Spectrum sharing

Overview and new approaches

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Executive summary

Spectrum sharing[[1]](#footnote-2) is a fundamental component of effective spectrum management and is a key tool in maximising the benefits derived from the use of the spectrum resource. The ACMA, like many national spectrum managers, consistently implements the sharing of spectrum to maximise the overall public benefit.

Spectrum sharing can take different forms and in its most basic forms has been commonplace in day-to-day spectrum management for many years. There are, however, a range of emerging techniques and technologies that are triggering an interest in potential new regulatory approaches to spectrum sharing.

The purpose of this paper is to provide an overview of spectrum sharing concepts as they currently exist and outline new approaches to spectrum sharing arrangements, including examples of sharing arrangements being either introduced or considered internationally. This is intended to provide a common information base against which new proposals for spectrum sharing can be considered.

## Traditional approaches to sharing

All access to spectrum is on a shared basis in some form. Various combinations of domestic and international planning frameworks, administrative and legislative regulatory tools and technology itself pave the way for shared access to spectrum on a day-to-day basis. This is what we call ‘traditional’ sharing, which in general takes the form of either:

* uncoordinated access—for example, class-licensed access to industrial, scientific and medical (ISM) frequency bands (such as Wi-Fi, Bluetooth, drone control)

coordinated access—licensing and assignment frameworks are optimised to accommodate multiple uses/users within a given frequency range, geographic space and/or time period.

A key characteristic of most traditional approaches to spectrum sharing, at least coordinated access approaches, is that the arrangements are based on licensed use. This means that these sharing arrangements will sometimes not be well equipped to dynamically respond to an environment where actual spectrum use changes.

## New approaches to spectrum sharing

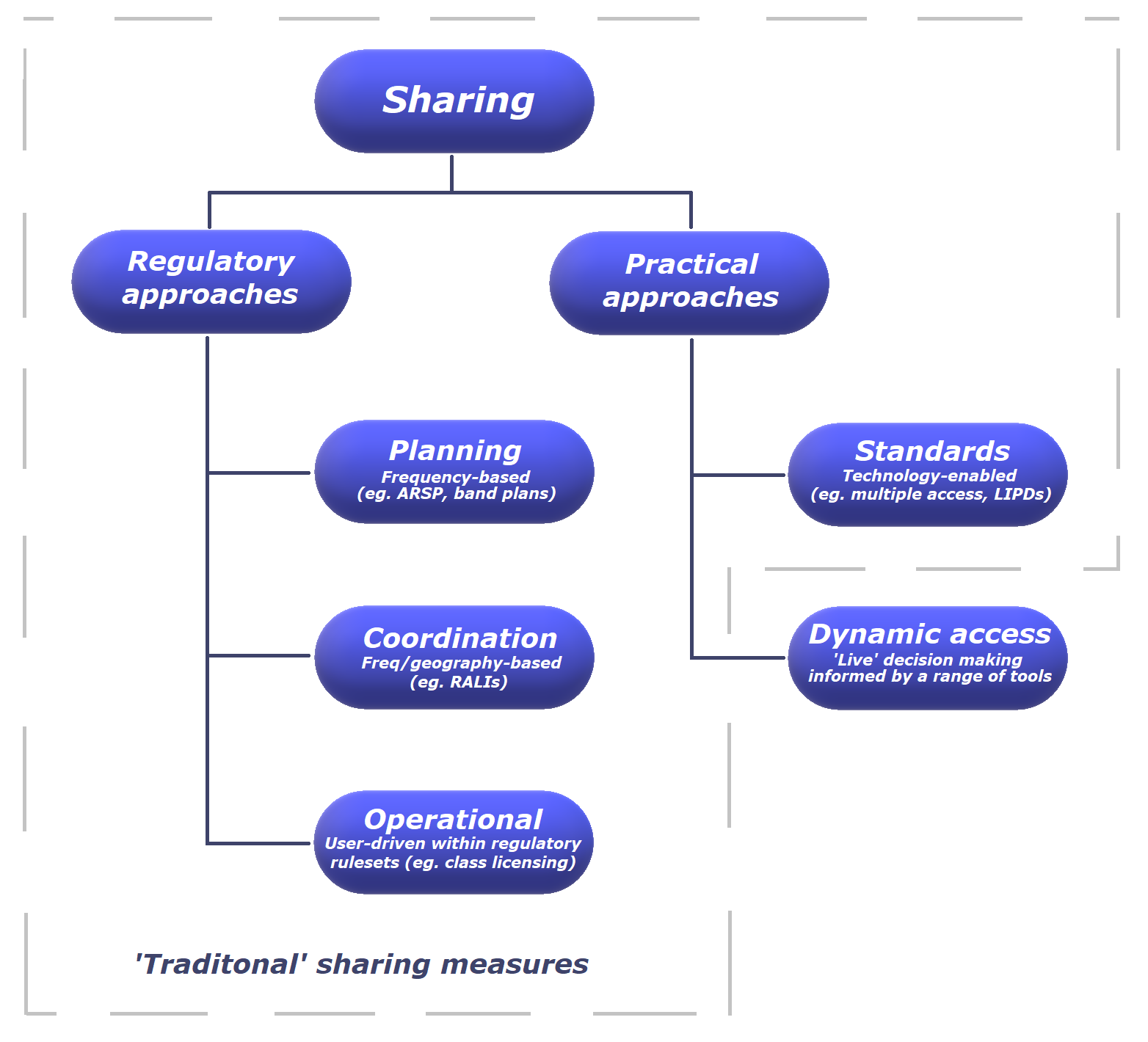
As technology develops and spectrum scarcity is a pressure, innovations in spectrum sharing have emerged.

A key concept in many new and emerging sharing approaches is that they are informed by information on actual spectrum use, as opposed to authorisation/licensing descriptors that might appear, for example, in a database such as the Register of Radiocommunications Licences (RRL)[[2]](#footnote-3). Devices and/or systems that access spectrum under these sharing approaches usually need to be aware of the surrounding radiofrequency environment and be able to react to changes in the environment in a timely manner—certainly well outside traditional licensing/authorisation timeframes which can span multiple years in some cases.

These new sharing techniques are often collectively referred to as dynamic spectrum access (DSA)[[3]](#footnote-4) techniques. Although there are numerous specific instantiations of these techniques with a range of different names, a common feature is that they all typically take advantage of time-based changes in spectrum occupancy by incumbent users—that is, allowing access to spectrum that may not be in use in all geographic areas, all the time.

We’re calling these newer approaches ‘non-traditional’ sharing techniques, as they sit outside the broader category of traditional sharing approaches (Figure 1 illustrates this distinction). Non-traditional (including dynamic) sharing techniques are the focus of this paper.

1. Contemporary dynamic sharing approaches are distinct from more traditional, day-to-day approaches to facilitating shared access to spectrum.



Until recently, there have been very few implementations of non-traditional sharing arrangements of any significant scale. Specific measures such as dynamically occupying the so-called ‘white spaces’ in television broadcast areas have been mooted—even urged by some sectors of industry—but for a range of reasons implementation of these measures have failed to take flight either internationally or domestically.

Recently, however, initiatives such as the US’s Citizens’ Broadband Radio Service (CBRS) arrangements, which involve dynamic sharing between government radiodetermination and wireless broadband services, have shown that such approaches continue to be seen as viable options for sharing under certain circumstances.

## Australian relevance

Non-traditional approaches to spectrum sharing that leverage the dynamic nature of some spectrum use are the focus of this paper. It is timely to look at how some contemporary shared access models might potentially improve the utility of spectrum in Australia. How ‘dynamic’ in nature this sharing is, and to what extent technology and/or regulation will necessarily play a role, are matters for further discussion—indeed how the ACMA might balance regulatory/licensing structures and technology types is a key part of the conversation we want to have.

We have included examples of sharing arrangements in other countries, not to express any explicit endorsement or intention to mirror those arrangements, but to open up a discussion on the fitness for purpose of those arrangements (or any variations that might be conceived) in the Australian spectrum environment.

Most arrangements to date have only been either trials of DSA-type arrangements or simply variations on more traditional approaches to sharing (that is, more static than dynamic). The only truly broad-scale DSA undertaking that has been commercially implemented internationally has been the CBRS, with the formal launch scheduled for September 2019.

Non-traditional sharing approaches described in this paper may not always be the most appropriate spectrum management responses to any given set of circumstances. In discussing these new and emerging approaches to spectrum sharing in this paper, the ACMA remains alert that there are other means that may be of assistance to enabling new deployment models that require access to spectrum.

For example, there has been increasing interest from parts of industry in deploying small private area-based networks (sometime referred to as ‘private LTE networks’), which might be better served through implementation of the ACMA’s proposed [area-wide apparatus licence](https://www.acma.gov.au/theACMA/proposed-area-wide-apparatus-licence) type. These types of deployments may require new approaches to authorisation, noting some such networks are already deployed in some areas such as at mine sites.

In some instances, it might be more appropriate that variations on more traditional means are developed, rather than trying to shoehorn prospective new use cases into a dynamic spectrum access-type arrangement. More broadly, it remains the case that facilitation of spectrum access through the application of traditional techniques will continue to be most appropriate in the majority of circumstances for a long time yet. The concepts introduced in this paper will likely only be appropriate for a subset of spectrum access scenarios, for the foreseeable future at least.

# Issues for comment

The ACMA invites comments on the issues set out in this information paper:

1. Given current momentum in international markets and opportunities for other sharing models offered by 5G technologies, is it timely to develop a more detailed consideration of spectrum sharing opportunities in Australia?
2. Are there recent developments in sharing techniques that industry and the ACMA should be aware of?
3. What are the (potentially new) use cases that might benefit from secondary or tertiary access to spectrum and who benefits?
4. What are the potential challenges/impediments to the introduction of DSA in Australia—technical, industry capability, licensing and regulatory frameworks?
5. Facilitating spectrum access (e.g. monitoring, control, reporting, assignment) logically necessitates involvement from both government and industry. Are there any early thoughts on what an appropriate industry/government balance might look like? How might the ACMA facilitate shared spectrum access? How might the ACMA address this?
6. What is the relevance of DSA examples such as the US Citizens Broadband Radio Service (CBRS) arrangements to the Australian spectrum environment? Are there other or lower cost alternatives to help inform access control and assignment systems of incumbent usage in a timely manner?
7. Under a multi-tier DSA approach:
   * + Tier 1 (highest priority or incumbent) users would be expected to share spectrum with lower tier users when not being utilised. Are there any specific licensing and/or regulatory arrangements that might incentivise the tier 1 users to release unutilised spectrum for lower-tier access?
     + Tier 2 and 3 users need to vacate spectrum (regardless of their service type or communication urgency) for tier 1 users to operate seamlessly. Do we see potential services/service types in Australia who would fit the criteria of second or third tier users? What are the incentives to adopt a conditional (lower priority) spectrum than an unconditional (full access) spectrum?

# Introduction

Spectrum sharing is fundamental to effective spectrum management and a key tool in maximising its benefits. Effective sharing allows spectrum uses and users to coexist (that is, achieves coexistence) permitting both uses/users to operate. Coexistence of spectrum uses/users is the desired outcome and the objective of sharing and contributes to maximising the overall utility of the spectrum.

## What is spectrum sharing?

Spectrum sharing is primarily concerned with optimising spectrum utility by both facilitating access by multiple users and minimising mutual interference. Wanted and unwanted radiofrequency emissions—often referred to as ‘signals’ when the emission is intended—cannot be entirely isolated. For example, they cannot be contained on a single frequency or range of frequencies or within a defined geographic area. Emissions therefore ‘leak’ into adjacent frequencies and adjacent areas (or otherwise interact with other emissions), albeit at very low levels in some cases.

When a receiver receives its desired, or ‘wanted’, emission at the same time as an unwanted emission, interference occurs. If the unwanted emission does not affect the receiver’s ability to properly interpret the wanted signal, and the desired communication is possible, the interference level has been adequately managed, and coexistence between the wanted and unwanted emissions—noting that one receiver’s unwanted emission is another’s wanted emission—is achieved. However, if the ability of the receiver to interpret the wanted signal is compromised to the extent that the wanted signal cannot be adequately reproduced by the receiver, the interference can be detrimental, so coexistence has not been achieved.

Spectrum sharing is the process or technique for managing interference so the spectrum resource can be utilised by multiple uses (services and/or applications) and individual users (individual licensees, assignments), while maintaining coexistence between those users.

In simple terms, the entire radiofrequency spectrum is shared through a range of technical and administrative arrangements. As outlined in Recommendation ITU-R SM.1132-2[[4]](#footnote-5):

‘Utilisation of the radio spectrum is dependent on the dimensions of frequency, spatial location, time and signal separation. Any sharing of the spectrum will have to take into account one or more of these four dimensions. Sharing can be accomplished in a straightforward fashion when any two of these dimensions are in common and the third and/or fourth dimension differs by a degree sufficient to ensure that all the involved services or stations (two or more) can operate satisfactorily.’

As with all forms of resource sharing, spectrum sharing requires some degree of compromise between multiple uses or users sharing the spectrum. This need for compromise, which can range from major to insignificant, is one of the key causes for tension within the spectrum management process.

An example of a major or material compromise is geographical separation, where one use or user is required to be located at a not inconsiderable distance away from the other to ensure coexistence is maintained. An example of a simple compromise might be where a frequency is assigned following established rules. While sharing is generally applied through specific parameters applied to a licence, these parameters do not typically have a material impact because they are fit for the intended purpose.

In such cases, sharing takes the form of technical and/or operational restrictions, on one, some or all parties involved. These restrictions identify and put in place measures that manage the potential for interference between uses and users. Effective sharing through limiting use/users to certain technical and operational parameters allows spectrum uses and users to coexist, which is the primary objective of spectrum sharing. This can lead to increased spectrum utilisation but importantly does not imply that there will be no interference between different uses/users.

There is always a balance to achieve to optimise efficient spectrum utilisation. An objective of ‘no interference[[5]](#footnote-6)’ is likely to result in an overly conservative access framework which fails to yield the full benefits of sharing, but interference also needs to be managed in a way that the practical usefulness of the available spectrum is not compromised. Also, the tolerance to interference can reasonably be expected to differ between primary/incumbent and secondary users in some cases, for example when the primary use is mission or safety-critical but itinerant and sporadic in nature.

This heterogeneous distribution of burden is put into effect by a form of ranking, tiering or prioritisation, which may be informed by government policy, operational criticality or market settings.

## How sharing is achieved

Different sharing models are underpinned by varying combinations of technical and regulatory concepts and techniques. The aim of these sharing techniques is not to eliminate interference but to manage it such that the resulting operating environment is both known and understood by all parties and is adequate for the intended use(s) of the shared environment.

Sharing techniques are intended to sufficiently isolate uses or users of the spectrum through controlling one or more broad dimensions:

* Frequency domain sharing—separation of uses/users based on operating frequency (including in-band and out-of-band emissions). This is implemented through varying combinations of planning segregation and technology, for example, through filtering radiocommunication transmissions (to constrain the transmitted level of out-of-band emissions—‘leakage rejection’) and/or receivers (to constrain the received level emissions from other frequency-adjacent transmitters—‘selectivity’).
* Geographic domain sharing—geographic separation of different devices spatially through both siting (distance separation), environmental shielding (for example, terrain and other clutter such as buildings, trees) and diversity of the radiated signal through controlling parameters such as transmission power and antenna characteristics (including height, directivity and azimuth).
* Time domain sharing—separation of different uses/users by time (users are permitted to transmit only at certain times intervals).

Signal sharing—the use of signal characteristics and other technology-aided techniques to enable the use of the same spectrum by different uses/users (for example, spread spectrum techniques).

These techniques are employed across the various functional levels of the spectrum management process to facilitate spectrum sharing:

* Planning level: Via the design of frequency band arrangements (for example, Australian Radiofrequency Spectrum Plan (ARSP), band plans). Here, spectrum uses are generally planned in the broad frequency domain based on their broad usage category such as radiocommunications ‘service type’ (for example, fixed, fixed satellite services) or application (for example, point-point, point-multipoint, coordinated earth stations, ubiquitous earth stations).
* Assignment and licensing level: Through coordination of individual frequency assignments and the issuing of licences (that is, focussing on ‘users’) based on technical rulesets defined engineering processes. Rules defined in documents developed by the ACMA such as Radiocommunications Assignment and licensing Instructions (RALI) are existing examples of the application of frequency and geographic domain sharing at the assignment and licensing level.

Operational level: On a technology and operational rules basis that achieve signal sharing focussed on device characteristics (for example, class licences, standardised devices).

Figure 1 touched on where these differing levels of involvement in facilitating sharing fit within the broader sharing concept. They each draw, to varying degrees, from the range of different sharing domains. Frequency-based sharing is a common element in all the above levels and is a focus at the planning level.

At the assignment and licensing level, the combination of geographic and frequency-domain separation has most commonly been applied to facilitate spectrum sharing, through coordination. This has traditionally been the purview of the regulator, either directly or through delegation to accredited industry professionals.

Time domain and signal sharing are not often applied at the assignment level, given the (in general) technology neutrality of these processes. These techniques are instead generally applied at the operational level by users themselves, albeit in many cases unwittingly as the access techniques in these cases are most often built into device standards (for example, techniques based on time-division and code-division multiple access schemes).

## 

# New approaches to sharing

Spectrum sharing techniques have continued to evolve with technology developments and in response to an ever-increasing spectrum scarcity. A key concept in many new and emerging sharing approaches is that they utilise information on actual spectrum use rather than authorised/licensed use.

To do this effectively, these approaches usually need to be aware of the local radiofrequency environment to some extent and be able to react to changes in that environment in a timelier manner than traditional licensing/authorisation processes allow.

These new sharing techniques are often collectively referred to as DSA. While there are various specific implementations with different names, all typically take advantage of time-based changes in spectrum occupancy by incumbent users—that is, allowing use of spectrum that may not be in use in all geographic areas, all the time.

In practice, these newer approaches have relied on a hierarchical approach for access to spectrum.

Lower-tier users must make way for higher-tier users wherever and whenever that spectrum is required for use. Clarity on tier rights is important as it provides confidence to each user about the terms of access, which allows an assessment of whether the access rights on offer are suitable to their needs. In many cases such a model might not provide the level of certainty needed to meet a lower-tier user’s business requirements, in which case a more traditional licensed access to spectrum would be more appropriate.

Tiered sharing works best when accommodated uses are complementary, rather than competing, in nature—for example, when one user’s spectrum access is intermittent (often the top-tier user) and the lower-tier user can accept that in some circumstances they will need to alter their operations in some way (including to the possibility of ceasing operation all together) for some period of time.

The current global scarcity of DSA implementations likely reflects technology limitations, spectrum availability factors and an inability for those models to meet user expectations/requirements.

## DSA framework

Dynamic spectrum access requires a set of rules and a decision-making process that can operate rapidly with little or no intervention by the regulator. While there are various specific implementations of the DSA concept, each requires a framework that identifies a:

* hierarchy of spectrum users (and in some case a mechanism to determine/allocate rights to be part of the various hierarchal layers)
* set of rules articulating the rights and responsibilities of those users in a hierarchy
* mechanism(s) to determine actual spectrum use (as opposed to authorised/licensed) that is, a way to understand the current spectrum environment

dynamic feedback or control system to implement changes to spectrum use by users based on the rules and the current spectrum environment.

These elements influence when a DSA approach may make sense. Some key considerations are:

1. Is there a viable hierarchy of spectrum users that are complimentary to each other? For example, is one use/user infrequent and/or itinerant basis on one of the users in the hierarchy?
2. How is hierarchical status determined? In other words which user is the higher tier user?
3. What rights do each tier of user have? For how long does a lower tier operator have to switch off or change their operation to permit the higher tier user access? Should there be a limit to how often and for how long a user has to ‘yield’ to a higher user?
4. How is the system made aware of actual spectrum usage? For example, different options such as spectrum sensing and geolocation reporting/databases, are available.
5. How is the feedback loop implemented? For example, different options such as direct human intervention and automated, computer access systems, are possible.
6. Who pays for the system? Governments? Regulators? Users? A third-party spectrum access broker/facilitator?

Is this approach, on balance, economically viable? Costs might not be just monetary; they could also come in the form of administrative burden, reduced certainty and/or flexibility for users and reduced spectrum utility for lower tier or users. In some case a more traditional sharing model might make more sense.

There are multiple approaches to dynamic sharing implemented or contemplated around the world. Examples include:

* TV whitespace systems (multiple variants in the US and UK for example)
* CBRS in the US

various Licensed Shared Access (LSA) models in Europe.

These all employ various combinations of the broad dynamic access-enabling schemes described in the following sections, being:

* tiered access models (including a pre-emption variation on this model described below)
* spectrum sensing models

knowledge base-enabled models involving incorporation of geo-location or databases.

In practice, dynamic sharing is most likely to be implemented through a combination of these models and the below sections describe possible combinations and linkages between them.

## A generic hierarchical or tiered access model

A tiered access model sets out a hierarchical structure which defines users as being primary or secondary (or even tertiary). Access rules are implemented in a system which includes a database that contains technical and operational characteristics which determine the operational ‘footprint’ for each user. This spectrum footprint is derived from a range of metrics such as the amount of spectrum accessed, likely duration of operation, location and physical device characteristics (such as transmitter powers, antenna parameters). Users are assigned access to spectrum by the system in accordance with their assigned priority level. Multiple access tiers can be defined, including:

1. Incumbent users have the highest priority of access. These services will typically be licensed under normal licensing conditions and, under the rules governing secondary access, should not be adversely impacted by shared access by other users.
2. Highest priority of secondary access. Must alter (or cease) operation upon the detected operation of an incumbent user.

Lowest priority of access. No interference can be caused to priority 1 and 2 users, and no protection will be afforded from interference from priority 1 and 2 users as well as other tier 3 users operating within their licence conditions.

If spectrum is not needed by one tier of user, it can be accessed by another based on the established rules of the DSA system.

Under this model, the rules are implemented within an automated system that includes a database to record system parameters (in a particular location and operating parameters) to manage interference potential between prospective access seekers at the various system tiers. Managing spectrum use is achieved through the systems issuing commands to devices operating in the DSA system to operate in a certain way (for example, switching off when and where a higher tier user is present).

To determine where the actual spectrum is used (as opposed to where it could be used) these systems may utilise a geolocation reporting system that provides location (and use) data to the system to permit the access rules to be dynamically applied. Some approaches might also use a sensing network (see *Spectrum* s*ensing* discussion below) to detect the presence (or otherwise) of higher users to inform the systems decision-making process (such as a central controller for the area). Protection of priority 1 users may be reinforced by the application of exclusion zones in areas where interference potential to tier 1 users from tier 2 or 3 users is considered to be too high. This is depicted in Figure 2.

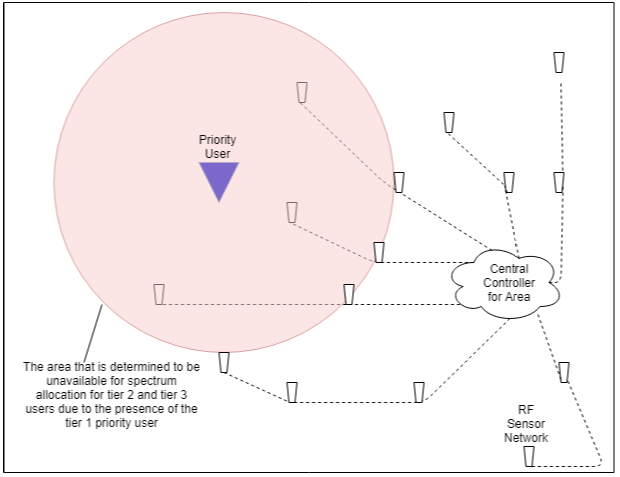
Combining real-time device geolocation with sensing networks allows spectrum occupancy to be determined in real time, providing for more responsive sharing and more efficient use of spectrum.

This model is supported by the deployment of infrastructure, such as a dedicated spectrum access system (SAS) and associated database (and potentially a complimentary fixed sensor network, as is the case in the US), and as such is potentially costlier to implement than a simple cognitive device-based sensing model).

Issues that need to be considered when implementing this type of approach include:

* responsibility for the development and deployment of the system
* degree of automation or human decision making in the system
* financial management and ongoing system support
* quality standards, for to ensure priority 1 users can be protected at all times.

1. Integrating spectrum sensing in a tiered sharing system.



### Pre-emption model

This model is a variation on the generic tiered sharing model discussed above that has been conceived by the ACMA as an alternative approach for when tier 1 use characteristics are not, or cannot be, sensed or contained in a database. It draws from the tiered access model in that there is an assumed tier 1 incumbent licensed user, but further assumes there is no knowledge base associated with that user’s operations. Logically this might apply in the case of spectrum use that is itinerant or sporadic in nature, such as some government applications.

Pre-emptive shared access offers a relatively simple implementation model, as it does not require any complementary infrastructure or databases. It classifies users hierarchically in a similar way to that of a tiered approach, where the tier 1 service would likely be an existing incumbent licensee and tier 2 (or lower) users would be secondary access seekers.

As with the tiered access model, secondary access would be entirely contingent on meeting the operational requirements of the primary user and lower tier users may need to alter or cease operation for periods of time in order to prevent interference to primary users. Presence of primary users might also bring temporary protection zones into effect.

The principle difference of this approach is that awareness of the presence of tier 1 users would be informed through a simple notification process, where tier 1 users provide advance notice of their intention to operate in each area on a given frequency(s). The notification process and actions/mitigations to be taken by lower tier users subject to notification would be specified in licence conditions for secondary access. A notification ‘portal’ could be established as a single point of contact to avoid administrative burden on the tier 1 user.

This approach best lends itself to cases where tier 1 access is itinerant and infrequent within a given area and lower tier access is supported by fixed infrastructure (for example, fixed networks or mobile networks served by base stations, as opposed to nomadic or ambulatory systems).

In many cases an occasional, localised reduction in capacity or coverage on certain frequencies might not be tolerable for potential secondary access seekers. This model would therefore not be suitable for them and they should seek more traditional licensed access. However, this access method has the advantage of being simple and would not require supporting infrastructure such as fixed sensor networks or databases to manage access and might be attractive to some access seekers that can tolerate occasion loss of access.

## Spectrum sensing

The core premise of a sensing model is that devices or supporting infrastructure can detect which communications channels are in use and which are available to be accessed in real time. Channel availability varies by location—a channel that may be in use in one location might be available at another location. Some models have a learning function which can determine which channels are more frequently available for a given location and sets weights its scanning algorithm accordingly.

Once free channels are identified, channel allocation can either be done cooperatively, through active negotiation with other nearby devices operating on the same platform (by either device-to-device or network interfaces, depending on the model used), or independently through a simple passive sense-and-avoid approach. Spectrum sensing does not necessarily rely on any external knowledge base (for example, database) to obtain information on spectrum usage patterns, rather it relies purely on technology. In some models it can certainly be augmentedby an integrated knowledge base (as described above in the discussion on *a Generic tiered access* model).

Some spectrum sensing solutions comprise a network of dispersed sensors to ascertain spectrum occupancy over a larger geographical area. Input from sensors is fed to a central aggregation point where a holistic picture of spectrum/space availability is derived. This approach is useful in sharing scenarios where incumbent users transit across wide areas and/or involve high power or directional transmissions which cannot accurately be described by localised, non-networked sensors.

In other, less infrastructure-intensive models, the sensing may be done at the device level. The most well-known application of this is the Cognitive Radio System (CRS) concept. While this concept is both broad and complex and can incorporate numerous techniques of managing spectrum access, one commonly known technique involves device-borne sensors dynamically scanning the local spectrum environment to find available channels. This carries what is known as the ‘hidden node’ problem where sensing is localised and therefore channel occupancy (or location even, in mobile implementations) at the receive end of links can’t be ascertained—this can, in part at least, be mitigated by deploying some form of knowledge base to devices.

## Geolocation/database

This is a well-established dynamic spectrum access model that involves the use of central databases that record individual device locations to manage access in a way that minimises interference to incumbent and (in some cases) other secondary access seeking users.

Under a typical implementation of this model, a database typically holds information pertaining to the location, operating parameters and protection requirements of incumbent services. This information is referred to by prospective access seekers in determining which spectrum spaces could be accessed while meeting incumbent protection requirements.

Devices can dynamically modify their operating parameters to protect incumbent services, including manipulation of transmitter powers, operating frequencies, antenna steering/positioning etc.

## Decentralised access control

The use of databases, sensing networks and pre-emption arrangements assume some sort of central access controller, which may be either an industry third-party provider or a government/regulatory function. This reflects the general trend of DSA considerations internationally, whereby governments prefer a ‘managed’ access regime over delegation of access decisions to the device level. Logically, this type of approach is most conducive to optimal interference management and spectrum efficiency.

Nonetheless consideration has previously been given to uncoordinated device-centric DSA technologies—again, the abovementioned CRS concept in its purest form was initially an example of this approach. Such approaches might have merit in, say, LIPD frequency bands, where something like a ‘token passing’ access scheme between otherwise uncoordinated users (similar to a MANET and a blockchain in digital currency terms—see example in the box below) might be a useful way of optimising access in a decentralised framework.

### Example of a decentralised DSA architecture: Application of blockchains

At a high level, blockchains are mechanisms of creating artificial scarcity. It is a kind of distributed database or ledger, and a way to keep track of information shared among multiple parties. There is no single party to control this secure and decentralized form of database. This makes it different to other dynamic spectrum access, such as TV white space which requires trusting third parties to administer their database. This highlights the unique feature of blockchain as a dynamic distributed spectrum management system requiring a dynamic distributed database.

There are two primary types of distributed ledger networks: Public and permissioned. In public (permission-less) blockchain systems such as Bitcoin, anyone can join the network. Permissioned blockchains limit participation to identified users. While this restriction simplifies security and governance, it could make it easier for one or a small number of participants to exercise control.

The potential for blockchains to be applied to dynamic spectrum access has recently become a topic of interest. Four primary categories of shared access might be considered:

* unlicensed (primary non-cooperative)
* secondary markets (primary cooperative)
* opportunistic (secondary non-cooperative)

cooperative sharing (secondary cooperative).

The term ‘primary sharing’ in this case means that all users have equivalent rights to access the spectrum, as is the case, for example, in unlicensed bands (or in Australia, bands listed in the LIPD class licence). In contrast, a secondary sharing regime implies a hierarchy of rights, where incumbents/primary users have superior rights to spectrum entrants/secondary users. TV white spaces, CBRS and LSA are all examples of this kind of rights-based relationship. Cooperative sharing means that ex ante agreements have been struck between the sharing parties regarding sharing. Secondary markets that involve voluntary exchange can be thought of as cooperative sharing. Finally, in non-cooperative sharing, users do not coordinate their use ex ante. Whether a public or permissioned distributed ledger is used might depend which of the above sharing scenarios are sought.

In France, the Agence National des Fréquences (ANFR) commenced a trial of blockchain for spectrum management in late-2018 with the aim of understanding the opportunities and risks of embedding this approach in new access technologies. The scope of this project was limited to frequency bands that can be used without authorisation, such as the 2.4 GHz and 5 GHz bands and bands between 470 MHz and 789 MHz that are used for short-range devices such as wireless microphones in Europe. They utilised a permissioned ledger rather the public version of blockchain.

## Regulatory considerations

Dynamic access informed by spectrum sensing carries with it a range of regulatory considerations. As secondary devices will (presumably) access parts of spectrum that are licensed, there are challenges for spectrum managers on how to manage secondary access at a regulatory level. For example, in Australia, frequency bands that have been designated for spectrum licensing are subject to very prescriptive legislative provisions and constraints regarding access by non-licensed users.

Regulations that facilitate secondary access necessarily need to consider the heterogeneity of the status of different frequency bands and licensing constructs. Failure to do so can result in a risk of causing harmful interference to primary or licensed spectrum users at a practical level, or compliance action and/or legal recourse at a regulatory level.

For example, if a second-tier device occupies a channel that is accessed by a primary incumbent licensed user on an occasional basis, the model must ensure that that device vacates spectrum in a timely manner when the incumbent seeks to access that channel.

So, there is a clear role for regulation in setting up these processes. If implemented well, there is an opportunity to reduce the ongoing spectrum management burden for regulators. For example, DSA could in some cases render regulators’ frequency assignment and coordination roles redundant if the DSA technology can perform this function adequately. Spectrum sensing capabilities, for example, may dynamically take the place of traditionally static coordination processes, or operational databases could, if appropriate, act as a proxy for, or supplement to, or static knowledge bases such as the register of radiocommunications licences.

# International developments

This chapter describes sharing initiatives that are being, or have been, considered or implemented internationally, either by individual administrations or regional bodies. While these initiatives may differ significantly to options that might be contemplated in Australia, the sharing frameworks that have been developed can help inform domestic considerations.

## Regional bodies

### European Conference of Postal and Telecommunications Administrations (CEPT)

In February 2014, CEPT’s Electronic Communications Committee (ECC) published ECC Report 205[[6]](#footnote-7) on LSA in Europe. This report set out rules and conditions for sharing between prospective and incumbent users based on technical and operational characteristics. Under this proposal, all parties currently afforded or seeking access would need to be licensed before shared access to the band would be permitted.

The document highlighted that licensees require a degree of certainty of spectrum access in order to provide incentives and secure investments in network and equipment.

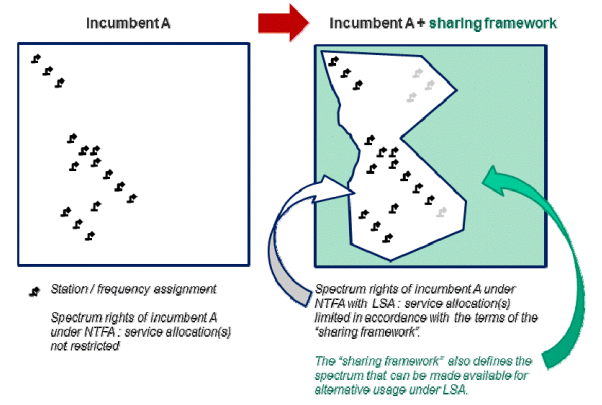
Figure 3 demonstrates this concept: The discrete black-coloured sites are registered incumbent stations and grey sites are intended for future use by incumbents. Areas available for secondary access are green-shaded (this example only pertains to operation on a specific frequency at a specific timesharing can be implemented by exploiting any combination of the time, frequency and spatial dimensions).

The report described an LSA repository (which is a knowledge base of incumbent users’ technical and operational parameters and protection requirements, including registered potential future use requirements) and an LSA controller which manages shared access to spectrum in available areas (for example, those green shaded areas in the below example).

Information in the repository is used to determine available spectrum/spaces and define access conditions based on incumbents’ protection requirements. This repository is updated on a dynamic basis to reflect the continuously changing sharing environment. An LSA controller can interface with one or multiple LSA repositories as well as with multiple LSA licensees’ networks.

This is a relatively mature technical solution that has precipitated the development of several technical specifications by the European Telecommunications Standards Institute (ETSI) and 3rd Generation Partnership Project (3GPP)[[7]](#footnote-8), which include descriptions of the repository and controller relationship.

1. ECC LSA framework (ref: ECC Report 205[[8]](#footnote-9))



### Asia-Pacific Telecommunity (APT)

In 2016, the Asia-Pacific Telecommunity’s (APT’s) Wireless Group (AWG) developed the *Authorized/licensed shared access as a national solution to access spectrum for IMT*[[9]](#footnote-10),[[10]](#footnote-11)report. The two main objectives of this report were:

* to provide a general analysis of ASA/LSA arrangements, including how they fit with (individual countries’) regulatory framework(s) on the use of spectrum and current practices in terms of spectrum management and management of frequency authorisations

to explain how ASA/LSA might be implemented in frequency band currently allocated to the mobile service bands.

A specific sharing model was proposed that is similar to the CEPT model in that it comprises a range of shared access knowledge base repositories and controllers and explains the relationships and interfaces between those components. However, the scenarios that the model might suit are largely based on situations where incumbent use is static and predictable and might not fully cater for scenarios where incumbent use cannot be predicted or measured, such as highly dynamic use by itinerant government services.

## National initiatives

### Spain

In 2014–2015, the Ministry of Industry, Energy and Tourism of Spain (SETSI) commissioned a study to identify spectrum availability for mobile broadband services in Spain in the 2300–2400 MHz (2.3 GHz) band based on a shared basis with programme-making and special events (PMSE) services[[11]](#footnote-12). PMSE based services are primarily used for electronic news gathering (ENG).

The final stage of this study was a live demonstration of sharing between mobile services and incumbent PMSE video links operating in the 2.3 GHz band at the GSMA Mobile World Congress, Barcelona (March 2015). Exclusion and protection zones around PMSE services were prescribed to ensure protection from sharing access seekers.

The demonstration, which comprised a cordless camera equipped with a video link operating co-channel (with some geographic separation) with a single IMT system, showed that as a worst case (mutual antenna beam coupling), 95 per cent IMT system availability could be achieved with a 3 km radius exclusion zone in urban areas. Under a more realistic case scenario (20 degrees off-axis coupling) an exclusion zone of around 1 km radius was shown to be required.

### France

In 2016, the French regulator commissioned a trial to demonstrate how commercial 2.3 GHz LTE networks could be switched in and out to accommodate access requests from incumbent users while continuing to maintain a useful broadband service. Access by mobile broadband service providers was controlled by CEPT’s LSA repository (database) and controller arrangement (as described in the *International regional bodies* section). The repository stores information about incumbent users, including technical and operational parameters and protection requirements. The LSA controller manages access to spectrum, taking these parameters and protection requirements into account.

The intent of the trial was to validate the CEPT LSA architecture and demonstrate the ability to integrate the various elements and interconnections, most notably the repository and controller.

### Italy

In 2015, the Italian Ministry for Economic Development, in conjunction with the Joint Research Centre of the European Commission, undertook a pilot project to trial dynamic spectrum access by wireless broadband in the 2.3 GHz band[[12]](#footnote-13) in indoor environments. The purpose of the project was to assess coexistence potential between LTE wireless broadband systems and other co-frequency (mainly fixed) services. Coexistence was assessed as feasible for indoor LTE networks but more difficult for outdoor deployments without the application of additional, non-standard mitigation techniques such as power or siting restrictions.

The framework for sharing was based on an LSA approach which involved definition of specific technical and operational conditions for access seekers and protection zones around fixed service receivers. In concluding that co-existence between LTE and fixed services under tiered LSA arrangements was feasible, it was also proposed that these arrangements could be expanded into other frequency bands such as in 3400–4200 MHz, where larger bandwidths might be required for technologies such as 5G wireless broadband.

### United Kingdom

As recently as December 2018, the UK spectrum regulator, OFCOM proposed spectrum sharing approaches in several frequency bands. These approaches use methods involving static coordination with existing services to avoid interference, which is more in line with the traditional idea of sharing than contemporary dynamic sharing models.

Prior to this, in 2015 OFCOM had proposed high-level framework for spectrum sharing, which included non-traditional methods of spectrum sharing such as DSA, among other potential spectrum sharing methods[[13]](#footnote-14). The framework was intended to assist with the identification of how and where sharing spectrum might be feasible, by considering three key elements:

* characteristics of use for both incumbent and prospective users to inform an initial view on sharing potential and any tools that may be useful
* potential barriers to sharing, noting the liberalisation of licences and secondary market tools such in the UK

available regulatory tools and technology that might enablers that match the characteristics of use and barriers to facilitate new and/or more intense sharing.

Following industry input and taking into consideration the above three elements, the 3800–4200 MHz band was identified as a candidate for sharing between wireless broadband services and incumbent fixed links and satellite earth stations.

In 2015, OFCOM announced a proposal to implement access to TV white spaces in the 470–790 MHz band. This involved making spectrum that is allocated to TV broadcasting services available in locations where they are not being used. Spectrum for TV broadcasting services goes unused in some locations because high-power TV broadcast transmitters using the same frequency need significant geographical separation between their coverage areas to avoid interference.

Spectrum in these areas that would normally go underutilised can be accessed by devices which are designed to occupy frequency segments that are not used by broadcast services or Programme Making and Special Events (PMSE) services within a given area.

Access to white spaces is permitted dynamically through a central controller that refers to a database which contains information on the locations of TV broadcasting and PMSE services, as well as technical constraints on/operational guidelines for TV white space devices. These constraints and guidelines pertain to geographical locations, transmission powers, frequencies and times where TV white space devices can safely be deployed without adversely affecting TV or PSME reception.

### United States

The National Telecommunications and Information Administration (NTIA), who manage access to government-held spectrum in the US, initially trialled dynamic sharing in the 3550–3700 MHz band[[14]](#footnote-15) prior to considering more permanent commercial arrangements. Early analysis showed that large exclusion zones would be required to protect incumbent radar systems from typical macro-cell wireless broadband systems (which were the most likely service to seek access to that band), which would compromise the utility of those bands for wireless broadband deployments in coastal areas.

In 2015, the FCC proposed new rules based to facilitate lower power small cell wireless broadband deployments that meant the necessary exclusion zones could be reduced by 77 per cent. This was initially the subject of a trial and ultimately led to what is now known as the CBRS which enables sharing between government and commercial users under a three-tiered sharing framework.

Under the CBRS, access is controlled by an SAS which automates spectrum allocation on a priority/occupancy basis. Secondary access is provided for TD-LTE services in the band (3GPP band 48) which includes 3GPP bands 42 (3400–3600) and 43 (3600–3800 MHz). 10 MHz blocks are automatically assigned on request and priority access is given to indoor deployments as this most readily enables co-existence with both incumbent (primary) and secondary users.

Users requesting access must report their location to within 50 m (horizontally) and 3 m (vertically). The SAS uses terrain data and propagation modelling to calculate the potential interference impact to other users and assigns or denies access accordingly. Additional outdoor sensors are also used to assess potential for interference into prospective wireless broadband from radars, which are generally itinerant in nature.

The scheme defines three tiers of shared access:

1. Incumbent Defence (naval) radar systems operating under the radiolocation service are the most common Defence use of this band and receives the highest priority. Areas of operation are mainly coastal but involve very high-power transmissions which can impact land-based services some distance inland. Fixed Satellite Service (FSS) and grandfathered terrestrial wireless broadband services comprise the remaining tier 1 users.
2. Priority access is given to this second tier of user, having access to a 10 MHz block in defined geographical areas for a three-year period. Access is restricted to seven contiguous blocks (that is, 70 MHz of the total 150 MHz available).

General Authorised Access (GAA) is most common and lowest priority access to the band. GAA access is permitted to the entire 150 MHz but receive no interference protection from other CBRS users.

This hybrid framework is intended to optimise licensing approaches to account for local environmental factors and, supply and demand. Where demand for spectrum access is low, the GAA tier provides a low-cost entry point to the band, similar to class licensed access in Australia. In geographic areas where demand for spectrum is high, three-year priority access licenses are awarded through price-based allocations.

In 2018, following a review of trial results and industry input, the FCC made some changes to the CBRS spectrum sharing rules which included enabling larger licensing areas. So, the new rules would enable both larger mobile wireless providers and smaller operators servicing industrial applications. The FCC also modified the emission limits to enable wider bandwidth applications as a means of promoting the deployment of new and emerging technologies. The FCC intends to put in place authorisation arrangements for full commercial access to the band under CBRS sometime this year.

The US has also implemented a spectrum sharing arrangement in their TV white spaces, which was finalised in late 2010. The FCC arrangement makes access to unused TV broadcast spectrum on an unlicensed basis (comparable to the class licence system in Australia), on the basis that TV broadcast and wireless microphones would continue to be protected. This concept is described in the above section on arrangements in the *United Kingdom*).

# Domestic considerations

The common premise of most sharing models considered to date is that entities responsible for managing spectrum access by secondary access seekers have some degree of knowledge of usage patterns. The underlying idea is that an access-seeking user can ‘avoid’ or ‘work around’ incumbent users, through interference avoidance techniques based on spectral, geographic or time separation.

These traditional sharing methods do not cater for scenarios where incumbent use cannot be predicted or measured, such as highly dynamic/itinerant services that are authorised by wide area licenses. In the case of the CBRS example, this is partially overcome through the deployment of sensor networks to provide real-time information on tier 1 use and inform the access controller accordingly. While this has been deemed an appropriate approach in the US environment, the infrastructure cost would unlikely be justifiable in a relatively small market such as Australia.

A potential variation on CBRS might involve replacing sensing with pre-emption, for example, in which case incumbent users would be furnished with the regulatory tools to be able to pre-empt access to frequencies and/or areas at their discretion. This pre-emption would be the ‘exception’ case (although this is not to suggest it would be irregular); the ‘default’ would be that secondary access seekers would be able to deploy in the absence of any pre-emption notification.

Such a model enables secondary access-seekers to deploy networks across the frequencies identified for shared access but allow incumbent users to pre-emptively clear that use within the areas/frequencies they require, when they are required. This aligns with the pre-emptive sharing model which relies on active communication (notification) between the incumbent and access-seeking services, rather than passive observance of protection requirements and knowledge of incumbent users’ operating characteristics.

This model best lends itself to scenarios where the primary service is itinerant, sporadic and infrequent in nature, in terms of both geographic location and frequency. Such users might hold spectrum on a contingency basis for often nomadic platforms that might not necessarily be used everywhere or all the time. A sharing arrangement would not be intended to diminish this access, rather make better use of the unused spectrum/spaces.

Under this example, in some cases it might be useful to identify certain areas where incumbent use is more intensive or common. These areas may not be available for secondary use given the increased likelihood that these areas will experience high rates of incumbent usage, hence making them practically unattractive for a secondary user for commercial use.

This approach, if managed effectively, would mean that parts of spectrum would be available to secondary access seekers that would otherwise not have been available, and the impact of notifications to secondary access seekers would be limited to specific geographical areas on an occasional (in some, potentially many cases, never) basis.

In the context of fixed or mobile wireless broadband services sharing with itinerant, nomadic or sporadic services, application of a pre-emptive sharing model would mean wireless broadband operators would assume tier 2 status and would be required to alter or cease operation where and when specified when notified of pending use by tier 1 users. A notification portal could be set up to streamline the process and minimise administrative overheads on tier 1 users.

Again, these notes are simply intended to stimulate discussion—at this stage there are not defined plans to implement DSA in Australia. The ACMA welcomes suggestions on the appropriateness of such arrangements in the Australian environment, where the opportunities might exist, what the implementation challenges might be and what roles government and industry might play in introducing such a regime.

# Conclusion

This paper is intended to stimulate consideration of how spectrum sharing models can be developed in Australia.

Sharing in a broader sense is in no way a new concept—all spectrum access is shared in some form or another. In that sense, ‘traditional’ sharing can be considered as access to spectrum facilitated through everyday spectrum management functions such as allocations, licensing, coordination and so on.

More contemporary spectrum sharing approaches such as LSA/DSA, cognitive radio, whitespace devices and the like have in recent times appropriated the term ‘sharing’—these concepts should more correctly be grouped as ‘non-traditional’ sharing approaches. The international case studies floated in this paper fit within that latter category.

Adopting flexible regulatory frameworks, through implementation of measures at both the planning and assignment/licensing level and through enabling technologies and protocols that provide for negotiating access to spectrum directly between users, might help bring about the introduction of these non-traditional sharing approaches. This could unlock previously unrealised opportunities for improved spectrum utilisation.

The ACMA acknowledges that spectrum sharing has design and implementation challenges and there is a significant body of work to follow if we are to go down this path. However, we hope that current international developments—and this paper more broadly—can lead to a wider discussion on how more forward-thinking approaches might provide additional flexibility in the management of/access to spectrum.

# Invitation to comment

## Making a submission

The ACMA invites comments on the issues set out in this information paper.

* [Online submissions](http://www.acma.gov.au/theACMA/Consultations/Consultations) can be made via the comment function or by uploading a document. Submissions in Microsoft Word or Rich Text Format are preferred.
* Submissions by post can be sent to:

The Manager

Spectrum Planning and Engineering Branch

Australian Communications and Media Authority

PO Box 78

Belconnen ACT 2616

**The closing date for submissions is COB, 27 September 2019.**

Consultation enquiries can be emailed to freqplan[@acma.gov.au](mailto:xxx@acma.gov.au).

Publication of submissions

The ACMA publishes submissions on our website, including personal information (such as names and contact details), except for information that you have claimed (and we have accepted) is confidential.

Confidential information will not be published or otherwise released unless required or authorised by law.

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[*Privacy and consultation*](https://www.acma.gov.au/theACMA/About/Corporate/Accountability/privacy-and-consultations) provides information about the ACMA’s collection of personal information during consultation and how we handle that information.

Information on the *Privacy Act 1988* and the ACMA’s privacy policy (including how to access or correct personal information, how to make a privacy complaint and how we will deal with the complaint) is available at [acma.gov.au/privacypolicy](http://www.acma.gov.au/privacypolicy).

1. A more complete reference to ‘sharing’ should be ‘sharing and compatibility’ to be consistent with established international (i.e. ITU) terminology. In that framework, ‘sharing’ refers to in-band coexistence while ‘compatibility’ refers to adjacent band coexistence. However, for readability, the term ‘sharing’ will be used in this document but should be read as referring to both in band and adjacent band considerations. [↑](#footnote-ref-2)
2. See [ACMA website](https://web.acma.gov.au/rrl/register_search.main_page). [↑](#footnote-ref-3)
3. Dynamic Spectrum Access has been referred to in other publications as Dynamic Spectrum Licensing Model and Dynamic Spectrum Licensing Management. [↑](#footnote-ref-4)
4. ITU-R SM.1132-2: General principles and methods for sharing between radiocommunication services or between radio stations. [↑](#footnote-ref-5)
5. Note that from a theoretical perspective, a scenario of completely ‘no interference’ is often impossible to achieve. [↑](#footnote-ref-6)
6. *ECC Report 205 Licensed Shared Access (LSA),* February 2014. [↑](#footnote-ref-7)
7. ETSI TS 103 154—Reconfigurable Radio Systems (RRS); System requirements for operation of Mobile Broadband Systems in the 2300–2400 MHz band under Licensed Shared Access (LSA).

   ETSI TS 103 235—Reconfigurable Radio Systems (RRS); System architecture and high-level procedures for operation of Licensed Shared Access (LSA) in the 2300–2400 MHz band.

   ETSI TS 103 379—Reconfigurable Radio Systems (RRS); Information elements and protocols for the interface between LSA Controller (LC) and LSA Repository (LR)for operation of Licensed Shared Access (LSA)in the 2300–2400 MHz band.

   3GPP TS 28.302—LTE; Telecommunication management; Licensed Shared Access (LSA) Controller (LC) Integration Reference Point (IRP); Information Service (IS). [↑](#footnote-ref-8)
8. Diagram published in: Electronic Communications Committee, [*ECC Report 205*](https://www.erodocdb.dk/document/312), February 2014, p. 19. [↑](#footnote-ref-9)
9. APT/AWG/REP-68 (September 2016), https://www.apt.int/AWG-RECS-REPS. [↑](#footnote-ref-10)
10. IMT stands for International Mobile Telecommunications and is an ITU term for mobile wireless broadband technologies. [↑](#footnote-ref-11)
11. Document FM52(15)05 *Update of Spanish PMSE usage pattern in the 2.3-2.4GHz band,* from the January 2015 meeting in Bonn,can be found [here](https://www.cept.org/ecc/groups/ecc/closed-groups/fm-52/client/meeting-documents/). [↑](#footnote-ref-12)
12. Ministry of Economic Development (Italy: Results from this study and supporting documentation can be found [here](https://www.mise.gov.it/index.php/en/2014-06-27-15-06-15/2033594-licensed-shared-access-lsa-pilot). [↑](#footnote-ref-13)
13. OFCOM consultation work on shared access to spectrum, https://www.ofcom.org.uk/consultations-and-statements/category-2/spectrum-sharing-framework. [↑](#footnote-ref-14)
14. See NTIA, *An Assessment of the Near-Term Viability of Accommodating Wireless Broadband Systems in the 1675–1710 MHz, 1755–1780 MHz, 3500–3650 MHz, 4200–4220 MHz, and 4380–4400 MHz Bands* (Oct. 2010), http://www.ntia.doc.gov/files/ntia/publications/fasttrackevaluation\_11152010.pdf [↑](#footnote-ref-15)