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Research study on spectrum-management mechanisms—overall summary of findings

Research prepared for the ACMA by Analysys Mason

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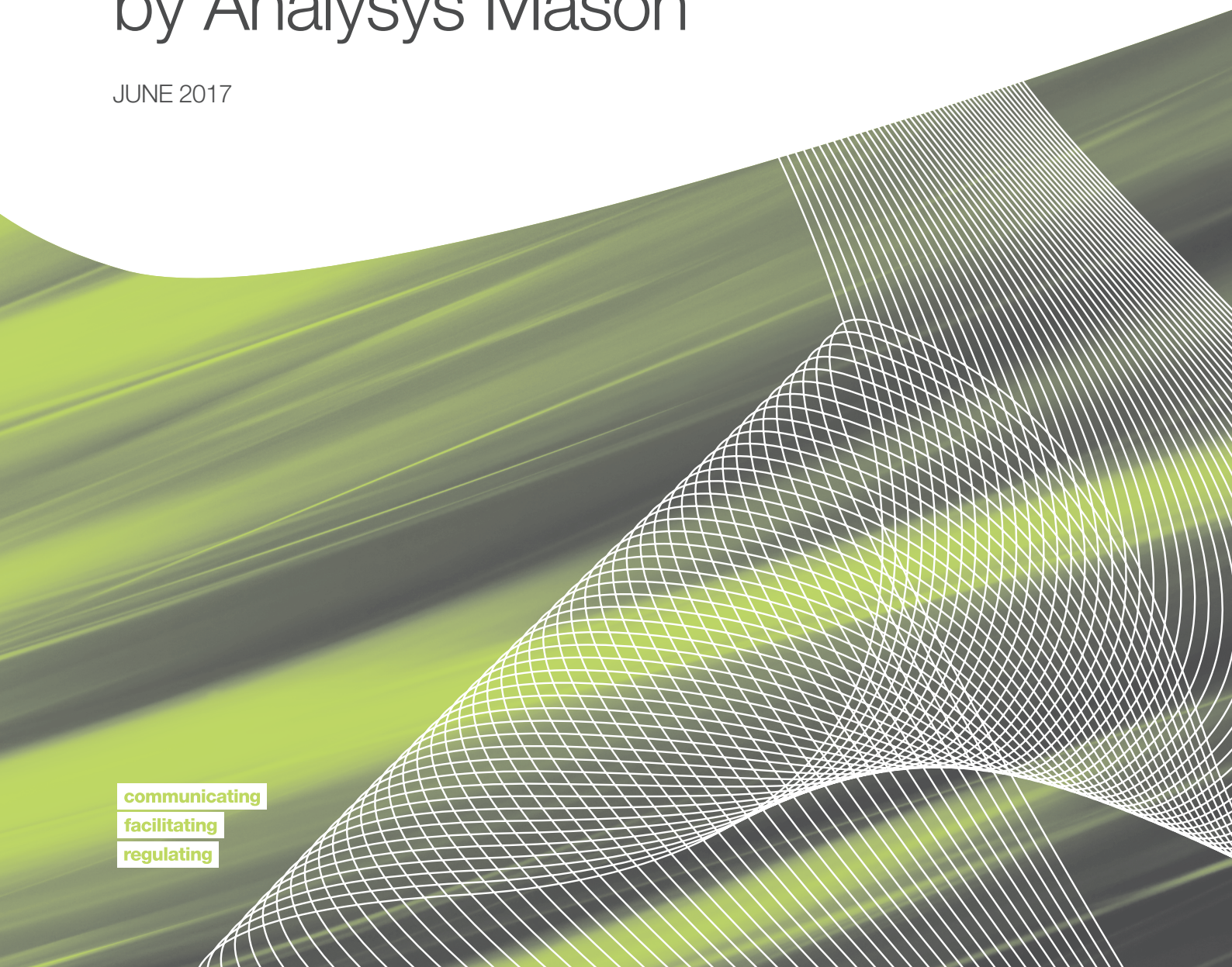

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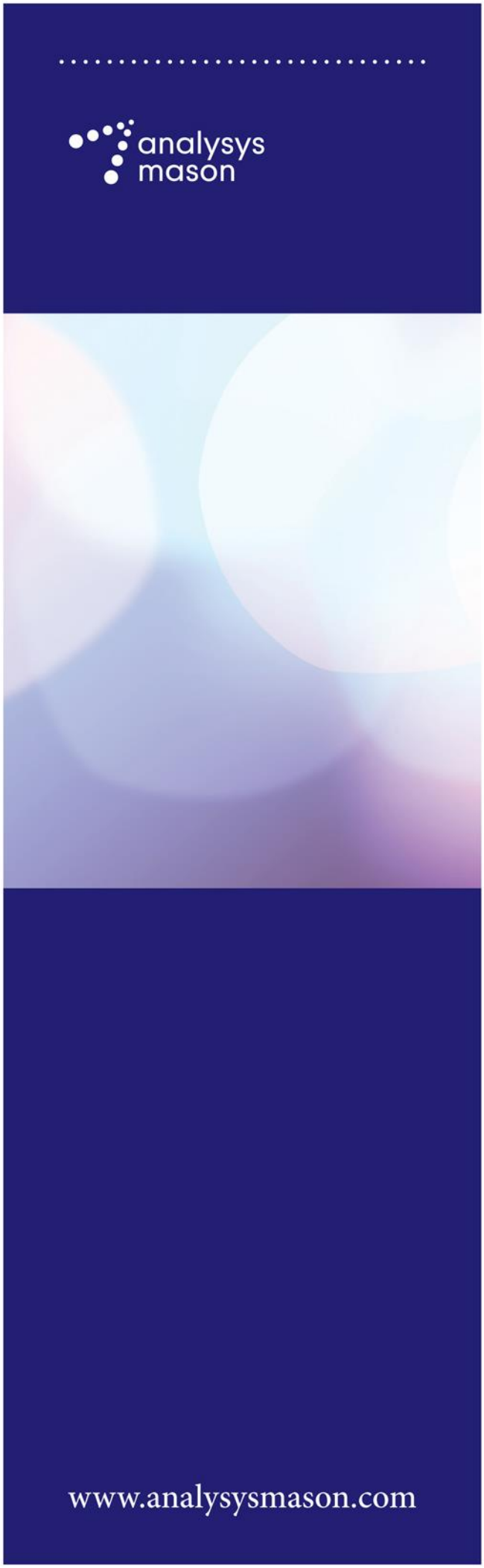

Report for the Australian Communications and Media Authority

Research study on spectrum-management mechanisms – *overall summary of findings*

June 2017

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Summary and key findings

This document is the summary report from a research study on spectrum-management mechanisms, which the Australian Communications and Media Authority (ACMA) commissioned from Analysys Mason. The objectives of the study were to:

- understand the application of best spectrum-management practices globally, and
- identify approaches that might offer benefits in the Australian market context and priorities for spectrum-management reform in Australia.

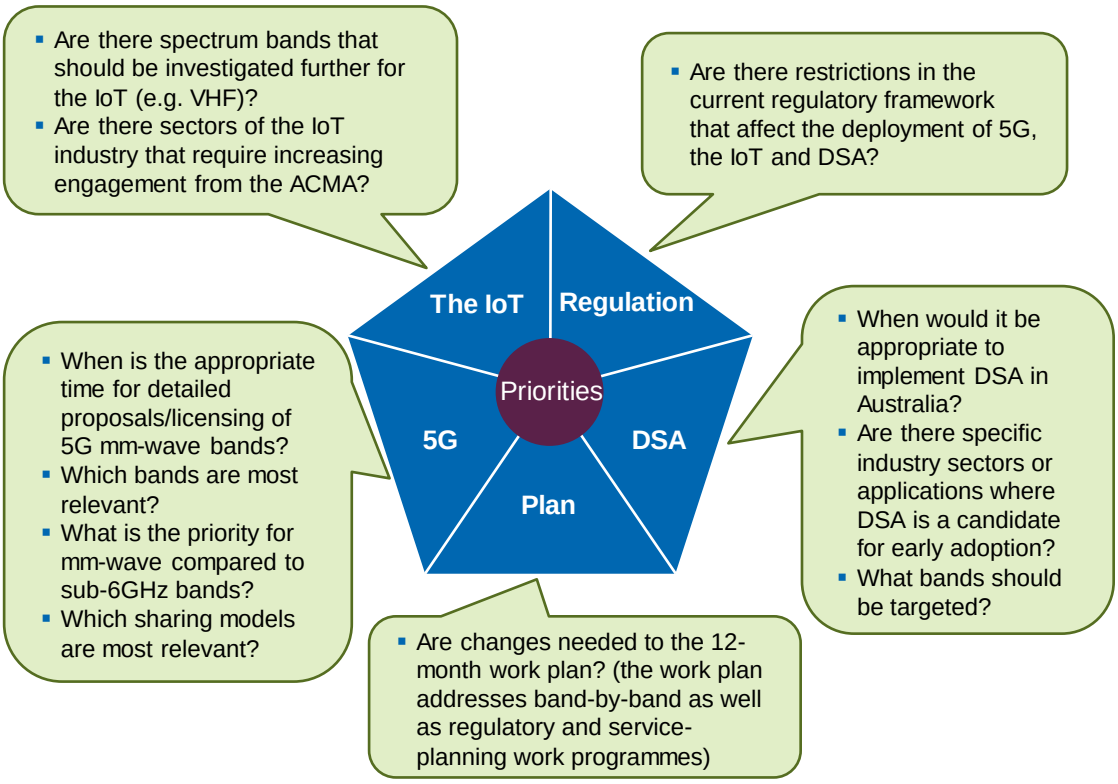
1 Background to the study

The existing legislation for spectrum management in Australia (i.e. the Radiocommunications Act of 1992) has been in place for 25 years. Over this period, the ACMA has progressively migrated towards market-based mechanisms for spectrum assignment, including the use of auctions, incentive (opportunity cost) pricing and secondary trading. Recently, trends such as growing demand for spectrum, advances in wireless technologies and changing global supply chains (with expectations of rapid growth of the Internet of Things (IoT)) have emerged, prompting a need to consider changes to the spectrum-management framework.

New spectrum-management legislation is now being implemented to replace the 1992 Act, giving the ACMA new powers and allowing it to respond to rapid changes in market demand and the latest developments in wireless technology, including trends towards more dynamic operation of wireless systems.

The ACMA's latest five-year spectrum outlook (FYSO), published in 2016, envisaged implementation of the government's spectrum reforms and the draft new legislation, and set out a work plan for the next five years, focusing on: spectrum for mobile broadband (MBB) and further evolution of networks to 5G, growth of the IoT and the use of technological solutions for spectrum sharing such as dynamic spectrum access (DSA). A summary of these key priorities is provided in Figure 1 below.

Figure 1: The ACMA's priorities in its five-year spectrum plan [Source: ACMA, 2016[1]]



The draft new legislation was published for consultation on 18 May 2017, along with a package of consultation proposals from the Department of Communications and the ACMA.[2] A key feature of the new legislation is migration to a single licensing system, the overall aims being to give the ACMA greater flexibility to adapt the issuing of licences and licence conditions to meet the demands of new technologies, and to improve the scope for changes of spectrum use to occur. The inclusion of a 'spectrum authorisations' option could potentially create opportunities for different applications with different requirements for spectrum access to co-exist in the same spectrum. This might also facilitate emergence of the latest international wireless technological advances in DSA, such as geo-location systems, in Australia.

2 International best practice in spectrum management

To identify best international practice in spectrum management, we surveyed the approaches used in eight jurisdictions worldwide. From this survey, we selected examples where regulators are already implementing well-established market-based mechanisms for spectrum assignment, and have evolved existing mechanisms towards more sophisticated market-based spectrum assignment and sharing approaches, facilitated by technological coordination techniques. To provide the most useful findings from the survey, we reviewed both successful and less successful approaches and gave our views on why some approaches had proved more successful than others. Examples of

1 See http://www.acma.gov.au/theACMA/five-year-spectrum-outlook-2016-20

2 See https://www.communications.gov.au/what-we-do/spectrum/spectrum-reform

sharing mechanisms include TV white space, licensed shared access (LSA) – developed within the European Union – and novel spectrum access schemes such as the tiered service approach used in the USA's 'citizens broadband radio service' (CBRS) proposal in the 3.5GHz band. Technological coordination techniques used in different sharing mechanisms use various forms of dynamic spectrum access (DSA), notably geo-location databases to keep track of users, avoid use in certain locations and/or frequencies and protect existing systems from interference.

Based on experience from other jurisdictions, we considered the suitability of alternative approaches to extend the use of market-based assignment methods for spectrum in Australia. We then compared alternative approaches against the objectives for spectrum reform set out in the ACMA's recent publications related to the draft new legislation, to reach conclusions and recommendations on the prioritisation of new spectrum-management approaches in Australia.[3]

We found that current international trends highlight the importance of achieving more flexible and dynamic use of spectrum. To increase flexibility of spectrum use and encourage the adoption of wireless devices that can be reconfigured in real time, we recommend that regulatory approaches to the management of spectrum should evolve towards more sophisticated market-based mechanisms facilitated by technological solutions (e.g. the use of geo-location databases to manage the use of spectral gaps in real time and to control the operating parameters of systems to avoid interference with other spectrum users in the same location).

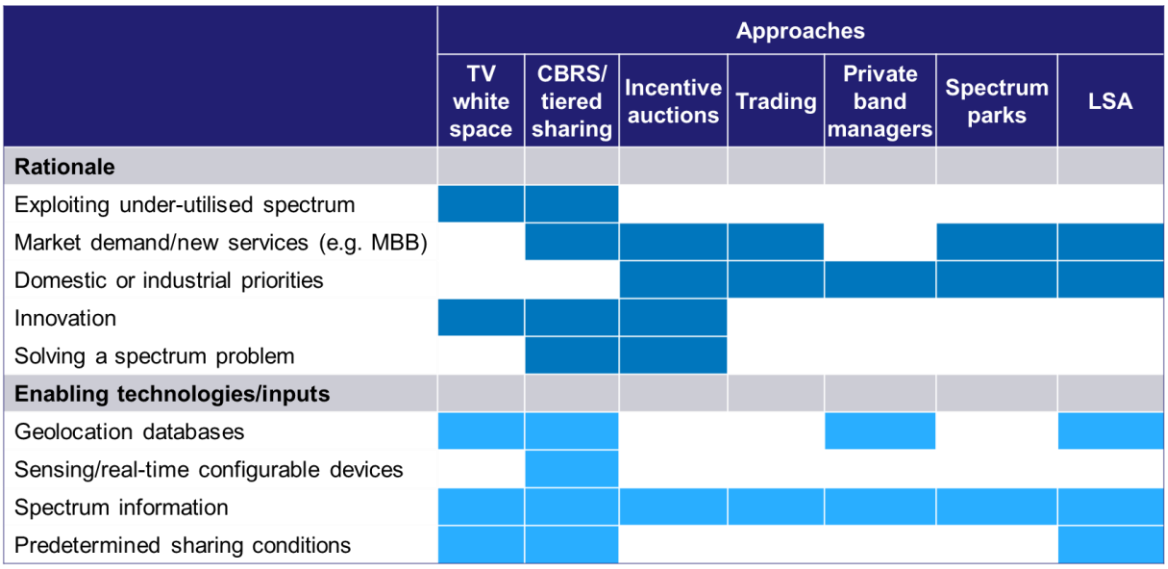
Although these more sophisticated forms of spectrum sharing facilitated by technological advances are increasingly important in meeting the rapid growth in demand for access to radio spectrum, there is a risk that the potential for interference will rise with increased numbers of users sharing the same spectrum. Depending on the approach to sharing (e.g. via a licence that the regulator enforces, or via a class licence or licence exemption, where devices must operate on a non-interference basis), there is a risk that interference becomes unmanageable by the market, to the extent that there is less willingness to invest in deploying services. The success of more sophisticated market mechanisms for spectrum sharing will rely on the availability of real-time information on spectrum management and the interference environment, to facilitate frequency coordination and interference avoidance.

From our review, it seems that support for innovation is a key driver for some of the more novel approaches to spectrum management witnessed in other markets worldwide. However, finding the right balance – between providing flexibility for new market players and ensuring predictability (including a stable competitive environment) for traditional mobile network operators (MNOs) – is one of the challenges that the ACMA faces in developing a new management framework for spectrum in Australia. Where large-scale investment in new nationwide networks is required (e.g. within the public mobile (cellular) market), there may still be a need for operators to have individual licences that provide exclusive use of spectrum, to avoid undermining investment certainty through a lack of guarantee concerning spectrum quality.

[3] See https://www.communications.gov.au/have-your-say/consultation-new-spectrum-legislation-licensing system, published by ACMA, 18 May 2017.

We found that alternative sharing mechanisms are facilitated by different forms of technological coordination techniques, such as DSA. A summary of sharing mechanisms is shown in Figure 2, together with the rationale(s) for selecting each one, and the enabling technologies/inputs.

Figure 2: Rationale for selecting different sharing mechanisms [Source: Analysys Mason, 2017]



As indicated in Figure 2, it appears that regulators in other jurisdictions base spectrum-management decisions on multiple variables, including market demand and the need to address a specific management issue (e.g. current use not in line with international harmonisation, under-utilisation in current use, and/or to facilitate a higher-value use), as well as more broadly to stimulate innovation – which might require the regulator itself to be innovative and to select a novel approach to achieve a specific objective/outcome. The applicability of alternative approaches is strongly linked to the market need and where simpler approaches are available, these are more likely to be favoured by the market than more complex alternatives.

We have also noted that, although flexibility in spectrum use is a useful general attribute, it is less important in periods when market developments are clearly pointing towards re-assignment of key spectrum (e.g. towards mobile communications), as they are today. Pressure for service-neutral assignment methods in key bands is reduced if a band is harmonised internationally for a particular purpose. However, use of service-neutral assignment methods is an important goal for the ACMA, both in the short term to deal with more-complex spectrum sharing situations, and for the medium term when market directions may change. The same also applies to methods of interference management, which support more and quicker changes of use.

From our review of international approaches to spectrum management, we found that:

- Increased demand for spectrum – especially for wireless broadband services – is placing increasing emphasis on making better use of spectrum and on spectrum sharing. This trend is being witnessed worldwide, although to date there have been relatively few examples of new

and novel approaches to sharing resulting in new commercial deployments (there are indications, however, that these models might evolve in future).

- If a presumption of spectrum sharing becomes commonplace in future, this will have market implications in terms of licence durations and how these are defined (noting that for spectrum assigned on an exclusive basis, licences typically have a longer fixed duration of 15 to 20 years). In a shared spectrum environment, clear regulatory policy on licence duration - and application of similar longer term licence durations - will be needed to avoid widespread uncertainty, which could dampen incentives for operators to invest in new solutions. There might also be implications in terms of the pricing of spectrum – further consideration of how 'opportunity-based pricing' (i.e. reflecting the market value of spectrum) applies in shared spectrum might be needed.

- Private band management may play a greater role in future, enabling operators to manage their own deployments within a block of assigned frequencies, or granting authority to private companies to co-ordinate spectrum for specific equipment types.

- Future markets will be more dynamic, and so it is essential that real-time information on spectrum management becomes available to facilitate more flexible spectrum use and sharing, which might imply the need for new forms of spectrum monitoring.

- The time taken to reach agreement on implementing spectrum sharing in some markets seems to be a key disadvantage of current sharing models, and more rapid deployment is likely to be required in future.

- Tiered spectrum access, whereby users can bid for higher-priority rights of spectrum use, has merit and might overcome issues within some sharing models where new users can only operate under class-licence conditions (i.e. no guarantee of quality of service (QoS) and increased risk of interference, such as in the case of television white space (TVWS)).

- To prevent poorly performing receivers being a limiting factor in the introduction of more flexible sharing models in future, receiver design might need to be more actively regulated, to improve performance and achieve greater conformity between different models.

- Without sharing, finding sufficiently wide contiguous frequency bands needed for the 5G 'new radio' radio access network (5G RAN) (e.g. in multiples of 100MHz) will be challenging to achieve. Given the frequency bands being considered internationally for 5G (e.g. 26GHz and 28GHz), there may be a need to implement appropriate sharing provisions between 5G and the existing services in those bands.

A summary of the band characteristics and other factors that influence overseas regulators in their choice of spectrum-management options is provided in Figure 3 below.

Figure 3: Summary of rationale for choosing different spectrum-management options [Source: Analysys Mason, 2017]

	TV white space	CBRS/tiered sharing	Incentive auction	Spectrum parks	LSA
User requirements	(a) Facilitate wireless distribution around the home (b) Create local or personal area networks (c) Enable new applications (e.g. the IoT)	(a) Release further spectrum for MBB use (b) Enable new applications and business models (d) Create local or personal area networks	Release further harmonised sub-1GHz spectrum for MBB use	Enable new applications and business models	Release further spectrum for MBB use
Competitive environment	Systems using white-space spectrum typically provide wireless broadband connectivity in a local area but do not compete directly with mobile networks, since white-space spectrum is typically used where mobile network coverage is limited (e.g. remote or rural locations)	A mixture of MNOs and alternative operators in the USA were seeking access to spectrum to provide further capacity for MBB use (by MNOs) and to enable new applications and business models (by alternative operators)	Other sub-1GHz bands already assigned for MNO use; need for further sub-1GHz spectrum driven by wireless data traffic growth plus uneven distribution of existing sub-1GHz bands among existing MNOs	Other blocks of 2.5GHz spectrum were assigned for exclusive licensed use, with a smaller portion of the band reserved for managed spectrum-park implementation	Driven by MNOs' need for additional capacity to accommodate growth in wireless data traffic
Usage and demand	Although demand for use of white-space spectrum was initially high, the number of deployed systems has been more limited in all the markets where this management approach has been implemented	Demand for access to this band has been strengthened by its harmonisation for 4G/5G use. Six firms (Google, Qualcomm, Nokia, Intel, Ruckus Wireless and Federated Wireless) have formed the CBRS Alliance to develop an eco-system for systems to use this band (based on LTE)	In the USA, the forward auction within the 600MHz incentive auction concluded with buyers for most regional licences, with only a few regional licences remaining unsold. Net proceeds were USD19.3 billion, and the highest bidder was T-Mobile (the MNO with the least sub-1GHz spectrum before the auction)	This approach appears to have been popular in New Zealand, with companies offering wireless area networking to hard-to-reach areas	Although not yet fully implemented, various European countries are conducting trials, including Italy and France
Regulatory development environment	Once implemented, the geolocation database approach minimises the effort needed to	The objective has been to make the environment as	Has required significant regulatory development effort to implement. Mobile licences	The objective is to make the regulatory environment as flexible and lightly licensed as	Requires regulatory effort to establish predetermined sharing conditions, but with

	TV white space	CBRS/tiered sharing	Incentive auction	Spectrum parks	LSA
	manage white-space spectrum, but significant regulatory effort is required when designing the approach. The objective is to make the environment as flexible and 'lightly licensed' as possible	flexible and lightly licensed as possible	awarded in the repackaged spectrum are like existing MNO licences (i.e. designed to provide predictability, to maximise investment)	possible, and to encourage experimentation and innovation	flexibility for market players to negotiate commercial solutions based on established sharing conditions
Band characteristics	TV white space use has mostly been implemented within UHF spectrum allocated on a primary basis to broadcasting services. Where white-space spectrum has been trialled and/or implemented (e.g. the UK and Singapore), the spectrum below 694MHz is not allocated for primary mobile use (nor is it harmonised for this purpose)	Potential global harmonisation for MBB use/included in 3GPP standards for LTE time division duplex (TDD) and prospects for global 5G use	Spectrum below 694MHz was identified for mobile use on a co-primary basis with broadcasting in the USA and selected other markets at WRC-15; further worldwide harmonisation might occur based on decisions of future WRCs (e.g. WRC-23)	The frequency band used to deploy a managed spectrum park in New Zealand – in the 2.5GHz band – is globally harmonised for MBB use and included in 3GPP standards for LTE	LSA is not band specific, but in Europe is likely to be most widely applied in the 2.3GHz band. This band has been globally harmonised for LTE TDD use, but is not yet widely available for MBB use in Europe due to existing government/defence use

3 Identification of spectrum-management approaches for Australia

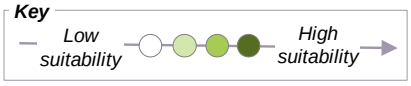
The study went on to consider the implications of international trends for Australia's wireless market. We first looked at the characteristics of the Australian market and the link between spectrum management and competition, especially in relation to provision of commercial mobile (cellular) networks. We identified that demand for spectrum, in the Australian market, as well as internationally, is a derived demand (based on users' willingness to pay for spectrum to provide wireless communications services and governments' desire to provide public services, which also rely on wireless systems and/or wireless connectivity). The way that regulators manage access to spectrum can have profound implications for the structure of wireless communications markets, as well as for the services being delivered and the prices charged to consumers.

In future, spectrum management in the Australian market as well as internationally will involve a trade-off between offering greater flexibility in the use of spectrum (e.g. sharing mechanisms that make it easier to deploy smaller systems in local environments), and exclusive use and/or other types of individual national-operator licences with additional occupancy rights (e.g. longer duration, and increased certainty over quality of service). Regulators in other markets have cited various reasons for implementing different sharing mechanisms, ranging from releasing further spectrum for MBB to encouraging innovation and exploiting under-utilised spectrum.

As part of this study we compared more novel market-based spectrum-sharing mechanisms used in other markets with the ACMA's considerations for the new licensing system in Australia. We identified that mechanisms such as white-space spectrum and tiered sharing, and the use of geolocation databases to manage the sharing environment, might provide a good fit in bands where there is market demand for new uses, but where geographical and/or temporal use of spectrum is limited. Figure 4 outlines the suitability of different mechanisms for meeting selected spectrum-management objectives in Australia (based on priorities in the ACMA's FYSO).

Figure 4: Suitability of different approaches to meet selected priorities in Australia [Source: Analysys Mason, 2017]

Priority issue	TV white space	CBRS/tiered sharing	Incentive auctions	Spectrum parks	LSA
5G	Might suit where density of deployment is low (e.g. rural)	Might suit, subject to QoS and licence tenure	Might suit for re-allocation of sub-694MHz (if allocated to mobile)	Might be suitable for test and development/trials	Might be suitable in some bands (2.7–3.1GHz?)
IoT	Good	Might suit for some solutions (e.g. small cells in smart cities)	Not likely to be relevant	Might encourage test and development/trials	Not suitable
DSA	Good	Good	Not likely to be relevant	Might enable interference coordination by licensees	Some LSA implementations might feature DSA
To facilitate new uses in bands under review (VHF, 2.7–3.1, 3.5–3.7GHz)	Suitable for some bands (VHF?)	Might be suitable in some bands	Suitable to repurpose use from one service to another	Might be suitable for test and development/trials	Might be suitable in some bands (2.7–3.1GHz?)



Whilst Figure 4 presents possible new sharing models, shared spectrum is unlikely to be applicable in all situations within the Australian market. Although sharing with some existing uses is inevitable in some frequency bands (unless existing uses can be migrated to other bands), it can be challenging to manage sharing involving a combination of existing and new uses, and it is likely that demand for spectrum for some uses might be for exclusive-use spectrum. Exclusive-use licences will continue to be relevant in situations where spectrum is being made available for new, nationwide deployments (e.g. in the context of the further evolution of 4G and introduction of nationwide 5G networks, requiring significant investment in network infrastructure).

In practice, the choice of approach will depend on the characteristics of the new use, the nature of the current use and the characteristics of the spectrum in the band(s) being considered. The ACMA should pay attention to new sharing mechanisms and approaches that might help to address band-specific projects that have already been identified in the FYSO – for example, to encourage future uses of VHF broadcasting service bands (which might include the IoT), a white-space access approach managed using DSA techniques might be relevant.

In terms of the relevance of different reforms in the Australian wireless market context, we drew the following conclusions:

- The Australian cellular mobile communications market is competitive, and has recently attracted a new market player which aims to roll out an MNO-type network in exclusive-use spectrum in the 700MHz band. Exclusive-use licences will continue to be needed where large-scale

investment in new networks is envisaged, requiring a high certainty of spectrum access. In contrast, spectrum reform aimed at more spectrum being shared in some bands might help to attract new types of wireless operator. Such reform could also help to address specific coverage issues, such as providing ubiquitous coverage for wireless broadband (e.g. into remote areas), or providing additional capacity in areas of very high traffic demand (e.g. 'small cells')

- Release of sufficient amounts of harmonised spectrum is especially important for the mobile market to remain competitive, but harmonised spectrum is also relevant for emerging uses of spectrum, including in bands where DSA techniques are proposed

- There is a link between spectrum management and downstream competition, but concerns about market power in the provision of spectrum can be addressed through appropriate remedies

- It would be sensible to consider delegated or private band management, but market take-up and the benefits are uncertain, based on experience in other markets to date. To encourage the emergence of private band management, we recommend that the ACMA conducts further work to investigate where demand for band management exists (i.e. within identified bands, or sectors of the market) and what the costs and benefits of alternative band-management models might be in situations where there is demand, so that it can identify the best approaches for minimising costs, administrative burdens and risks and thus allow band managers to flourish. This would include considering how the ACMA might charge band managers for access to spectrum, how to promote competition in band management (if relevant) and how to avoid any distortions in pricing and availability where similar spectrum is available from different sources (e.g. in situations where the ACMA might offer spectrum that has been priced administratively, which could serve as a substitute for spectrum that band managers are offering at commercially derived prices)

- International trends are towards longer licence durations in key bands to provide greatest certainty, but there should be provision to recover spectrum to prevent value-destructive behaviours.

4 Prioritisation of approaches for the Australian market

To prioritise the implementation of different approaches to spectrum management, a focus on additional market-based approaches in bands that have been identified as the most valuable in an alternative use could be a beneficial early activity for the ACMA – taking account of the value consumers might gain from new services, broader benefits to the economy and society and the market needs for possible new users of the spectrum being considered (including their likely requirements in relation to exclusive versus shared spectrum use, licence duration, ability to trade and lease spectrum and so forth).

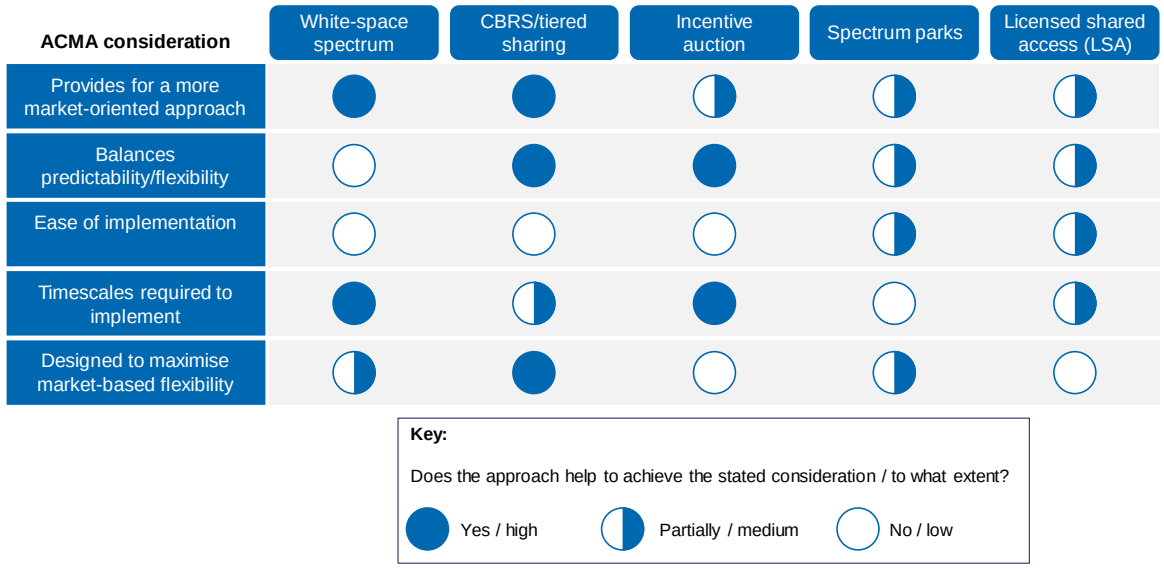
The ACMA has identified the following considerations when designing the new licensing system:

- providing for a more market-oriented approach where practicable

- accommodating an appropriate balance between flexibility and predictability for spectrum users
- the extent of change to licence issuing processes and licence design
- the period over which changes to licence issuing and licence design occur, especially with respect to spectrum sharing, licence renewal, refarming and trading
- the extent to which the ACMA may seek to liberalise control of spectrum management, using management rights or reconfigured licences.

We have compared the alternative management approaches identified in Figure 3 against the ACMA's considerations when designing the new licensing system, to assess the potential suitability of each approach. Our assessment is summarised in Figure 5 below.

Figure 5: Comparison of different approaches against the ACMA's considerations for the new licensing system [Source: Analysys Mason, 2017]



Implementation of these sharing mechanisms would need to be considered on a band-by-band basis, based on market demand and in line with anticipated deployment and characteristics of the band. The most suitable bands for these sharing mechanisms would be bands where utilisation is currently low, and/or bands which have frequencies available in some locations, and/or in some parts of the band, and where wide-scale clearance of existing use is not being envisaged and/or not currently possible.

A summary of the high-level approach that the ACMA might follow to prioritise its choice of alternative spectrum access mechanisms is shown in Figure 6.

Figure 6: Approach for prioritising applicable mechanisms [Source: Analysys Mason, 2017]

As the new legislation is being implemented, there will be a transition phase, while the ACMA moves from the current licensing system to the proposed new single system. During this transition period, the ACMA will need to address key market developments that emerge, such as planning for the deployment of 5G and ensuring there is sufficient spectrum for the IoT, as set out in the latest FYSO. Whilst transitioning to the new legislation, the ACMA might continue applying current approaches to spectrum management alongside implementing spectrum reforms. The approaches used – and prioritisation of reforms for the ACMA to implement – will be guided by market demand, anticipated deployments of new networks and systems and the characteristics of the frequency bands being considered.

5 Recommended next steps for the ACMA

Based on the results of this study, we recommend the following next steps for the ACMA:

- Further analysis into the implementation of long-duration, 'spectrum space' licences, and the conditions of those licences. For example, offering longer-duration licences with spectrum leasing might give further flexibility for spectrum exchange where needed, whilst also offering the longer duration desired by operators of nationwide networks, which have to make large-scale investment in network infrastructure. This would avoid the possible risk of longer-duration licences impeding access to spectrum for a wider range of users, since operators could lease spectrum in specific locations/over specific periods within the licence duration, in line with market demand

- Specific implementations of the newer spectrum sharing approaches identified in this study could be studied on a band-by-band basis, taking account of market demand and the characteristics of the band(s) being considered. Combinations of sharing approaches (e.g. using multi-tiered sharing) should be considered if simpler approaches are not feasible, but we note that more complex sharing approaches might be more complex to implement, as well as giving rise to increased investment risks (e.g. if there is a lack of certainty regarding the accessible spectrum, or the interference environment)

- Given that the new legislation is intended to facilitate private band management, there would be merit in considering further the market conditions most suited to fostering successful band management. For example, further consideration might be given to the bands and/or sectors of the market are most suitable for private band management and the conditions most likely to result in successful emergence of commercial band managers (e.g. the amount of spectrum needed, and whether a single band manager, or multiple band managers, are likely to be needed in each band/sector). Further consideration should also be given as to whether spectrum availability via the ACMA might undermine private band management (e.g. if administrative pricing was applied to ACMA-managed bands, these might provide a substitute for spectrum managed by the band manager).

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