# Imperfect Harmony: International harmonisation and national spectrum management

## Introduction

Final preparations are underway for the World Radiocommunication Conference 2019 (WRC-19), a two-month conference beginning this October in Egypt. The world radiocommunication conference (WRC) is held every three to four years, with the overarching objective to review and revise the Radio Regulations. The Radio Regulations are international treaties between member states of the International Telecommunications Union (ITU)[1] that govern the use of radio spectrum and satellite orbits.

International governance of radio spectrum use aims to reduce cross-border interference and develop equipment ecosystems. This is done by regional (or global) allocation of frequencies for particular communications services[2] and through implementation of technical and regulator standards. This process is referred to as *spectrum harmonisation*. Although spectrum harmonisation is an international effort, spectrum resources are (typically) managed and assigned at a national level. Harmonisation can therefore limit the decisions of national spectrum managers, and there may be instances where the collective international interest does not align with national interests.

Though the role of spectrum harmonisation and role of cross-country coordination between national spectrum managers are well established, this essay discusses the benefits and limitations of harmonisation and considers emerging coordination issues that need to be addressed at national and international scale[3]. This essay argues that the harmonisation facilitates benefits of coordination – but fundamentally cannot deliver without national action. It also supports the view that national spectrum managers should, at times, prioritise national interests over international harmonisation. The essay concludes by summarising future issues beyond the scope of coordination that are relevant to cross-country coordination.

## Spectrum as an economic resource

Before analysing the need for international harmonisation of spectrum, it is useful to consider the aspects that characterise radio spectrum as an economic resource. Specifically:

1. Spectrum occurs within nature and can be used for economic gain (a natural resource);

2. There is a finite supply of frequencies and capacity to meet existing and future demand (a scarce resource); and

3. Consumption is rival but not excludable – or at least highly costly to exclude – potential users (a common-pool resource, as defined in Figure 1).

[1] The ITU is a United Nations specialised agency for information and communications technologies, founded in 1865 to facilitate international connectivity of communications markets. See ITU: https://www.itu.int/en/about/Pages/default.aspx

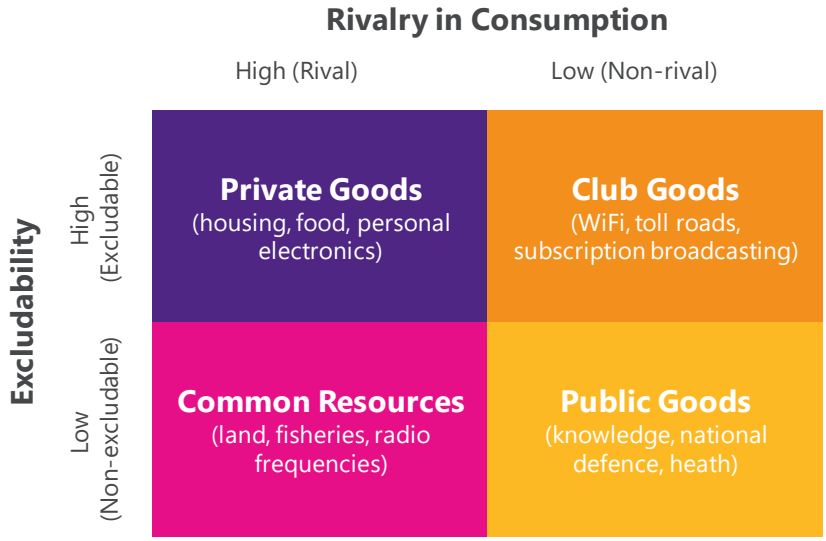
[2] Note on terminology: "Allocation" refers to the international or national identification of services which may use the specified frequency ranges on a primary, co-primary or secondary status (i.e. priority status for use). Allocation does not imply assignment of frequencies to users, or that the frequencies are in-use. "Assignment" refers to licensing or identification of frequencies to an identified users or group of users in order to permit transmission and/or receipt of frequencies (i.e. to permit frequency use).

[3] Note on terminology: "Harmonisation" refers to spectrum harmonisation, as defined above. Harmonisation may be global (international) or specific to ITU regions (regional harmonisation). "Coordination" refers to cross-country agreements between jurisdictions to manage cross-border interference and cooperative development of regional practices.

These characteristics of spectrum (as an economic resource) impact on how it is managed. As an intangible natural resource, the state assumes ownership of spectrum as it has no inherent owner or producer. Management for the use of the resource often delegated from government to a national regulator[4]. It is, however, the characteristics of scarcity and spectrum as a common-pool resource which shape spectrum management.

Spectrum is a scarce resource; multiple users require spectrum to support a variety of communications services and applications demand use of a limited frequency range. It is due to scarcity that maximising efficient use of spectrum is commonly identified within best practice spectrum management principles[5]. However, it should be noted that scarcity varies across frequency bands. For example, frequencies identified for cellular mobile services in the sub-1 GHz ('coverage') and 1-3 GHz (mid- 'capacity') ranges experience higher – or excess – demand as mobile data usage continues to grow rapidly. In contrast, higher frequency bands have more ability to supply bandwidth (higher capacity) but their propagation (coverage) characteristics mean that there are fewer meaningful applications and limited users. In short, not all spectrum is affected by scarcity – only usable spectrum which supports one or more services which require a significant proportion of available bandwidth are scarce.

**Figure 1: Characteristics of common-pool resources**




Spectrum can also be defined as a common-pool resource (Ostrom and Ostrom, 1977)[6]. Spectrum is utilised by a number of users and it has no inherent owner as it occurs within nature (with ownership often assumed by the Crown or the State), and use of specific frequencies in a particular location or geographical range can exclude other users from using the same frequency in this area. Without management or coordination, users of spectrum will act in their own self-interest without regard on the impact that this has on others and may lead to over-use of a common pool resource, defined by Ostrom and Ostrom (1977) as "tragedy of the commons". In the example, spectrum over-use may have two specific consequences:

- Spectrum hoarding – a *land-grab* of frequencies where users claim use of more frequencies than they require which excludes other potential users; and/or

[4] Note on terminology: this essay refers to a "national spectrum manager". This is typically a national regulatory authority, though institutional arrangements differ across jurisdictions.

[5] 'Best practice' principles of modern spectrum management include transparent, non-discriminatory, economically efficient and effective spectrum management policies, that provide regulatory certainty. See: ITU (2015), Handbook on National Spectrum Management, ed. 2015. Available at: https://www.itu.int/dms_pub/itu-r/opb/hdb/R-HDB-21-2015-PDF-E.pdf

[6] Ostrom, V., and Ostrom, E. (1977). Savas, E S ed. Public Goods and Public Choices, *Alternatives for Delivering Public Services: Toward Improved Performance*. Boulder, CO: Westview Press.

- (Harmful) interference – disruption or failure in the frequency signal due to another user transmitting on the same or closely located frequency. Interference can be considered as a negative externality from other users.

It is therefore in the interest of the designated spectrum manager to coordinate the different users of radio spectrum and maximise efficient use of spectrum in order to maximise availability.

Ostrom (1992)[7] notes that centralised government control or privatisation are typically offered as solutions for managing common-pool resources and also proposes a third approach: designing institutions that are organised and governed by the resource users. Modern spectrum management practices combine aspects of all three approaches. Spectrum managers allocate portions of spectrum (frequencies) to different services and then assign those frequencies to users in various methods. Regulators may give exclusive property rights to users, authorising them to use specific frequencies in a defined geographical area in the form of a *spectrum licence*, or authorise a specific piece of equipment or infrastructure, referred to as *apparatus licensing*. Coase's (1959)[8] seminal article on establishing spectrum property rights, assigned on the basis of competitive bidding, notes that: *"The main reason for government regulation of the radio industry was to prevent interference… this situation is avoided by assigning property rights (rights, that is, to exclusive use)"*. This, however, overlooks non-exclusive (or shared) use of frequencies.

Regulators may assign frequencies on a non-exclusive basis through *licence-exempt* or *class-licensing* arrangements. Such users do not require formal licensing to use frequencies providing that they operate within the criteria defined by the regulator when allocating the frequencies to particular service uses. Non-exclusive spectrum rights are typically used where there is minimal risk of harmful interference. There has also been an introduction of hybrid spectrum-sharing approaches recently to maximise spectrum availability whilst supporting incumbent and new (service) users.

Although the above discussion outlines why and how spectrum is managed within jurisdictions, it excludes one of the key characteristics of radio spectrum:

4. Spectrum transcends national borders – radio waves travel across, and cannot be limited by, jurisdictional borders. In-country users of spectrum may experience interference from out-of-country spectrum users, particularly in border regions or across small territories.

It is for this reason that international (coordination and) harmonisation of radio spectrum is required. Although national regulators may be able to mitigate the impact of cross-border interference originating outside the country by limiting use of vulnerable frequencies in-country, greater benefits are likely to result from neighbouring countries taking collective measures to mitigate cross-border interference.

## Role of spectrum harmonisation

The GSM Association ('GSMA') defines spectrum harmonisation as: *"the uniform allocation of radio frequency bands across entire regions – not just individual countries"* [9]. Spectrum harmonisation is a global effort by the ITU which aims to reduce cross-border interference and (re)allocate spectrum to capacity-constrained users, which can help maximise (efficient) spectrum usage. Harmonisation also aims to facilitate interoperability and roaming across jurisdictions, delivering benefits for equipment and device users.

The WRC plays a key role to harmonise spectrum across international regions. The outcome of the WRC is reflected in the international treaties, referred to as the Radio Regulations. These define frequency allocations

[7] Ostrom, E. (1992), Governing the Commons: The Evolution of Institutions for Collective Action, Natural Resources Journal, Spring 1992.
[8] Coase (1959) "The Federal Communications Commission", *Journal of Law and Economics*, October 1959.
[9] See: https://www.gsma.com/spectrum/managing-spectrum/

and the technical and regulatory conditions of use for services[10]. They aim to prevent and resolve cases of harmful interference across-countries and between services.

Each ITU member state has a national delegation and is represented at the WRC. However, the ITU member states also collaborate in regional preparations prior to the WRC in order to share their national contribution and gather consensus on proposals that may impact other regional members. There are six regional groups representing Europe, Africa, Middle East, Asia-Pacific, Americas, and former-Soviet Union states. Developing consensus at a regional (and cross-regional) level is an important step, especially given that the Radio Regulations identify three ITU regions[11].

As identified in the previous section, the main benefit of spectrum harmonisation is to reduce harmful interference, particularly in border areas. However, there are two important caveats to acknowledge before the other benefits of harmonisation can be discussed.

1. Certain jurisdictions benefit more from harmonisation than others. The majority of countries share borders with other states, or are otherwise close enough to experience potentially harmful interference. However, some jurisdictions use communications networks in locations that are remote enough not to receive or cause harmful (cross-country) interference. Nevertheless, these jurisdictions will benefit from accessing a harmonised eco-system for devices and equipment and may still face problems of interference. One such example is the Falkland Islands, a British overseas territory in the South Atlantic (ITU Region 2) but which follows ITU Region 1 allocations. The Falkland Islands are unlikely to cause harmful cross-country interference due to their remote location. However, they experience interference between different service users within the Falkland Islands: proximity to the Americas mean that consumers bring device not compatible with the territory's frequency allocations.

2. Harmonisation is more beneficial to certain services, particularly for services with global mass-market appeal, such as international mobile telecommunications (IMT)[12] and Internet of Things (IoT) solutions which benefit from harmonisation of technical standards and common frequency availability. Satellite services which provide international connectivity benefit from internationally frequencies and protection from interference from other users.

## Additional benefits of harmonisation

International coordination of spectrum assignment delivers significant benefits, in addition to assisting with the coordination of spectrum deployments in border areas. Harmonising spectrum allocations across ITU Regions can deliver benefits from economies of scale in the manufacturing of network equipment and devices, assist economic development at a regional (cross-country) level, amongst other wider benefits.

Specifically, defining technical standards as part of spectrum harmonisation can support development of the equipment and device ecosystems. Network effects occur when the value of a service or good to an individual user increases as the number of users increase (also referred to as the 'bandwagon' effect). In the case of frequencies, a frequency band becomes more useful and valuable when it is recognised and used across more jurisdictions. This provides more incentives for vendors to develop compatible devices and network equipment for this frequency band. Thus, harmonisation can enhance ecosystem development for communications networks.

[10] Ibid. See: https://www.gsma.com/spectrum/managing-spectrum/

[11] For the purposes of spectrum management and harmonisation, the International Radio Regulations identifies three ITU regions: ITU Region 1 covers Europe, Africa, Eurasia (former Soviet Union countries and Mongolia), and the Middle East (excluding Iran); ITU Region 2 covers the Americas, including Greenland and some of the eastern Pacific Islands; and, ITU Region 3 includes Asia-Pacific countries, Iran and the majority of the Pacific Islands.

[12] IMT is a standard and system created by the ITU, for the creation, operation and management of (wireless) mobile networks.

Vendors (or manufacturers) of network equipment and devices may also benefit from economies of scale. Harmonised spectrum allocation means that vendors can develop and produce equipment that is compatible with numerous frequencies across multiple jurisdictions. Thus, vendors can increase their productive efficiency by reducing the costs associated with development and production of products specialised for country-specific spectrum arrangements. The benefits – or economies – of scale that are facilitated by international coordination may benefit vendors through:

- Technical economies – by being able to increase production at lower costs (due to reduced market-specific differentiation in equipment and devices);

- Purchasing economies – where larger firms are able to bulk buy and achieve discounts. For equipment vendors, greater coordination may mean there is less need to buy several specialised components required for country-specific allocations which will be more costly than bulk-buying components which are compatible internationally; and

- Administrative savings – harmonised frequency allocation and usage across international regions may reduce administrative and management costs associated with equipment compatibility and may reduce research and development costs incurred from developing products that are only applicable to small market.

The cost savings incurred by vendors from spectrum harmonisation and economies of scale of production may then be passed through to network operators and consumers that purchase network equipment and devices and use communications services (or services supported by communications services) through lower wholesale and retail prices. Therefore, spectrum harmonisation may deliver cost-savings to network operators and service providers and increase consumer welfare.

Regional harmonisation may also facilitate sharing of spectrum management practices and encourage economic development at the regional and country-level. The WRC process relies on regional spectrum management groups that collectively represent countries within the same geographic regions[13]. The regional spectrum management groups aim to achieve regional consensus on the spectrum allocations for different services across the regional. One of the benefits of regional spectrum harmonisation is that it may encourage coordination between jurisdictions, such as to resolve cross-border interference issues, and regional 'leaders can become a blueprint for spectrum management and frequency assignment throughout the region.

Spectrum harmonisation can make it easier for other jurisdictions to learn and, in some cases, emulate, the spectrum allocations and awards of regulatory and market 'leaders' within their nation. In Europe, for example, the CEPT and the Radio Spectrum Policy Group (RSPG), a high-level advisory group to the European Commission, are supporting countries across Europe to release the 700 MHz, 3.5 GHz and 26 GHz 5G frequency bands. Several Western European countries – typically with more developed regulatory institutions – have or are in the process of assigning these frequencies to wireless operators. The assignment methods and technical conditions are being adapted and imitated by other European countries looking for 'best practice' examples.

Harmonisation is also compatible with other trends of globalisation, including infrastructure development and manufacturing. Vendors are typically large multinational firms that supply equipment and devices across international markets. However, examples of regional harmonisation and jurisdiction-specific arrangements and the resulting product differentiation should be noted. For example, Apple offers different model of iPhone to the US and Europe, which account for differences in the regional band plans, with cross-country functionality based on a limited number of common frequency bands. Whilst multinational vendors may benefit from harmonisation

[13] There are six regional groups that contribute to identification of frequency bands and allocation to appropriate services. These include Asia-Pacific Telecommunity (APT), Arab Spectrum Management Group (ASMG), African Telecommunications Union (ATU), European Conference of Postal and Telecommunications Administrations (CEPT), Inter-American Telecommunications Commission (CITEL), and Regional Commonwealth in the field of Communications (RCC).

(see discussion on economies of scale), consumers may also benefit from being connected using their devices abroad or purchase devices from these countries as the device is compatible abroad.

Furthermore, vertical industries which integrate IoT solutions and private LTE or 5G networks may benefit from the ability to seamlessly transfer manufacturing or their services from one country to another, without needing to consider equipment compatibility. In the case of IoT, devices range from mass-market solutions commonly be found in households to niche solutions that may have small but international consumer base. Both benefit from spectrum harmonisation; the former from economies of scale in production and the latter by being able to access more markets with a single niche product.

## Limitations of harmonisation

Harmonisation limits what nations can do and there may be times that harmonisation goes against national interests.

One of the main difficulties with harmonisation is that it can constrain the possibilities and autonomy to make national spectrum decisions. This may result in unused or inefficient allocation of spectrum in some countries. In Europe, sub-700 MHz spectrum is allocated to, but not uniformly used for, digital terrestrial television (DTT) services. The consumption and market share of DTT and other broadcasting services varies across European countries[14]. As a result, there are several countries where DTT frequencies are vacant. These frequencies are particularly valuable to IMT services because of their coverage capabilities, yet cannot be assigned by national spectrum managers.

Additionally, harmonisation may open up frequency bands, but spectrum may not be available due to persistent coordination issues. It useful to consider the 3.5 GHz, the core 5G band for enhanced mobile broadband services. The band overlaps with C-Band frequencies dedicated to fixed satellite services (FSS). There is heavy satellite use of this frequency in tropical regions due to its comparatively better performance under adverse weather conditions than higher frequencies designated to satellite. Therefore, options of clearance of incumbent FSS users or sharing arrangements (namely, the implementation of mitigation measures) are more challenging than in other regions. National spectrum managers in this region face several issues, including cross-border interference, limiting interference between IMT and FSS services, and inter-operator synchronisation of 5G TDD networks (frame and slot of signal transmission) to reduce cross-country interference of 5G IMT services. It is also likely that countries will release spectrum to IMT services at different times, requiring on-going coordination arrangements between multiple jurisdictions.

Furthermore, there may be instances where harmonisation goes against what is best for national interests. In such cases, national spectrum managers may not fully implement standards or may formally exempt themselves from harmonisation. The latter is reflected in the country-specific footnotes of the Radio Regulations; this is illustrated by several Asia-Pacific countries that have country-specific footnotes in the Radio Regulations relating to country allocation of 3.5 GHz for IMT. National choices need to account for predominance of different services, users with varying spectrum need and size of the national market.

A limitation of harmonisation itself is that it does not ensure spectrum is released; it acts only as top-level identification of frequency bands in the release pipeline. Nevertheless, it is the role of national spectrum managers to follow through and designate allocation at the national level. Only national spectrum managers can provide the benefit of certainty that spectrum will be available. One such example is 26 GHz, a core 5G millimetre wave (mmWave) band harmonised in Europe (though not yet internationally harmonised and reflected in the Radio Regulations)[15]. National regulators have been criticised for being slow to release 26 GHz to IMT. Clearance of incumbent fixed-link services or appropriate sharing arrangements have to be introduced,

[14] See: Farncombe & Plum Consulting (2014), Challenges and opportunities of broadcast-broadband convergence and its impact on spectrum and network use, report for European Commission. Available at: https://plumconsulting.co.uk/challenges-and-opportunities-broadcast-broadband-convergence-and-its-impact-spectrum-and-network-use/#

[15] The term mmWave refers to a specific part of the radio frequency spectrum between 24GHz and 100GHz.

and the number of incumbent users and solutions are unique to each jurisdiction. To expedite the process, the European Commission adopted an Implementation Decision to encourage member states to harmonise the 26 GHz band by the end of 2020[16].

Fundamentally, spectrum harmonisation can be viewed as a framework for national allocations and cross-country coordination. Choice regarding spectrum management and allocation are made at national level, and the benefits of harmonisation are delivered through the actions and implementation choices of national spectrum managers.

## Harmonisation is an imperfect process

The current harmonisation process presents additional challenges, in addition to the limitations of national spectrum management. The process to update the Radio Regulations at WRC may not keep pace with market development and may be criticised on grounds that interests of specific groups may be prioritised.

The WRC takes place every three years, with the agenda for the next WRC decided at the end of conference. There have been criticisms that market development and emerging frequency use can be ahead of WRC timing. This is apparent in the core mmWave frequencies for 5G. Harmonisation of mmWave bands are included on the WRC-19 agenda; however, these frequencies have already been identified for 5G at national level. 28 GHz is already assigned to operators in Korea and the US to enable provision of wireless broadband (5G) services, and as previously discussed, 26 GHz has been harmonised in Europe. Misalignment between industrial cycle and process of harmonisation to national release (and vice versa) remains an on-going challenge.

Scrutiny should also be given to the parties that drive particular issues. Harmonisation only works where there is a common interest across countries and/or relevant communities. Following the interests of particular groups should not be pursued where there are consider adverse impacts on other jurisdictions. Furthermore, harmonisation needs to prioritise the needs of all communications services. Developments in cellular mobile have placed significant pressure on national spectrum managers globally to identify additional frequencies for IMT. There are, however, other essential communications services that use spectrum, including Public Protection and Disaster Relief (PPDR) and Emergency Service networks. The eco-system for these services may adaptable to alterations in frequency allocations and technical standards. The interests and needs of all users of spectrum need to be balanced when making both international and national frequency allocations.

## Beyond harmonisation – outlook on future coordination

Harmonisation to date has been beneficial to reduce (and resolve) interference and develop equipment eco-systems. National spectrum managers are responsible for implementing national allocations and also need to be responsive to changing spectrum management practices and the evolving needs of the market.

Spectrum harmonisation is dynamic; each WRC identifies new batch of frequencies that are to be allocated to various users and technical standards are revised to reflect technology and deployment developments. One can already observe how international harmonisation has supported and reacted to the introduction of new technologies and services, and the introduction of innovative spectrum management practices. It is therefore important that spectrum management is flexible and forward-looking in order to ensure international harmonisation and national policy are flexible to meet future needs.

An emerging issue is the increased use of spectrum sharing, where frequency rights are assigned on a non-exclusive basis, as a response to increasing demand for a finite supply of scare spectrum. Until recently, spectrum sharing has relied on static arrangements, with two or more distinct services have co-existing within the same frequency band. In many cases, the services have been assigned the right to use a specific portion of

[16] See: https://ec.europa.eu/digital-single-market/en/news/european-commission-harmonise-last-pioneer-frequency-band-needed-5g-deployment

frequencies within a defined geographical area in order to mitigate interference between different services within the jurisdiction and across borders. Licensed Shared Access (LSA) is a pan-European regulatory framework which has been introduced to facilitate spectrum sharing in the 2.3 GHz band. Although the 2.3 GHz band is globally harmonised for IMT, there were difficulties in assigning the band due to incumbent, largely military, users. Regional harmonisation, followed by development of LSA, has facilitated IMT use into the band in multiple member states.

There is also the emergence of dynamic spectrum sharing methods. This is an extension of spectrum sharing, flexing users' access to spectrum over time. The dynamic approach relies on a geo-location database and allocates frequencies over time and geographic area to users based on the rules set for sharing. Citizens Band Radio Services (CBRS) in the US is one well-known example of a dynamic spectrum sharing framework. It aims to allocate 3.5 GHz spectrum to wireless broadband whilst protecting incumbent users (navy radar, FSS and grandfathered fixed links. There are, however, challenges in introducing such SASs in smaller territories or those with that share multiple borders due to the need to establish cross border rules to use in the dynamic (often automated, algorithm-driven) systems.

This additional complexity for cross border operation partly explains why some dynamic spectrum sharing methods are developing from manual coordination of the geo-location database rather than using automated systems, such as Ofcom in the UK. In view of this, there will be a need for coordination between national spectrum managers. Although ambitious and potentially difficult to achieve, pursuing international harmonisation may provide additional clarity and principles that inform dynamic spectrum access arrangements in border areas.

The spectrum needs of all communications services need to be considered in international and national allocations is a further issue. Wireless communications services are characterised by continuous innovation and change. This is evidenced by a wide array of new user IoT devices, introduction of 5G services to benefit both consumers and vertical industries, and advancement in satellite technologies to support low earth orbit (LEO) satellite constellations. Both international and national spectrum allocation should react to developing needs of spectrum users. However, to fully support innovation of wireless communications services, spectrum allocation needs to be forward-looking and flexible enough to support access for innovative use by existing and new services. Allocating specific frequency bands as "innovative" bands or loosening (over-cautious) standards and technical requirements could support innovation. Prioritising innovation within in the international telecommunications standards is likely to support and complement efforts by national regulators and governments to facilitate industry-led innovation.

## Summary

Spectrum harmonisation is an international effort to reduce interference across jurisdictional borders and between different wireless services. It is important to acknowledge that harmonisation can both facilitate and limit national spectrum management actions, in some cases resulting in sub-optimal decisions at a national level.

Mitigating harmful interference and developing equipment ecosystems, both of which help maximise use of scarce spectrum resources, are the main benefits of spectrum coordination. It is important to acknowledge that harmonisation alone is not enough to deliver these potential benefits; the benefits can only be delivered by national choices and actions.

Going forward, international and national efforts will need to become more ambitious in order to identify and deliver more available spectrum for capacity constrained services, particularly for IMT. Spectrum managers will need to implement and work around the limitations of existing harmonisation arrangements, whilst also finding their own solutions to the remaining omissions and coordination challenges. National spectrum managers have

the ability to set the future agenda of harmonisation by overcoming or anticipating these challenges at a national-level and reflecting this into the international policy discussion.

Word count (including footnotes and figure): 4,542