Spectrum Management: National Policies, Technology Advancements and Best Practices

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INTRODUCTION

The availability of affordable and powerful devices for business-to-business, business-to-consumer, consumer-to-consumer, and machine-to-machine communications, alongside the expanding suite of cloud based services and applications, as well as voice, data and video content, continues to create increasing demand for communications. This demand fuels competition among service providers and intensifies pressure on network operators to maximise capacity and quality of service at lower cost in an environment of growing commercial scrutiny.

At the same time, policy-makers are increasingly sensitive to the importance of excellent telecommunications infrastructure to deliver on objectives. These include improved economic productivity, medical services, education, social mobility, transportation, and defence and security.

This paper examines how improved spectrum management practices and the application of technology can help meet some of these challenges.

Background

Radio spectrum is the limited natural resource that enables all wireless communications. Wireless communications and the corresponding use of radio spectrum can be local, national or international in nature, and encompass a multitude of different radio services and applications which are integral to our daily lives. It is therefore essential that this finite natural resource is managed effectively. Spectrum management is the practice of managing the use of radio spectrum to maximise the commercial and societal return on the use of spectrum while ensuring different technologies and services can coexist with minimum interference. A few examples of everyday uses of radio spectrum include, but are not limited to, broadcast and direct-to-home television and radio, wireless broadband, mobile phones, GPS, radar, radio astronomy, defence, public protection, scientific research, earth exploration, car keys, baby monitors, smart cards and wireless chargers.

Access to radio spectrum has traditionally been granted by governments, or their national regulatory authorities, which typically assign spectrum for use by different users and applications through administrative licensing. This process has commonly included both command and control (government decides who gets the spectrum) as well as market driven spectrum management models (for example, an auction decides who gets the spectrum) resulting in licensees having rights of use of radio spectrum in a specific geographic area for a fixed period of time.

Recognising the ever-increasing demand and that future use of spectrum resources for machine-to-machine communications will far exceed that of communication between individuals, we consider that there is a need to modernise spectrum management practices employed by regulatory authorities. This paper examines why.

Who is Responsible for Spectrum Management?

Internationally, the use of spectrum is governed by the International Telecommunication Union (ITU) Radio Regulations (RRs) which have treaty status and are binding to ITU Member States. The legal framework for the ITU are its administrative instruments which includes the ITU Constitution and Convention and its Administrative Regulations of which the RRs are an integral part.

Governments of member states and their regulatory authorities develop their national radio frequency plans in line with the RRs and define technical standards for different services and applications with their stakeholders at a national level, or in collaboration with regional regulatory fora or technical standards institutes.

Stakeholders' authorised access to spectrum in different bands takes place through administrative licensing or on a licence-exempt basis. Increasingly, tiered spectrum access models are being introduced, allowing a mixture of both licensed and licence-exempt access within the same band of frequencies and sometimes also in between. In all cases, however, the overarching technical framework ensures that different radio applications are compatible with each other without increased risk of unacceptable interference. Where different users have access to the same spectrum at different times or locations, access is coordinated to ensure radio compatibility. Depending on the country, this coordination is performed by the applicant for rights of use of spectrum or by the national regulatory authority. However, with the explosion of demand for access to spectrum resources new ways of undertaking this co-ordination are needed and technology must play a larger role. This idea is being embraced by technologists and service providers alike and we expect that spectrum managers within national regulatory authorities will become increasingly dependent on technology to solve their technical and regulatory co-ordination challenges in the coming years.

SPECTRUM MANAGEMENT: A TOOL FOR NATIONAL POLICY OBJECTIVES

When planning spectrum management policy, it is important to recognise the pervasive manner of spectrum use in society. Spectrum is used by governments, businesses and consumers across an increasing number of competing and complementary telecommunication infrastructures to support an ever-expanding number of applications. When determining how best to implement administrative licensing to permit spectrum access, it is essential to recognise that a "one size fits all" solution is not optimal and will introduce unnecessary inflexibility and inefficiencies.

A few examples illustrating this point are as follows:

Licensed spectrum access

It is common for national regulatory authorities to license spectrum on a nationwide basis for a set period. This approach is suited to frequency bands with excellent propagation characteristics – travelling long distances and covering large geographic areas – for applications with a regulatory obligation to provide universal service.

Tiered-licensed access

Tiered-licensed access can take many forms, but it is an increasingly important tool used for maintaining protection of incumbent licensed services, while permitting access to the band by other users on a secondary licensed or unlicensed basis. Tiered-licensed access is successful when deployment of incumbent users is limited geographically rather than by specific times. This allows for opportunistic access to spectrum by other users where the incumbent is not using the spectrum on a licensed or unlicensed basis, or both.

Examples of tiered-licensed access include:

- Television-band White Spaces (TVWS) – Some administrations, typically in countries where broadcast spectrum is assigned regionally to avoid interference between neighbouring regions, have permitted tiered-licensed access to the band by secondary and tertiary users of TVWS technology and devices, used for program making and special events (PMSE).
- Citizens Band Radio Service (CBRS) – In the US, the Federal Communications Commission (FCC) has established rules to allow the use of 3550-3700 MHz band by commercial broadband providers, while protecting incumbent US Department of Defence military radar and Fixed-satellite services. The FCC's CBRS rules allow for licensed protection of incumbent users from secondary and tertiary users, licensed secondary access and unlicensed tertiary access.

Tiered-licensed access provides national regulatory authorities with flexibility to improve efficiency in how spectrum is used in different geographies, at different times. Examples of such benefits include accelerated access to spectrum, licensed protection without the financial burden of a primary licensee, removal of entry barriers and stimulation of new business models and innovation. Additionally, tiered-license access can leverage existing economies of scale through standardisation of network and user equipment.

Owing to their relatively limited propagation qualities – travelling relatively short distances – we anticipate that tiered-spectrum access will play an important role in the deployment of mmWave networks. It offers licensed protection for incumbent users of these bands and provides regulatory certainty necessary to secure investment for opportunistic access to spectrum on a localised basis.

Unlicensed access

Unlicensed spectrum is a set of frequencies that do not have exclusive access. Unlike licensed spectrum which authorises its use through organisations for a specific purpose, unlicensed spectrum can be used by anyone that adheres to the rules for access.

Examples of unlicensed spectrum include:

- There are multiple everyday uses of unlicensed spectrum, including WiFi, Bluetooth, microwave ovens, vehicle radars, cordless telephony, wireless microphones, key-fobs, wireless chargers, baby monitors, drones and remote-control toys.

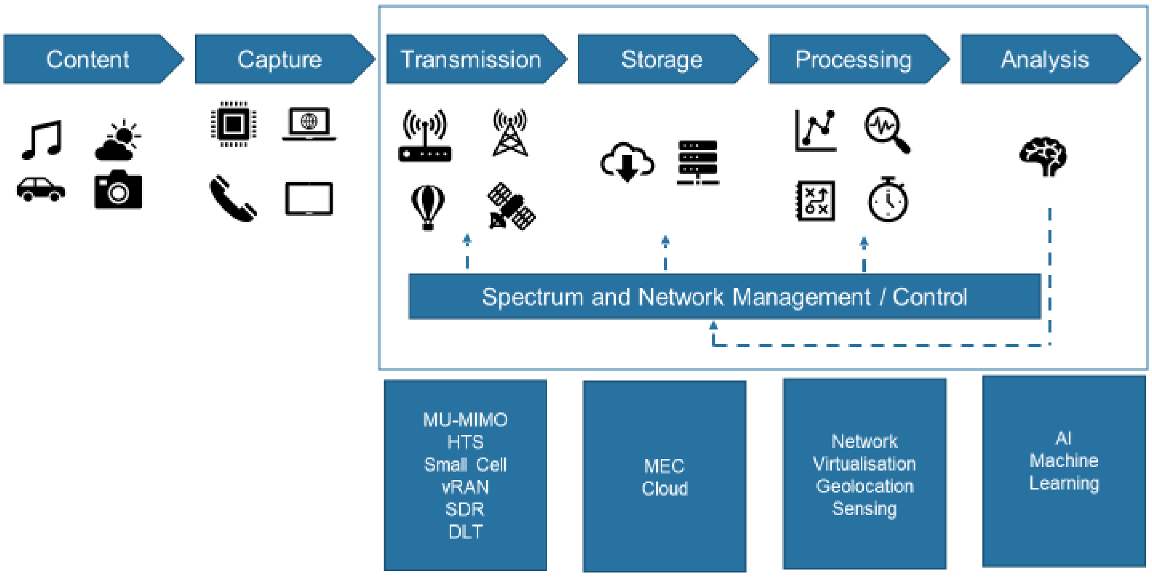
Unlicensed access to spectrum provides national regulatory authorities with a regulatory vehicle to stimulate innovation.

There are existing socioeconomic reasons to identify further spectrum for unlicensed access in addition to providing a resource for innovation of access technologies such as WiFi. As demand for mobile data increases, there is an implied demand for more spectrum to increase capacity to meet the growing demand. Unlicensed spectrum is widely used and is a more cost-effective alternative to additional licensed spectrum for technologists and innovators. WiFi is designed to operate using unlicensed spectrum and is well suited to adapt to the growing demand for connectivity, while complementing cellular-mobile networks. WiFi, along with other technologies designed to operate on unlicensed spectrum, supports national regulatory authorities in delivering social and economic policy – with an estimated annual value in excess of USD 2 trillion – while connecting rural communities, generating efficiencies in healthcare, social-inclusion, transportation and education.

TECHNOLOGY ADVANCES IMPROVING SPECTRUM MANAGEMENT

Technology plays a central role in spectrum management. It enables radio-compatibility among different co-frequency and co-located users and ensures minimum quality of service requirements. Businesses are driven by making the highest economic return from their product in terms of USD/Hz. In turn, technologists and service providers strive to ensure that their technologies and services use spectrum efficiently and effectively. Figure 1 illustrates the growing role of technology in spectrum management.

Figure 1 - Example of spectrum management in connectivity ecosystem



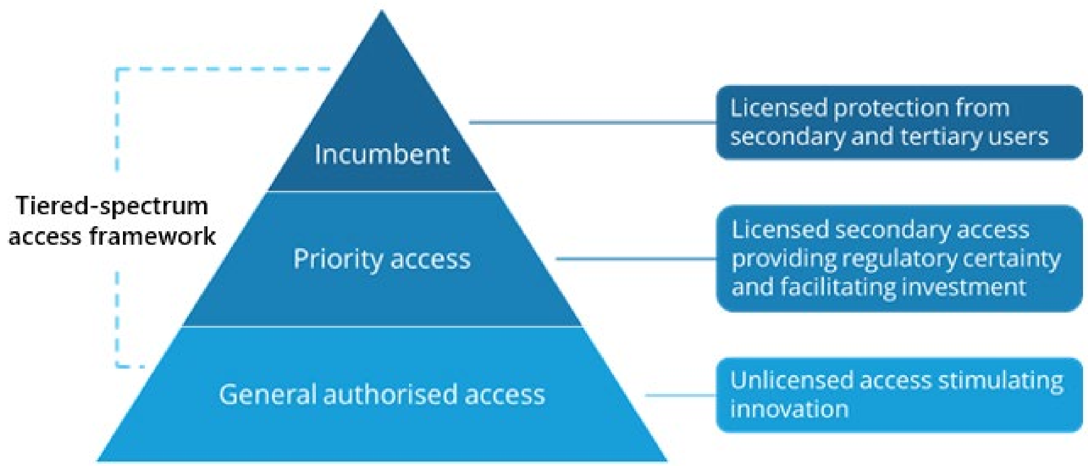
Examples of technologies that improve spectrum management by ensuring spectrum is used efficiently and effectively are as follows:

- MU-MIMO: MIMO (Multiple in Multiple Out) antennas increase the capacity of wireless communication links by using multiple transmission and receiving antennas to exploit radio signals reaching the same antenna by different paths (for example, reflections from the ground or buildings). MU-MIMO (Multiple User MIMO) applies this principle to multiple user terminals, each with one or more antennas, to communicate with each other.
- Small cells: Small cells deliver increased power in smaller cells to increase throughput (broadband speeds) and the Quality of Service for an increased number of end users.
- HTS: High Throughput Satellites deliver increased power in smaller footprint to increase throughput (broadband speeds) and the Quality of Service for an increased number of end users.
- MEC: MEC (Mobile Edge Computing) places computing power at the edge of a network. MEC reduces latency and improves Quality of Service in communications links, improving effectiveness for several real time applications including autonomous vehicles, intelligent transport systems, AR/VR and gaming.
- vRAN and SDN: VRAN (virtual Radio Access Network) and SDN (Software Defined Networking) is a response to meet increased demand for capacity while reducing or maintaining the cost

of network infrastructure and new service offerings. Communication service providers seek to use general purpose “white box” hardware to run software-based network functions such as network slicing.

- Geolocation databases: Understanding what spectrum is used where, when, and for what purpose enables spectrum managers to allow the opportunistic use of spectrum for other applications on a localised basis or for a specific period.
- Sensing: The ability to sense or detect the local spectrum environment provides network operators with the ability to select “clean” spectrum on which to transmit and avoid the possibility of interference to other spectrum users in the area.
- Distributed Ledger Technology (DLT): New approaches to spectrum management will require fast, secure and trusted verification and sharing of legitimate spectrum users, existing users, data about them and technical information on how spectrum is being used that would be suitable for DLT.
- AI: Artificial intelligence and machine learning algorithms applied to network and spectrum management practices to deliver superior performance. AI is particularly suitable for dynamic management of network and spectrum resources.

The adoption and application of technology can automate spectrum management processes. This will minimise the efforts necessary to coordinate access to resources by different radio services and applications and facilitate dynamic spectrum sharing and network optimisation. Technology is largely frequency agnostic and provides administrations with a tool that offers advantages to stakeholders over traditional approaches. These include: (a) speed to market and agility of deployment, (b) seamless protection of incumbent users, (c) increased spectrum efficiency through opportunistic spectrum access on a geographic or time dependent basis, and (d) attracting innovative business plans and the creation of a robust and sizeable ecosystem of suppliers and vendors.



SPECTRUM MANAGEMENT BEST PRACTICES

In our highly connected world, the ITU Radio Regulations remain a relevant reference for best practices of spectrum management. The Radio Regulations are founded on a set of principles that includes:

- ***Limit to the number of frequencies and spectrum*** used to a minimum
- Apply the ***latest technical advances*** as soon as possible
- Remember that frequencies and associated orbits are limited resources and must be used ***rationally, efficiently and economically***
- Operate stations in a way so as ***not to cause harmful interference*** to other members' services

The International Telecommunication Union (ITU), regional regulatory and standards fora, as well as national regulatory authorities have sought to harmonise the use of radio frequencies for specific services, both internationally and across geographic regions. The ITU has also worked to identify geographically harmonised spectrum for specific applications, including International Mobile Telecommunications (IMT), Global Maritime Distress and Safety Systems, Earth Stations in Motion and High-Altitude Platform Stations. Platform Stations.

The use of technology for spectrum management practices can facilitate market access for incumbent and emerging services, and further improve efficiency to ensure spectrum is utilised most effectively. Policy makers and national regulatory authorities should seek to remove any obstacles regarding the application of technology for spectrum management practices. This will include ensuring accurate records of spectrum use on a geographical basis at different times and making the information accessible for the purposed of spectrum management. This is not often the reality.

Unfortunately, we are now seeing some administrations grant authorisation for applications in frequency bands without a specific identification in the Radio Regulations, for example IMT in the 28 GHz band. We consider this to be poor spectrum management practice as it changes the radio interference environment, places further technical and operational restrictions on the incumbent services and ignores the principle of keeping the number of frequencies used to a minimum. It also calls into question the purpose of more than four years of studies by national, regional and international regulatory groups to harmonise frequencies for specific services and applications.

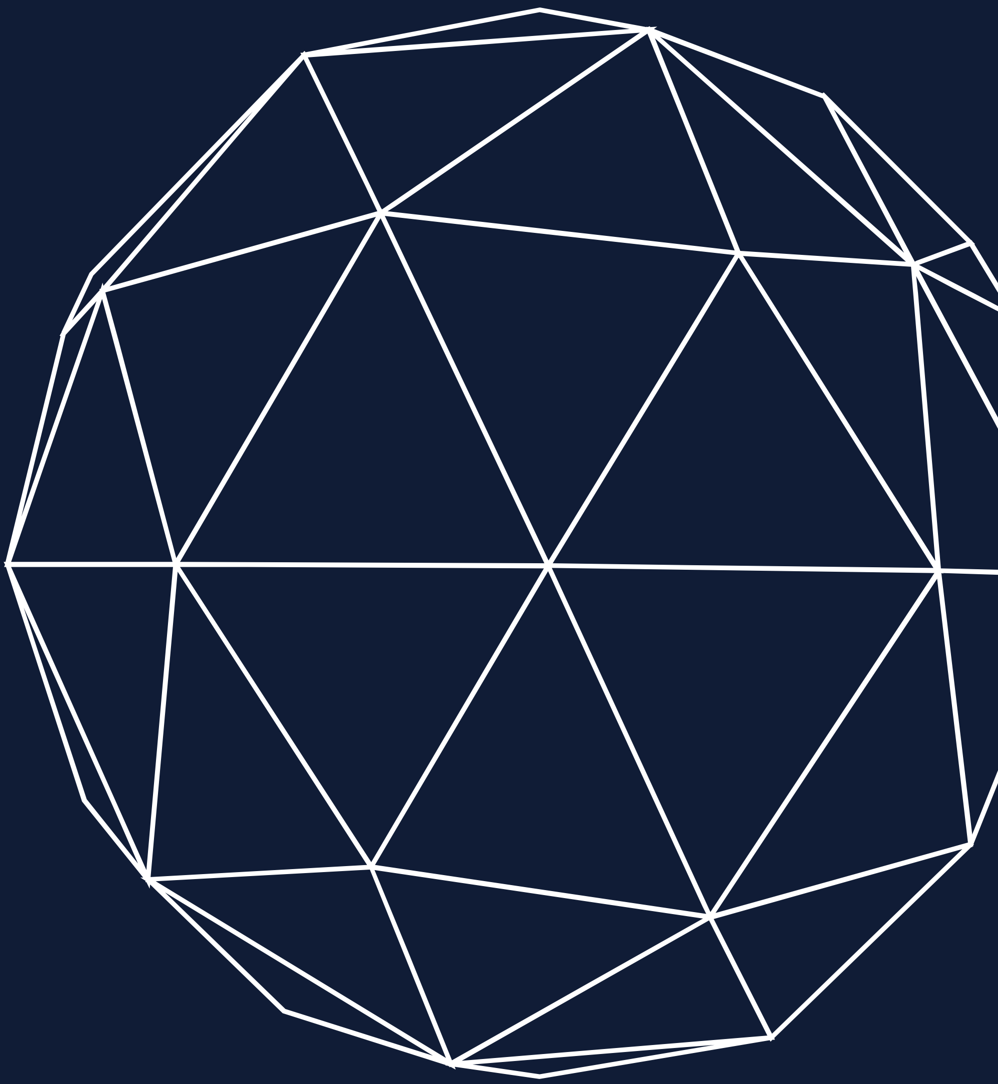
Disregarding the founding principles of the Radio Regulations introduces regulatory uncertainty and damages investment in new communication infrastructures. Additionally, it jeopardises the availability of critical network infrastructure in parts of the world not covered by IMT mobile-cellular networks and is a practice which should be avoided.

CONCLUSION

The demand for connectivity stems from all areas of society, from government to emergency services, businesses and consumers. As the availability of cloud-based services, applications and content expands, so will the need for additional capacity to accommodate it. As penetration rates increase in developing economies, this pressure will only intensify.

The ITU Radio Regulations and the principles upon which they were founded continue to provide a useful framework for best practice spectrum management regulation. The adoption and application of technology can significantly improve spectrum efficiency and increase the effectiveness of how it is used. As such, technology can assist national regulatory bodies in authorising spectrum access more effectively, reducing time to market, agility of deployment, seamless protection of incumbent users, stimulation of innovation and attract new business plans.

The challenge of delivering existing and future spectrum needs will be significantly reduced through the application of modern, spectrum management best practices.



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