Spectrum award dates across EU for 800 MHz and 2600 MHz

5.15 The grouping approach to comparing inputs with outcomes

5.15.1.1 Methodology

In this approach we have broken down the Member States into groups based on inputs relating to spectrum assignment, namely the following categories:

- Auction prices[100] (Data from PSD)
- License length (Data from PSD)
- Coverage requirements (Data from PSD, and ECC and RSPG reports[101])
- Reserve prices (Data from own research)

[100] For the groupings we treat auction prices as an input which may influence mobile markets, although it can also be seen as an outcome of spectrum assignment procedures. We explored this latter approach during the individual comparisons.

[101] ECC REPORT 231 *Mobile Coverage Obligations* March 2015 and RSPG *Report on Improving Broadband Coverage* (RSPG11-393) November 2011

To measure the impact on the mobile market we have used statistics which give an indication of network roll-out; quality and choice of services; take-up and competition. The data sourcing is explained below:

- Network roll-out:
  - Network availability data from Open Signal
- Quality and choice of services:
  - Network speed data from Open Signal
  - Number of operators offering 4G networks (from PSD)
- Take-up
  - Proportion of users subscribing to mobile broadband services (GSMA Intelligence data[102])
- Competition
  - Number of operators (from PSD)
  - Consumer prices (From *Mobile Broadband Prices in Europe 2016*[103])

As the market indicator statistics deal with the present day, we have restricted the input data to 2007 onwards, regarding the last 10 years as the period which is most likely to have influenced the current market.

For each input and outcome category we divide countries up into three groups, typically low, medium and high. These groups are equal where possible, and where not, the middle grouping has been made the largest. Some groupings are larger than others because we do not have complete national data for all categories.

The groupings are decided on the basis of ranking as this reflects the essentially comparative nature of the study, which is trying to identify a set of best practices which lead to better outcomes. Ranking data is also easily comparable.

5.15.1.2 How the input groupings were determined

The raw data for each of the categories can be found in Appendix A but in this section we explain how they have been calculated.

Auction prices

Here the groupings were determined by calculating the average price of a band in an auction then comparing this with the average price paid for that band in all Member State auctions since 2007. This was expressed as a percentage ranking: these rankings were then averaged for all the bands sold in a Member State to get the final figure used in the groupings. The use of percentage ranking prevents any distortion caused in cases where countries have predominantly held auctions only in popular bands.

Licence length

License length grouping is based on the average length of licences sold in a Member State since 2007. This is then ranked numerically.

---

[102] This is from Q4 2015 and available here: https://www.gsmaintelligence.com/ It includes 3G and 4G mobile technologies

[103] Published by the European Commission https://ec.europa.eu/digital-single-market/en/news/mobile-broadband-prices-europe-2016

Coverage requirements

There are strong political pressures to deliver the social and economic benefits associated with mobile voice and data as widely as possible and coverage obligations are the preferred tool in almost all Member States. They either are used, or have been used in nearly all of these countries. When the RSPG carried out a survey on this issue in 2011, only one Member State – Finland – said it had no coverage obligations, though it is possible that these had existed previously. Therefore just recording the presence or absence of coverage obligations will not yield useful data. Also, we did not want to focus on the population or geographic percentages required because the difficulty of achieving these depends greatly on population density and the topography of the country, making meaningful comparisons between countries troublesome.

We decided instead to focus on the extent to which administrations are prepared to let the market deliver coverage requirements. We analysed the information provided in the ECC and RSPG reports based on the following categories:

- Can the coverage target be achieved through more than one licence?

If an operator has a choice about the optimal band combination for delivering the coverage obligation, this is more market-driven than making specific requirements on each band.

- Is there a coverage obligation on 2.6 GHz and above?

As the higher bands deliver capacity rather than coverage it is often argued that demand for data in cities will be sufficient to provide reasonable levels of coverage.

- Within a single band do some licences have coverage obligations and some not?

This approach means that some bands are being operated on a purely commercial basis with the social policy objective delivered by single operator.

- Are there different coverage obligations for different operators?

This is a more market-led approach which stimulates competition because new entrants will take longer to achieve the same coverage levels as incumbents.

- How many bands do not have coverage requirements?

If, for example, there are already 95% coverage obligations for both voice and data on 900 MHz and 1800 MHz licenses it is arguably unnecessarily restrictive to impose coverage obligations on 800 MHz and 2.6 GHz because the social policy objective is already being met.

Based on the answers to the above questions we categorised each Member State policy on coverage obligations as most market-led, least market-led, or medium.

Reserve prices

A market-orientated and common way of setting reserve prices is to undertake an objective study which values the spectrum on the basis of benchmarking, opportunity cost and business case and then triangulate these figures to produce a valuation. The reserve price would then be set somewhere below that figure, depending on the level of competition in the market.

In our categorisation we aimed to produce simple data which could indicate whether this approach to reserve prices was being followed. We therefore compared the reserve prices

for each band auctioned with the average final price paid for each band in all EU auctions since 2007. We used $/MHz/pop figures to ensure comparability and then averaged the national figures to produce a mean reserve price for each country.

This tells us at what percentage of the benchmark price countries tend to set their reserve prices. The full data is available in the appendix and these were categorised into low, medium and high.

5.15.1.3 How the outcome groupings were determined

Network availability data from Open Signal

Network availability data comes from Open Signal's *State of LTE 2016* report[104]. This is the same source as used in the individual comparison with auction prices and a fuller explanation of their method of collecting data is given above.

To determine the groupings the network availability data is ranked from the highest to lowest.

Network speed data from Open Signal

The Open Signal app also collects the average download speed (in Mbps) achieved by a user when connecting to LTE networks. This has been ranked from the highest speed to the lowest and the countries categorised into low, medium and high speeds.

Proportion of users subscribing to mobile broadband services

This data shows the percentage of national users subscribing to either 3G or 4G mobile broadband services. These are ranked from the highest to lowest and categorised into high, medium and low.

Number of operators

The number of mobile operators in EU countries varies from three to five so we reflect the level of competition in the market by splitting these into three, four and five operator markets.

Consumer prices

Here the data comes from a European Commission report, *Mobile Broadband Prices in Europe 2016*, which gives the lowest prices for a range of mobile products offered to the consumer. We have taken the lowest price offered in each country for a median mobile product: 1GB data and 600 voice minutes. These are ranked from highest to lowest then categorised into high, medium and low.

[104] See https://opensignal.com/reports/2016/11/state-of-lte

5.15.1.4 Comparing grouped inputs and outcomes

Market indicators

Highest scoring countries

Network roll-out		Quality and choice of services	Take-up	Competition	
Network availability	Mobile CAPEX	Network speed	% mobile BB subs	Five mobile operators	Consumer prices
Sweden	Ireland	Netherlands	Portugal	Denmark	Lithuania
Netherlands	Italy	Lithuania	Denmark	Finland	Croatia
Slovenia	Finland	Hungary	United Kingdom	Bulgaria	Denmark
Lithuania	Malta	Romania	Austria	Lithuania	Estonia
Hungary	Sweden	Luxembourg	Netherlands		United Kingdom
Finland	Luxembourg	Croatia	Luxembourg		Poland
Czech Republic	Greece	Denmark	Sweden		Italy
Estonia		Bulgaria	Finland		Latvia
					Austria

Countries appearing 4 times or more:
Denmark Finland Lithuania

Lowest scoring countries

Network roll-out		Quality and choice of services	Take-up	Competition	
Network availability	Mobile CAPEX	Network speed	% mobile BB subs	Three mobile operators	Consumer prices
United Kingdom	Cyprus	Slovenia	Hungary	Portugal	Hungary
Romania	Bulgaria	Czech Republic	Bulgaria	Austria	Bulgaria
Poland	Latvia	Estonia	Czech Republic	Czech Republic	Czech Republic
France	United Kingdom	United Kingdom	Greece	Croatia	Portugal
Italy	Poland	Poland	Slovakia	Belgium	Greece
Germany	Romania	Germany	Croatia	Estonia	Spain
Greece	Lithuania	Ireland	Romania	Germany	Slovakia
Ireland		Portugal	Slovenia	Ireland	Malta
			Belgium	Malta	Cyprus
					Cyprus

Countries appearing 4 times or more:
Czech Republic

Inputs relating to spectrum assignments

Highest scoring countries

Auction prices	Licence length	Coverage obligations	Reserve prices
Low	Long	Most market-led	Low
Finland	Sweden	Belgium	Sweden
Lithuania	United Kingdom	Sweden	Denmark
Germany	Finland	United Kingdom	Spain
Latvia	Denmark	Finland	Latvia
Netherlands	Italy	Croatia	Netherlands
Romania	Spain	Denmark	Poland
	Ireland	Luxembourg	
	Czech Republic		
	France		

Highest scoring countries (Appearing four times or more)
Finland Denmark Sweden

Lowest scoring countries

Auction prices	Licence length	Coverage obligations	Reserve prices
High	Short	Least market-led	Highest
Sweden	Croatia	Lithuania	Belgium
United Kingdom	Slovenia	Germany	Croatia
Italy	Hungary	Latvia	Italy
Spain	Estonia	Netherlands	France
France	Austria	Portugal	Greece
	Romania	Czech Republic	
	Poland	Poland	
	Bulgaria	Slovakia	
	Slovakia		

Lowest scoring countries (appearing twice)
Croatia France Italy Poland Slovakia

Figure 34: Comparing market indicators and spectrum assignment inputs

The diagram above shows the market indicators groupings compared with the spectrum assignment inputs, with the highest groupings in green and the lowest in red. The countries which appear most often are highlighted in a darker shade of red or green. The boxes below each coloured section show the countries which appear most often.

The most notable finding is that two of the countries which appear most frequently in the highest market indicators section – Finland and Denmark - also appear most frequently in the top categories in the spectrum assignments section.

In other words, Finland has low auction prices, long licence lengths and the most market-led coverage obligations. These are all factors which operators are claiming make it easier to invest in networks and deploy services.

In terms of market indicators Finland has the characteristics of a dynamic, competitive market with high quality services: it has high network availability, high mobile CAPEX, a high level of mobile broadband subscribers and five mobile operators.

It is a similar picture in Denmark except that in terms of inputs it has low reserve prices instead of low auction prices; and regarding outcomes it has high network speed rather than high network availability and low consumer prices rather than high mobile CAPEX.

This suggests that low auction prices, long licences, low reserve prices and market-led coverage obligations are associated with positive market outcomes in terms of network rollout, quality and choice of services, take up and competition.

We also examine whether the opposite is also true. However, the data does not show a convincing relationship. Those countries on the right hand side of the diagram with the most policies which operators say discourage investment do not also appear among the list of those with the poorest market indicators.

One explanation is that while Denmark and Finland both exhibit four positive input characteristics, there is no country which displays a similar number of negative input characteristics. Croatia, France, Italy, Poland and Slovakia all appear in the lowest performing categories only twice.

Put simply, administrations typically only indulge in a small amount of what operators regard as poor practice, in other categories they often perform well. For example, Italy and France offer some of the longest licences. Good practice in most input characteristics is concentrated in a small number of countries while many countries display isolated examples of poor practice.

We will give further consideration to the implications of our grouping study in the analysis section.

6 Appendix B – Stakeholder engagement

6.1 Overview of the public workshop

A public workshop was held in March 2017 to gather input and feedback from across the EU telecommunications industry including regulators, government and other stakeholders on spectrum authorisation and assignment in the EU.

Almost fifty delegates took part in the workshop at the European Commission premises in Brussels and provided some useful insights and feedback relevant to the study scope. A summary of the output from the workshop is given below.

6.1.1 Purpose of the workshop

The aims and objectives of the workshop were to gather views and feedback from delegates that full consideration could be given against the main study questions and in particular help assess how spectrum authorisation and assignment can be used against the four different scenarios. The workshop objectives included:

- Discussion and validation of the study's the assessment of spectrum authorisation approaches used by MSs, spectrum usage and how 5G technologies will fit into the current framework.
- Discussion and validation of the project team's thinking around which elements of general authorisation or individual rights of use would benefit from a more consistent approach within the EU, operator business decisions and investment and market developments.
- Take feedback from wider industry participants across MNOs, verticals and regulatory bodies gathering further experience and anecdotal evidence of which service, applications and bands support a mix of approaches to authorisation in the context of 5G and future access to spectrum.

We also determined some key workshop outcomes which included:

- Produce a workshop report (a separate report produced for the Commission) including findings from breakout sessions and feedback
- Input to the study analysis, assessments and conclusions

A diagrammatic representation of the workshop is shown in Figure 35 below.

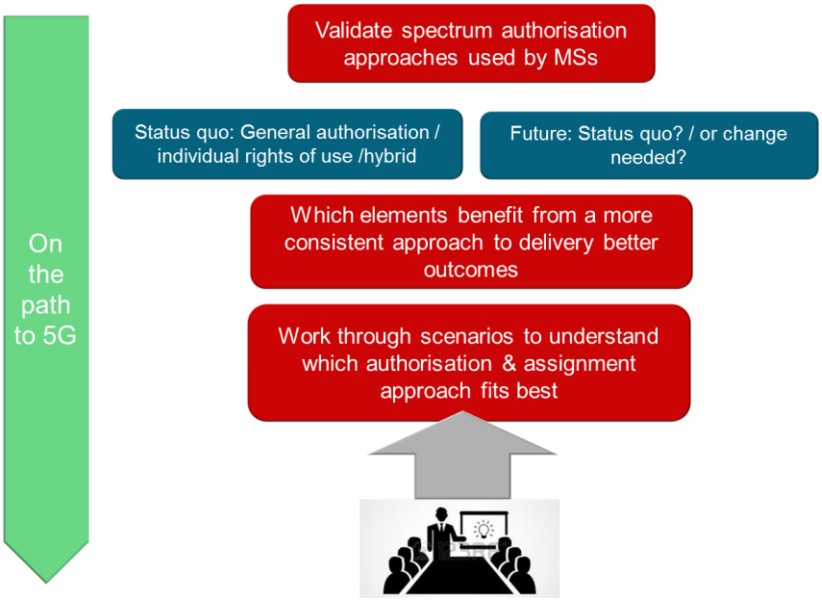


Figure 35: Approach to stakeholder workshop

Overall the workshop proved to be a useful way of gathering further input and evidence from across industry sectors, regulators and ministries in relation to spectrum authorisation and assignment approaches in use today for each of the scenarios.

It was challenging to ask participants to play a role for different sectors and we found that thinking differently beyond the current framework and methods was difficult. Nevertheless, the feedback provided was useful as it identified some of the key aspects that may affect making authorisations in future for future services and needs, where the restrictions and limitations may arise and what could be done to alleviate them.

The project team achieved its objectives and has used the outcomes from the workshop sessions and additional post workshop feedback to inform the analysis in this final report.

A summary of the key findings from each session is given below:

6.1.2 Mega MVNO

- Important to understand the value and the business model for creating a Mega MVNO
- Existing spectrum authorisation approaches can enable this scenario
- Quality of service must be guaranteed and extensive population coverage needed for viability purposes
- Fewer binding directives would create a better environment to make decisions yet consistency across the EU would best be achieved through peer review between SRAs
- Flexibility allowing spectrum trading and ensuring security of existing rights would also help to improve market outcomes
- Risk that Mega MVNOs get so big they become MNOs

6.1.3 Self-Organising Networks

- The SON scenario is a future case and more complexity is needed to support it but this will be enabled by technology developments and alternative authorisation approaches would neither improve nor hinder progress in this area

- MNOs require exclusive individual rights of use to be able to manage quality of service to users and control interference.
- MNOs value having the option to pay for these requirements and enjoy the benefits exclusivity brings
- However, MNOs seem to predominantly consider the capacity and QoS attributes of 5G rather than alternative, perhaps less economically driven, business cases
- CEPT acts as the body to develop recommendations and collegiate working and agreement no need for further directives particularly in the technical aspects
- The 700 MHz/ 3500 MHz should stick to the traditional approach to authorisation individual rights of use given their properties and characteristics and somewhat limited bandwidth
- Flexibility arises in specific niche locations such as in factories which could adopt a different approach, as the needs and environment varies, spectrum sharing could take place in these situations
- The risk of failure and boxing in to one approach could raise problems thus we need to pre-think what will happen and assess accordingly
- Flexibility will be key for making future authorisations which should enable other applications to be used in the same bands
- EU consistency impacts harmonisation enabling equipment to move across borders and services to be available to users over large regions
- Exceptions arise from the different cases and at present it is not clear where 5G is heading
- The business case for 5G is not a slam dunk - willingness to pay is an output of the business case and prices set too high then risk unsold spectrum. The spectrum should not be sold cheaply but the reserve prices should be low.
- Coverage - should be driven by the market and not be band specific. Many of the gaps in coverage have been solved. Little to gain for incremental coverage obligations attached to 700 MHz and definitely not for the higher bands
- Business cases require certainty - market based solutions are not always right i.e. much 3.5 GHz band spectrum is unused. Must be a way once it is licensed to get into users hands, spectrum trading should be easy, no taxes, if no trade then the regulator has the right to take back the spectrum (use it or lost it)

6.1.4 Infrastructure Economics

- This scenarios is already in place today and does not represent a future alternative for spectrum authorisation
- The scenario did further confirm that regulators and MNOs are satisfied with the status quo and there is not much that can be changed to existing models to encourage alternative business models or decisions
- The economics of the infrastructure although not directly linked to spectrum authorisation, the business models of the spectrum owners or infrastructure owners would benefit from more common practices
- Generally, there was a common agreed view that EU consistency is beneficial particularly for smaller countries however, it should be down to MSs themselves when making decisions on individual assignment approaches and rules
- Similarly, to the SON scenario it was found the three elements for making assignments (pricing, coverage and licence length) are interlinked and a decision on one could not be made without considering the others.

6.1.5 Vertically Driven

- This highly diverse scenario was able to address a wide variety of use cases that could be impacted from changes to specific authorisation approaches
- The diversity and flexibility are necessary to enable fully functioning vertical markets in which both exclusive individual rights of use and general authorisation are needed for both operational and business/mission critical use within the same sector/industry
- There is a reliance upon guaranteed quality of service and key performance indicators that must be ensured for the verticals to depend on either third party providers or their own private networks
- There are some uses in verticals in which spectrum access is directly linked and not so muc for others. However, free access to spectrum at point of use, combined with sufficiently wide area coverage and operators ability to meet KPIs would address key concerns across a number of verticals

6.2 Stakeholder representation

In order to gather relevant facts from industry in relation to the different authorisation and assignment approaches, we conducted an extensive stakeholder engagement survey. We sent out targeted questions to understand the settings and circumstances to spectrum regulatory authorities (SRAs), operators (MNOs), equipment vendors and organisations serving the vertical sector access spectrum.

We interviewed representatives from:

- 25 SRAs[105]
- 13 MNOs/MVNOs
- 5 from vertical industries
- 3 Equipment vendors/Device manufacturers
- 1 Ministry

The spectrum regulatory authorities can be either independent national regulatory authorities, specialised spectrum agencies, or Ministries in charge of spectrum policies (this varies among Member States). There are three SRA models[106]:

- Most or all spectrum management competencies are entrusted to a Ministry (e.g. Austria, Bulgaria, Belgium, Spain, Finland);
- Most or all spectrum management competencies are entrusted to a National Regulatory Authority (e.g. Czech Republic, Cyprus, Greece, Hungary, Ireland, Latvia, Lithuania, Malta, Portugal, Poland, Slovakia, Sweden);
- The spectrum management competencies are shared between the Ministry and the NRA (e.g. Croatia, Denmark, Estonia, Germany, Italy, Luxembourg, the Netherlands, Slovenia and UK). France represents a special case as it has a spectrum agency on top of the Ministry and the NRA.

[105] Only 18 of these had been added at the time of producing the graphs and diagrams

[106] The analysis is based on a investigation of RSPG Spectrum members (http://rspg-spectrum.eu/rspg-members-and-observers/) and the answer to our online survey.

In this section of the report we provide a summary overview of the responses received (not all relevant ministries responded) including a graphical format to readily identify patterns or trends from the responses.

Country	Organisation type	Organisation name	Interview status
AT	SRA	RTR	Complete
BE	SRA	BIPT	Complete
CY	SRA	Ministry of communications	Complete
CZ	SRA	CTU	Complete
DE	SRA	BNetzA	Complete
DK	SRA	DEA	Complete
EE	SRA	ECA	Complete
EL	SRA	EETT	Complete
ES	SRA	Ministry of Energy, Tourism and Digital Agenda	In progress
FI	SRA	FICORA	In progress
FR	SRA	ANFR	Complete
HR	SRA	HAKOM	Complete
HU	SRA	NMHH	Complete
IE	SRA	ComReg	Complete
IT	SRA	AGCOM	Complete
LT	SRA	RRT	Complete
LU	SRA	ILR	Complete
LV	SRA	Electronic communications Office	Complete
MT	SRA	MCA	Complete
NL	SRA	ACM	Complete
PL	SRA	UKE	Complete
PT	SRA	ANACOM	Complete
RO	SRA	ANCOM	In progress
SE	SRA	PTS	In progress
SI	SRA	AKOS	In progress
SK	SRA	TUSR	Complete
UK	SRA	Ofcom	Complete
BE	MNO	Liberty Global + Telenet	Complete
DE	MNO	Deutsche Telekom	Complete

DK	MNO	Telenor	Complete
DK	MNO	TDC	Complete
FR	MNO	SFR	Complete
IT	MNO	TIM – TelecomItalia	Complete
SE	MNO	Tele2	Complete
SI	MNO	Telekom Slovenije	Complete
UK	MNO	Vodafone Group	Complete
UK	MNO	Orange	Complete
IT	MVNO	Poste Mobile	Complete
UK	MNO	BT	Complete
UK	MNO	Three	Complete
UK	MNO	EE	Complete
UK	Verticals	Interdigital	Complete
DE	Verticals	Robert Bosch GmbH	Complete
DE	Equipment vendors	Siemens	Complete
UK	Equipment vendors	Intel	Complete
SE	Device manufacturers	Garmin Europe	Complete
DE	Verticals	DoCoMo Communications Laboratories Europe GmbH	Complete
SE	Verticals	ABB	Complete
UK	Verticals	Joint Radio Company	Complete

Table 25: Stakeholders participating in the study

6.2.1 Results of stakeholder feedback

In this section, we present the charts that summarise the interview responses from SRA and industry stakeholders.

6.2.2 SRAs

What authorisation regimes are currently used in your country?

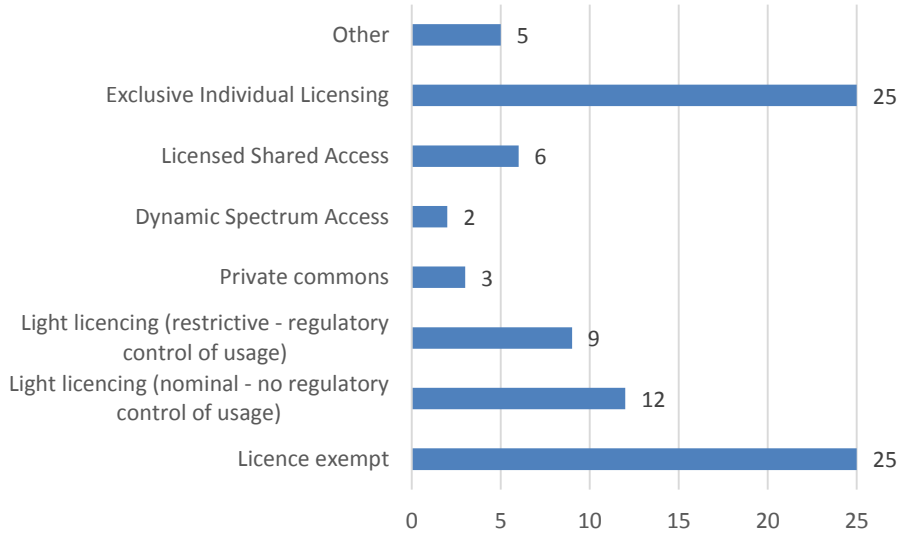


Figure 36: Authorisation approaches used in EU Member State countries

6.2.3 MNOs

Which of the authorisation regimes shown below is best suited for 5G services? (Industry responses)

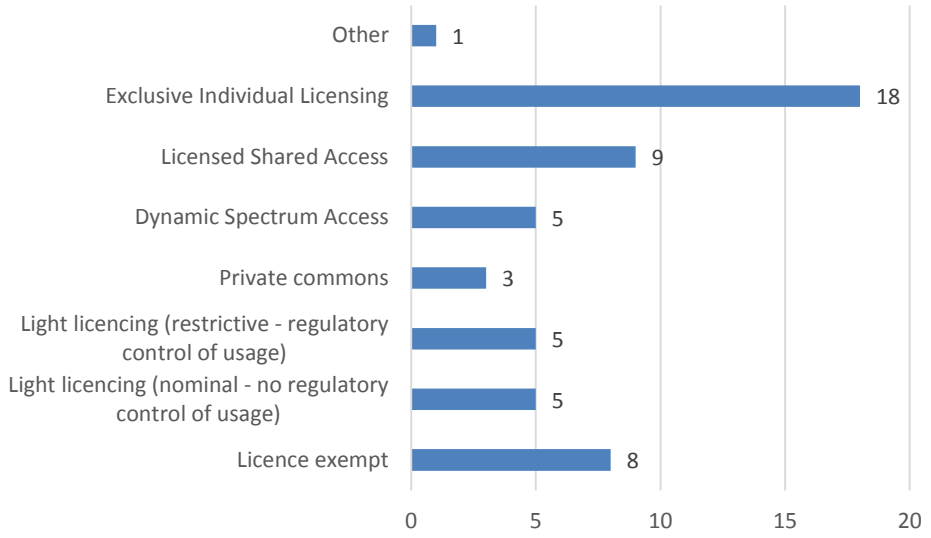


Figure 37: Authorisation approaches best suited for 5G services

Does the advent of 5G services require a re-thinking of existing authorisation regimes? (Industry responses: "1" no changes needed – "5" overhaul changes needed)

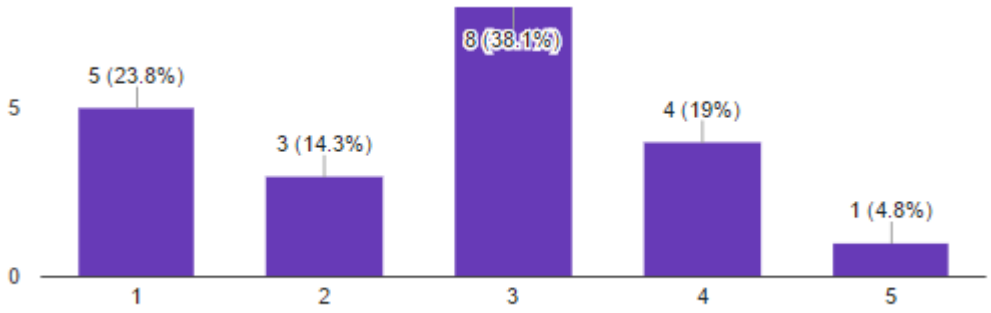
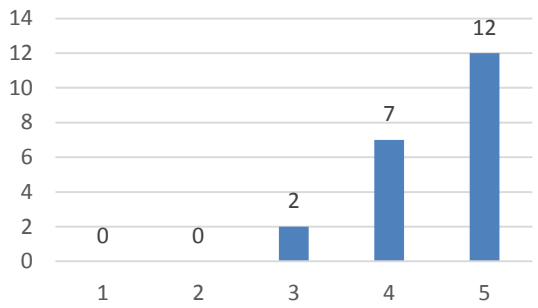


Figure 38: Changes needed of existing authorisation approaches

How important is it that the regulatory arrangements for 5G should be consistent across Europe and worldwide?

(Where 1 is of little importance and 5 is very important)

Europe



Worldwide

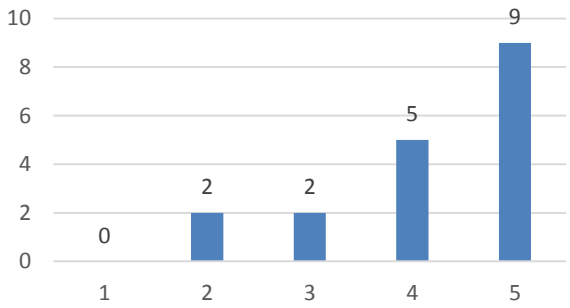


Figure 39: Importance of consistent regulatory arrangements for 5G

6.3 Approaches to assignment process

6.3.1 Elements and conditions

Do you apply generic criteria when deciding on the elements of an assignment procedure, or can decisions only be made on a case by case basis? ***(Question to regulators)***

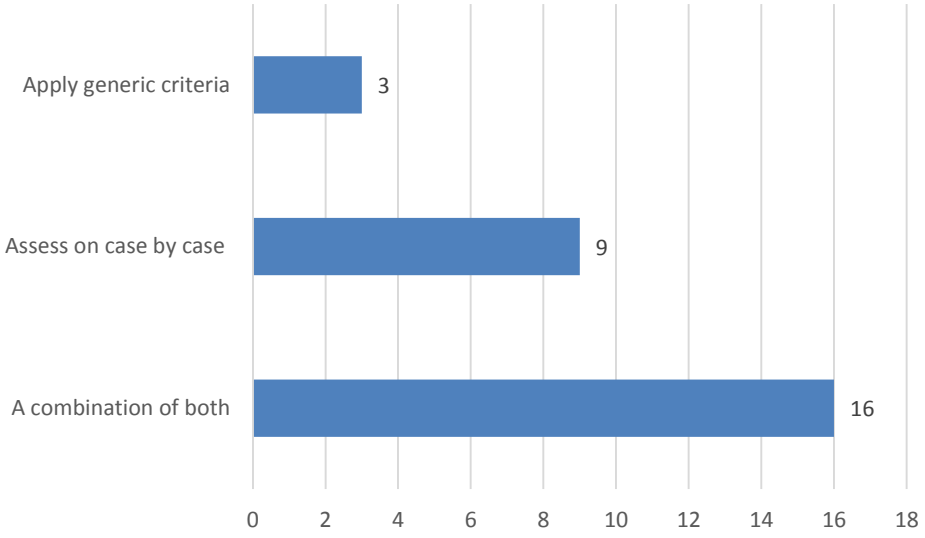


Figure 40: Regulator approach on taking decisions on assignment procedures

6.3.2 Industry feedback on time lag between the allocation of spectrum and deployment

Are you concerned by time lags between the allocation of spectrum and the deployment of services?
(Where 1 is not concerned at all and 5 is very concerned)

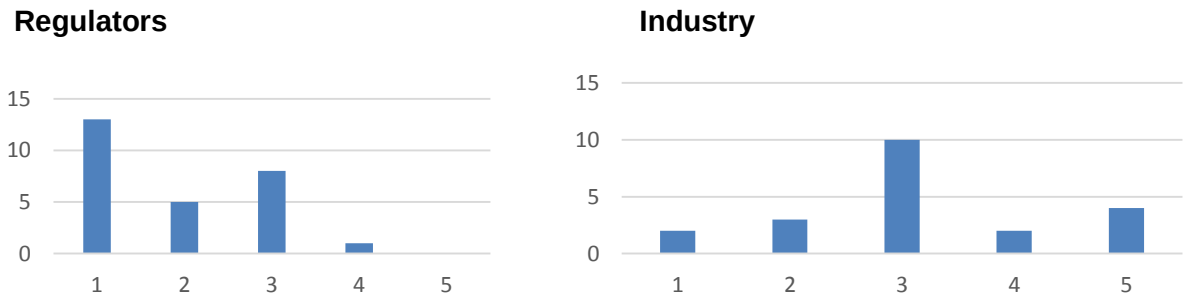


Figure 41: Views on time lags between the allocation of spectrum and the deployment of services

7 Appendix C – Expert workshop

7.1 Purpose of the workshop

The purpose of the workshop was to validate the early findings from the study with academic experts and discuss the proposed future what if scenarios.

7.2 Findings from the workshop

Overall the academic experts provided positive feedback to the future scenarios with some additional specific suggestions to refine the descriptions. The discussions centred on the mix of exclusive licensing and prioritised or open (general) access to spectrum for delivering 5G services. This was dependent on the band and scarcity of bandwidth but a private commons approach to a 'capacity layer' for spectrum was suggested with a coverage layer for the lower frequency bands that may have to have a more rigid authorisation regime.

The panel expressed some doubts and questions around infrastructure sharing and competition. However, it was acknowledged that infrastructure sharing would be necessary in dense urban environments and therefore multiple operators sharing access to infrastructure and therefore spectrum access. This would mean a requirement for discrete blocks of spectrum for capacity but does not necessarily have to be accessed in the traditional authorisation approach today

New approaches to investment for networks would be needed with a more flexible approach to spectrum access, i.e. opening up prime harmonized spectrum for 5G technology could enable smaller regional operators establishing in areas incumbent operators typically do not invest. Thus wholesale access to all required mobile spectrum (including 5G) would greatly enable new business models and investment but possibly in rural or emerging economic areas.

European Commission

Study on Spectrum Assignment in EU

Luxembourg, Publications Office of the European Union

2017 – 159 pages

ISBN 978-92-79-68724-2

doi:10.2759/509541

KK-02-17-577-EN-N

ISBN 978-92-79-68724-2 doi:10.2759/509541