

Beyond 2020— A spectrum management strategy to address the growth in mobile broadband capacity

Discussion paper

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Executive summary

The spectrum management implications of the growth in demand for mobile broadband capacity continue to be important issues for the ACMA. Mobile broadband spectrum management is one area where the ACMA has, for a number of years, provided very detailed public guidance on its associated strategy and work plan, given its importance and the potential effect on incumbent users. The ACMA's last substantial publication on this issue was in May 2011 with the release of *Towards 2020—Future spectrum requirements for mobile broadband*.¹

In the four years that have passed since the publication of *Towards 2020*, a number of developments have occurred, making it timely for the ACMA to review and rearticulate its strategies for addressing the growth in mobile broadband capacity.

In understanding and addressing mobile broadband growth, it is important to note that increases in mobile broadband capacity are enabled by three main factors:

1. access to additional spectrum or improved use of existing spectrum
2. use of increasingly spectrally efficient technologies
3. deployment of appropriate network infrastructure and topologies.

The mobile broadband industry has a leading role to play in the realisation of these factors. Enabling mobile broadband capacity growth is therefore the collective responsibility of both the ACMA and industry. However, the development of spectrum management arrangements that support the growth in mobile broadband capacity must be balanced with the ongoing requirements for other uses of the spectrum.

The evidence suggests Australia currently has sufficient spectrum available for mobile broadband services in the short to medium term. However, long lead-times for making additional spectrum available and the importance of international harmonisation compel the ACMA, as Australia's spectrum regulator, to press ahead with work in this area if it is to have options available in the very likely scenario that future demand for additional spectrum eventuates.

The ACMA has abandoned its focus on explicit quantitative targets of spectrum to be made available for mobile broadband, which have been found to be rigid and unresponsive. The ACMA has shifted towards a contingency planning model focused on the outcome of mobile broadband capacity growth that will enable the right spectrum to be made available, at the right time, for mobile broadband. This change in approach will allow the ACMA to be more flexible and responsive to the rapidly changing environment.

A set of proposed strategies, including a transparent spectrum management planning process for identifying potential future spectrum options for mobile broadband, have been developed to guide the ACMA in its actions. The proposed strategies are:

1. Encouraging a holistic approach to addressing the outcome of mobile broadband capacity growth that balances the available inputs of spectrum, technology and network infrastructure/topology.
2. Articulation of a transparent spectrum management process for identifying potential future spectrum options for mobile broadband. This includes the identification of a pool of potential spectrum options at varying stages of

¹ Available on the [ACMA website](#).

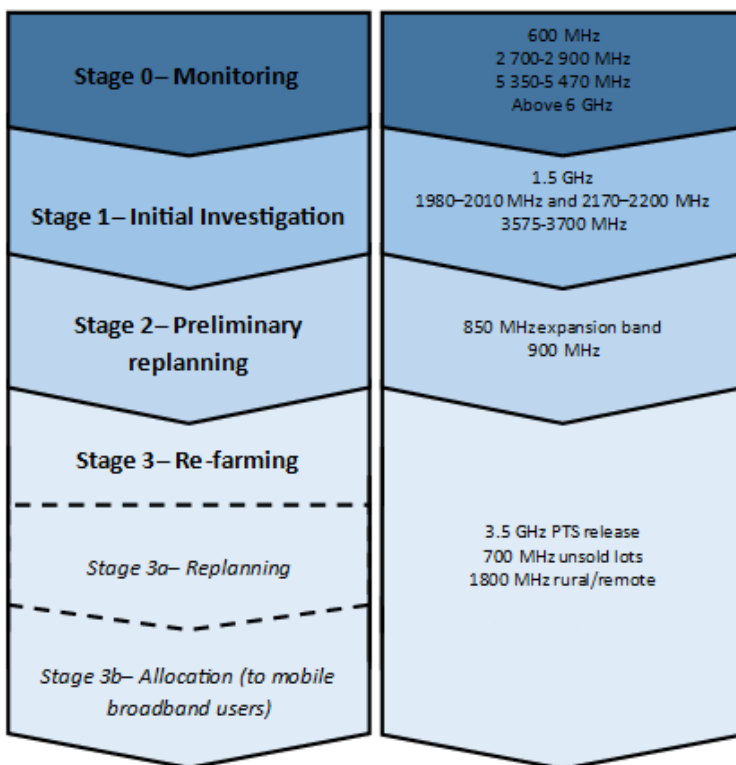
consideration. This will provide the ACMA with capacity to react to demand requirements on a contingency basis if and when needed, and when the evidence suggests that mobile broadband is, or is becoming, the highest value use of a particular band.

3. Where possible, utilisation of the often long lead-times to assist in reducing the effect on incumbents arising from re-farming of spectrum to mobile broadband.
4. Exploration and, where appropriate, the adoption of opportunities for greater sharing between mobile broadband services and other services.
5. Engagement in international deliberations to influence the development of domestically suitable internationally harmonised spectrum options.

While most of the fundamental concepts for management of spectrum for mobile broadband remain consistent with past practice, some of the strategies represent refinements of the ACMA’s traditional approach.

A four-staged process for consideration of additional spectrum for mobile broadband services has been developed and is shown in Figure 1, with the range of potential spectrum options at each of the stages of consideration noted. This approach will give the ACMA capacity to react to demand requirements on a contingency basis if and when needed, and when the evidence suggests that mobile broadband is, or is becoming, the highest value use of a particular band. Consistent with the idea of contingency planning, the appearance of a band at the ‘monitoring’ stage (Stage 0) does not necessarily imply the eventual re-farming of that band (Stage 3).

Figure 1: Stages of the process for consideration of additional spectrum for mobile broadband services and the position of current mobile broadband spectrum planning projects



This approach to addressing the growth in mobile broadband capacity recognises both the long time frames (and significant domestic and international engagement) involved in identification of suitable frequency bands for mobile broadband, and the uncertainty that surrounds both demand projections and the precise role new spectrum releases should play in meeting eventual demand. The approach can be seen as a long-term plan for addressing the full range of contingencies that might arise in relation to future broadband demand. Actual replanning of bands will only occur if and when the need actually arises, as indicated by a change in the highest value use of that band. However, the goal is to ensure that good options to meet any contingency will be available in a timely manner over the short, medium and long term.

It is intended that the Five-year spectrum outlook (FYSO) be used as a tool to keep stakeholders informed on the suite of mobile broadband spectrum planning projects.

In May 2014, the Minister for Communications, the Hon Malcolm Turnbull MP, announced a review of Australia's spectrum policy and management framework.² The review reported to the minister in March 2015. The *Spectrum Review Report*³ sets out a series of recommendations to improve Australia's spectrum policy and management framework. On 25 August 2015, the government announced it had agreed to implement the recommendations of the Spectrum Review. While the ACMA expects there will be an ongoing need for long-term planning to address future demand for mobile broadband services, the implementation of the review recommendations should assist the regulator (and the spectrum market itself) in a number of ways. The ACMA expects to review its broadband strategies following implementation of the recommendations of the Spectrum Review.

The ACMA seeks comment on the issues discussed in this paper. Following consideration of responses, the ACMA expects to release its updated mobile broadband strategy and work program in early 2016.

² The Hon Malcolm Turnbull MP, Minister for Communications, [Spectrum reform to drive future innovation and productivity](#), media release, 23 May 2014.

³ Available on the [Department of Communications website](#).

Introduction

Mobile broadband services deliver substantial economic and societal benefits to the Australian economy and community. The growth in demand for mobile broadband capacity is ongoing and is likely to lead to continuing pressures for additional spectrum, although the extent and timing of these needs cannot be predicted with any certainty. There is also a continuing need for spectrum for many other applications. The development of spectrum management arrangements that support the growth in mobile broadband capacity must therefore continue to be balanced with the ongoing requirements for other uses of the spectrum.

Spectrum management arrangements for mobile broadband services have been a key issue for the ACMA for many years. The purpose of this consultation process is to review the ACMA's spectrum management strategy on mobile broadband-related matters, and the associated work plan, in response to the ongoing growth in demand for mobile broadband capacity.

The ACMA considers that a review of its spectrum management approach for mobile broadband is timely in order to provide continued transparency and (to the extent possible) certainty on this issue. Transparency and certainty are particularly important given the substantial impact of mobile broadband spectrum issues on spectrum users and the wider Australian public. In conducting this review, the ACMA recognises that access to additional spectrum (or improved arrangements for existing mobile broadband spectrum) is just one component in delivering the benefits of increased mobile broadband capacity.

A key aspect of the ACMA's work is to encourage and enable spectrum to move to its highest value use. The ACMA acknowledges that the highest value use of spectrum will be vary between different frequency bands and locations. The ACMA also acknowledges that the value of a particular use may have a social as well as a monetary aspect (that is, it cannot always be left to markets to determine but may require value judgements). The ACMA has chosen to focus this review on a particular use—mobile broadband—on the basis that demand for spectrum for this use has been the major driver for changes in highest value use across a wide range of bands for many years now, with many national administrations world-wide currently planning on the basis that this is likely to continue. Moreover, these changes have often affected bands that are already used by other services. However, it should be recognised that such changes in highest value use typically take time to eventuate and are liable only to affect a small number of bands at any given time.

ACMA role

Section 9 of the *Australian Communications and Media Authority Act 2005* (the ACMA Act) sets out the spectrum management functions of the ACMA including:

- > to manage the radiofrequency spectrum in accordance with the *Radiocommunications Act 1992* (the Act)
- > to advise and assist the radiocommunications community.

Consistent with the spectrum management functions set out in the ACMA Act, the object of the Act is to provide for management of the radiofrequency spectrum in order to achieve a number of goals, including:⁴

- > maximise, by ensuring the efficient allocation and use of the spectrum, the overall public benefit derived from using the radiofrequency spectrum.

Subject to the statutory framework provided by the Act, the ACMA uses a [total welfare standard](#) as its overarching framework when assessing the optimal approach to individual spectrum management issues. Since 2007, the ACMA has adopted a total welfare standard for use when:

- > the policy and legislative framework provides the ACMA with discretion about the tests it might apply
- > a regulatory intervention might have a significant economic impact on consumers, producers or other stakeholders.

When a total welfare standard is applied, the impact of a regulatory proposal on the public interest is measured as the sum of the effects on consumers, producers, government and the broader social impacts on others in the community. A total welfare standard requires that, to the extent possible, all significant benefits and costs arising from a regulatory proposal are given the same weight regardless of the identity of the recipient; and the approach expected to generate the greatest net benefits for the community is the preferred approach. This is consistent with best practice regulation as guided by the Office of Best Practice Regulation (OBPR).⁵ The ACMA recognises that using a total welfare standard approach to assess costs and benefits will often need to take into account both quantitative and qualitative factors.

The ACMA takes into account both economic and broader social impacts when considering the public benefit derived from using spectrum. The economic value of spectrum is broader than the price paid for access (that is, licence charges and taxes) and the cost of equipment. It is best characterised as the impact that use of spectrum has on the Australian economy. In the absence of market failures (for example, interference or safety-of-life issues), what a user is willing to pay for the spectrum acts as a proxy for the economic value that that party expects to generate by using the spectrum.

As noted, the ACMA also takes into account broader social impacts when considering the public benefit derived from spectrum. These impacts can be characterised as 'non-economic' in that they are not well captured by an economic framework. For example, science services, including remote monitoring of the 'fingerprints of nature'⁶ provide an enormous social benefit that is not easily quantified in dollar terms. Such services are also usually unable to gather the information they need using alternative spectrum.

Therefore, the ACMA needs to assess the use of spectrum holistically and consult with affected stakeholders to enable informed determinations regarding the value of a particular spectrum band.

⁴ The object of the *Radiocommunications Act 1992* is to provide for management of the radiofrequency spectrum, to achieve the goals set out in paragraphs 3(a) to 3(h).

⁵ The OBPR, [The Australian Government Guide to Regulation](#), p. 48, viewed 1 May 2015.

⁶ The fingerprints of nature are the radio frequencies that are emitted and/or absorbed by particular molecules. The presence of molecules can be detected by monitoring radio emissions on these frequencies.

The ACMA is also guided by the [Principles for Spectrum Management](#)⁷ (the Principles), which are as follows:

1. Allocate spectrum to the highest value use or uses.
2. Enable and encourage spectrum to move to its highest value use or uses.
3. Use the least cost and least restrictive approach to achieving policy objectives.
4. To the extent possible, promote both certainty and flexibility.
5. Balance the cost of interference and the benefits of greater spectrum utilisation.

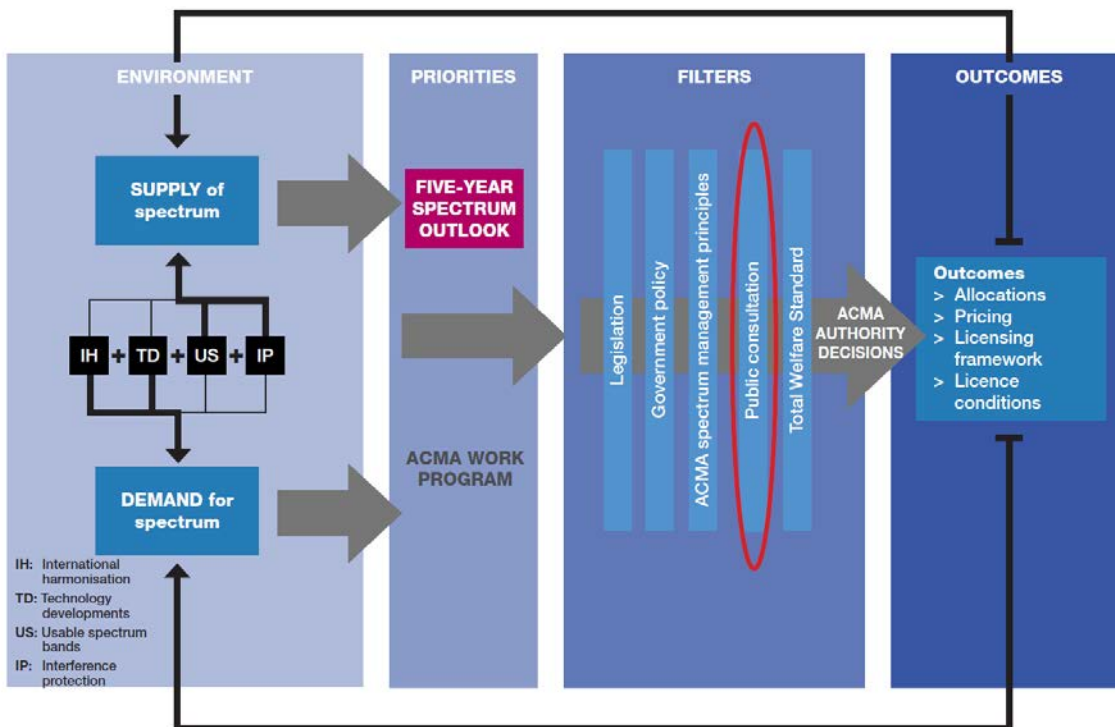
An important supposition in relation to the consideration of spectrum management strategy to address the growth in mobile broadband capacity is:

The highest value use of spectrum will vary between bands and geographic areas over time. As such, mobile broadband will only sometimes be the highest value use of a particular spectrum band.

The ACMA achieves the goals of the object of the Act and the Principles through a balanced application of market and regulatory mechanisms.

Figure 2 describes the ACMA's general approach to spectrum management decision-making. The update of the ACMA's mobile broadband strategy was flagged in the ACMA's *Five-year spectrum outlook 2014–2019*. In terms of the general approach, the release of this paper falls under the ACMA's public consultation 'filter'. The ACMA will continue to apply the elements of its spectrum management decision framework, including the spectrum management principles, as it considers the responses to this paper and finalises a strategy to address the growth in mobile broadband capacity.

Figure 2: Spectrum management decision framework



⁷ Available on the [ACMA website](#).

Spectrum Review

In May 2014, the Minister for Communications, the Hon Malcolm Turnbull MP, announced a review of Australia's spectrum policy and management framework.⁸ The Spectrum Review looked at the changes needed to cope with the increase in demand for spectrum and changes in technology, markets and consumer preferences. The review reported to the minister in March 2015. The *Spectrum Review Report*⁹ outlines recommended changes to improve Australia's spectrum policy and management framework. On 25 August 2015, the government released its response, agreeing to implement the recommendations of the Spectrum Review.¹⁰

The government will implement the three main recommendations of the review:

1. Replace the current legislative arrangements with new legislation that removes prescriptive process and streamlines licensing, for a simpler and more flexible framework.
2. Better integrate the management of public sector and broadcasting spectrum to improve the consistency and integrity of the framework.
3. Review spectrum pricing to ensure consistent and transparent arrangements to support the efficient use of spectrum and secondary markets.

Implementation of the recommendations of the Spectrum Review should assist the regulator (and the spectrum market itself) in a number of ways when it comes to addressing future demand for mobile broadband services. For example, it should make it simpler for the ACMA (or existing spectrum holders in bands) to change the use of spectrum to reflect changes in its highest value use. Other principles and strategies for addressing the growth in mobile broadband capacity are unlikely to change. An example is the need to monitor developments in the use of bands internationally and participate as appropriate in international forums to maximise the harmonisation of spectrum use nationally and internationally. For this reason in particular, the ACMA anticipates that planning to meet the likely contingencies for future mobile broadband demand will continue to be 'a long game'. The ACMA expects to review its broadband strategies following implementation of the recommendations of the Spectrum Review.

Background

Given its importance, mobile broadband spectrum management is one area where the ACMA has, for a number of years, provided detailed public guidance on its associated strategy and work plan. Maintaining appropriate spectrum arrangements for mobile broadband services remains a major element of the ACMA's spectrum management work program.

Strategy development

The ACMA and its predecessors have undertaken spectrum initiatives in support of cellular mobile telephony (which evolved into mobile broadband over time) since the release of the 850 and 900 MHz bands in the 1990s. However, a more coordinated

⁸ The Hon Malcolm Turnbull MP, Minister for Communications, [Spectrum reform to drive future innovation and productivity](#), media release, 23 May 2014.

⁹ Available on the [Department of Communications website](#).

¹⁰ The Hon Malcolm Turnbull MP, Minister for Communications, [Next stage of spectrum reform to commence](#), media release, 25 August 2015.

program of work on issues related to mobile broadband began in February 2006, when the ACMA consulted with stakeholders on wireless access services (WAS).¹¹

The purpose of the first discussion paper, *Strategies for wireless access services*, was to stimulate discussion and solicit information from stakeholders that would allow the ACMA to gauge the demand for future WAS and the associated spectrum support requirements. In December 2006, the ACMA released the second discussion paper, *Strategies for wireless access services: Spectrum access options*.¹² The purpose of that paper was to identify bands that the ACMA believed were the most suitable candidates for WAS in the short, medium and long term and seek comments on the identified bands, including some high-level options for band segmentation and licensing.

The WAS consultation process identified a need for more spectrum, and as a result, the 2.5 GHz and 3.6 GHz bands (in regional areas) were identified as bands that could be made available for WAS in the short to medium term.

The WAS consultation process also considered the dividend that would become available as a result of the transition to digital television. However, at the time of the release of the paper, the government had not decided if or when a 'digital dividend' would be realised. The government subsequently announced that 126 MHz of the 520–820 MHz UHF broadcasting band would be made available for delivering wireless communications services, including mobile broadband.¹³

The ACMA's dialogue with stakeholders on mobile broadband services continued in May 2011, with the release of *Towards 2020—Future spectrum requirements for mobile broadband*.¹⁴ That paper detailed the existing mobile broadband environment in Australia, provided an analysis of the quantum of spectrum that would be required to meet that demand, and identified frequency bands that could potentially be made available for mobile broadband services.

While the *Towards 2020* work has provided a solid basis for the ACMA's mobile broadband spectrum management work over the last few years, a number of factors have arisen since it was developed, making it timely for a review and update of the ACMA's overall strategy. Some of these factors include:

- > completion of the digital dividend auction and the resulting unsold lots in the 700 MHz band
- > commissioned research undertaken by the ACMA on demand for WAS and the economic benefits of mobile broadband
- > developments internationally and domestically on bands identified in previous ACMA papers, such as the 850 and 900 MHz bands, the 1.5 GHz band and the 3.5 GHz band
- > knowledge gained during preparations for the International Telecommunication Union Radiocommunication Sector (ITU-R) 2015 World Radiocommunication Conference (WRC-15), which is considering the identification of additional spectrum for IMT and mobile broadband under agenda item 1.1

¹¹ Available on the [ACMA website](#).

¹² Available on the [ACMA website](#).

¹³ Senator the Hon. Stephen Conroy, [Size and Location of the Digital Dividend](#), media release, 24 June 2010.

¹⁴ Available on the [ACMA website](#).

- > preparations for WRC-15, which will likely consider a possible future WRC-19 agenda item on IMT in bands above 6 GHz under agenda item 10
- > current studies showing that mobile traffic growth will continue into the future, more than likely at an increasing rate—at least in the medium term
- > evidence that estimates of future mobile broadband traffic prior to the ACMA's 2011 report tended to over-estimate actual traffic growth and consequently tended to overstate the short- to medium-term requirement for additional spectrum.

Mobile broadband spectrum availability

The evidence suggests Australia currently has sufficient spectrum available for mobile broadband services in the short to medium term. In addition to the quanta of spectrum available, the vast majority of this spectrum has been made available in a manner that is harmonised with international arrangements and consistent with international standards such as those defined by 3GPP.¹⁵ Currently Australia has 883 MHz of spectrum available in metropolitan areas, 888 MHz available in regional areas and 718 MHz in remote areas for mobile broadband use. See *Appendix A—Currently available spectrum for mobile broadband purposes* for further details. Further analysis comparing the availability of spectrum in Australia for mobile broadband services with other countries is outlined in the *International comparison* section.

In addition to the currently available spectrum, the ACMA has a number of projects underway considering possible future spectrum releases or improvements to existing spectrum arrangements for mobile broadband. These include the reviews of arrangements in the 803–960 MHz band and the 3.5 GHz band, and the recent decision to release 1800 MHz band spectrum for mobile broadband in regional areas via spectrum licensing and in remote areas via apparatus licensing. More details are available in the *Current and ongoing projects* section.

Purpose

The purpose of this document is for the ACMA to share its thinking on a range of matters related to the spectrum management implications of the growth in demand for mobile broadband capacity, and to seek inputs, views and ideas from the entire range of spectrum users. Following consideration of responses to this discussion paper, the ACMA expects to release its updated mobile broadband strategy and work program early in 2016.

Until an updated strategy is released, the ACMA will continue with current projects as deemed appropriate. To that end, ongoing work including, for example, preparations for WRC-15 and Agenda item 1.1, the review of the 803–960 MHz band and the release of spectrum in the 1800 MHz band in regional and remote areas, will progress while the update to our mobile broadband strategy is finalised.

¹⁵ The Third Generation Partnership Project (3GPP) is a telecommunications standardisation group responsible for the development of equipment standards for cellular mobile telephony technologies such as long term evolution (LTE).

Structure

The rest of this document is structured as follows:

- > Chapter 2 *Mobile broadband—Context* details background and a brief history of the ACMA's work toward addressing the issue of increasing demand for mobile broadband capacity
- > Chapter 3 *Addressing mobile broadband capacity growth* explores the major mechanisms for addressing increasing demand for mobile broadband capacity and the challenges associated with these mechanisms
- > Chapter 4 *Proposed mobile broadband strategies and work program* describes the ACMA's plan to address the issue of increasing demand for mobile broadband capacity.

Mobile broadband—Context

The importance of mobile broadband

Mobile broadband services deliver substantial economic benefits to the Australian community. The Centre for International Economics (CIE) was recently commissioned by the ACMA to identify the economic effects of mobile broadband on the Australian economy between 2006 and 2013.¹⁶ This study noted that mobile broadband has led to an increase in Australia's economic activity of \$33.8 billion in 2013, shown in Figure 3. Perhaps of more direct relevance to the average Australian, this study estimated that by 2013 mobile broadband had increased the amount of goods and services that could be purchased by each person by \$819.

Mobile broadband creates substantial value to the economy in three ways:

1. In the mobile communications sector, productivity growth created by mobile broadband was 11.3 per cent per year between 2006 and 2013. This growth would have been 6.7 per cent per year¹⁷ without mobile broadband. Mobile broadband prices for households and businesses have fallen by an average of 8.4 per cent per year¹⁸ over this same period.
2. Businesses that have taken up mobile broadband have been able to save time and resources, and improve the quality of their goods and services. A survey of over 1,000 businesses reported an average time saved of 2.3 per cent and average cost savings of 1.4 per cent from mobile broadband use.¹⁹
3. The range of applications and content available to households from mobile broadband use has increased, network quality has improved and download speeds have increased. This has created greater value to households that CIE has estimated as equivalent to \$3.8 billion per year or \$166 per person in 2013.²⁰

These direct economic impacts have flowed through all aspects of the Australian economy. The most important of these flow-on impacts is additional capital investment in the Australian economy, magnifying the impacts on economic growth.

Beyond these direct economic impacts, the services enabled by mobile broadband are now an integral part of our modern society. There are other benefits which have impacts that are more difficult to quantify, including increased interpersonal interconnectivity, increased productivity, access to education and increased engagement in both new online and existing communities.²¹

¹⁶ The Centre for International Economics (CIE) (Research Report prepared for the ACMA), [The economic impacts of mobile broadband on the Australian economy, from 2006 to 2013](#), April 2014, page 2.

¹⁷ Ibid, page 2.

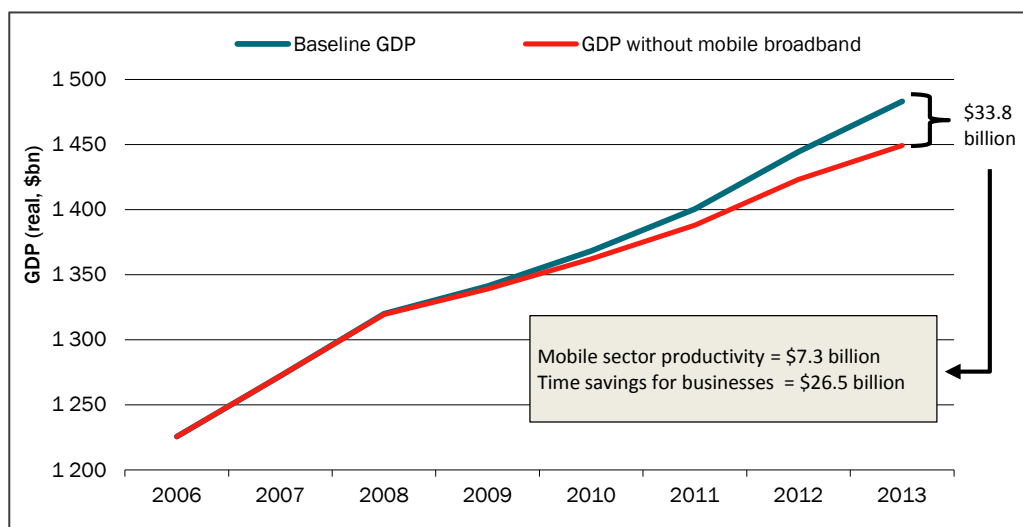
¹⁸ Ibid, page 2.

¹⁹ Ibid, page 2.

²⁰ Ibid, page 3.

²¹ Deloitte Access Economics (prepared for the Australian Mobile Telecommunications Association), [Mobile nation- The economic and social impacts of mobile technology](#), 7 February 2013.

Figure 3: Economic impacts of mobile broadband (Source: CIE)²²



An important conclusion from this discussion is as follows:

Mobile broadband services will continue to deliver societal and economic benefits to Australia and these benefits will increase with greater use of mobile broadband services made possible through increased network capacity.

Drivers of mobile broadband growth

Mobile data usage in Australia has been growing steadily since 2011 and is projected by Analysys Mason to increase almost four-fold from 2013 to 2017.²³ In the same time, the numbers of smartphones and tablets (connected mid-screen devices containing a SIM card) in Australia are forecast to increase substantially, with the proportion of smartphones predicted to increase from an average of 78 per cent of all mobile phones in 2013, to a saturation level of around 91 per cent in 2017, constituting a major driver of mobile data traffic growth.²⁴ While the number of devices are increasing, the mobile data usage per device is also rising²⁵, driven by trends including video downloads.

Beyond this growth in the 'conventional' mobile broadband use case, in the future it is predicted that mobile networks will offer wireless access to anyone and anything. Wireless access will go beyond humans and expand to serve any entity that may benefit from being connected. This vision is referred to in various ways including the Internet of Things (IoT), the networked society, machine-to-machine communications (M2M) or machine-centric communications.²⁶

The ACMA is facilitating M2M and IoT innovations within the scope of its existing regulatory remit. The ACMA is engaged in discussion with industry stakeholders about

²² The Centre for International Economics (CIE) (Research Report prepared for the ACMA), [The economic impacts of mobile broadband on the Australian economy, from 2006 to 2013](#), April 2014, page 4.

²³ Ibid, page 11.

²⁴ Ibid, page 13.

²⁵ Ibid, page 14.

²⁶ [4G America's Recommendations on 5G Requirements and Solutions](#), October 2014, page 5.

reviewing existing regulatory settings to identify regulatory tools and strategies that will further facilitate M2M and IoT.

To some extent, M2M and IoT applications will utilise existing class licensed spectrum (that is, spectrum ‘commons’), but a varying degree of certainty in their use of the spectrum is likely to be required and some applications may require licensed spectrum. The ACMA has been alert to the broad and diverse needs of M2M and IoT for some time. For example, potential options for low power, low duty cycle devices are being explored around the 900 MHz class licensed band. At the other end of the spectrum, the ACMA continues to monitor international developments in intelligent transport systems (ITS) in the 5.9 GHz band, waiting for the opportune time to establish a regime in Australia that will build on a pre-existing trial.

The impact of traffic growth in M2M-like applications is somewhat difficult to quantify. While it is likely that there may eventually be many more M2M connections than traditional mobile broadband type devices/connections, some of these connections will be for low data rate applications and tolerate high latencies.²⁷ Therefore, many M2M connections may be able to operate in ‘off peak’ periods where demands on the mobile broadband network are low.²⁸ Further, some M2M traffic will be carried over other networks (for example, low power, low duty cycle dedicated networks) rather than mobile broadband networks, which could possibly require specific spectrum management arrangements. In both cases, this may mean that the impact of network capacity demands from M2M will be less than for traditional mobile broadband connections, at least in some cases.

Estimating spectrum requirements to support mobile broadband growth

A significant amount of research has been conducted into estimating the amount of spectrum that is required to support mobile broadband growth. This research is two-fold: forecasts of mobile broadband traffic growth and methodologies for the calculation of spectrum requirements (which use the traffic forecasts as an input) to support this growth.

While the relationship between traffic growth, required network capacity and the resulting spectrum requirements is conceptually simple, the reality is that each step requires a number of assumptions that are subject to inaccuracies and variations over time. Accordingly, while these estimates provide insight into general trends, caution must be exercised in placing too much weight on specific numerical outputs.

Traffic growth forecasts

Below is a summary of predicted traffic forecasts from Cisco, Ericsson and Analysys Mason.

Cisco Visual Networking Index (VNI) Global Mobile Data Traffic Forecast

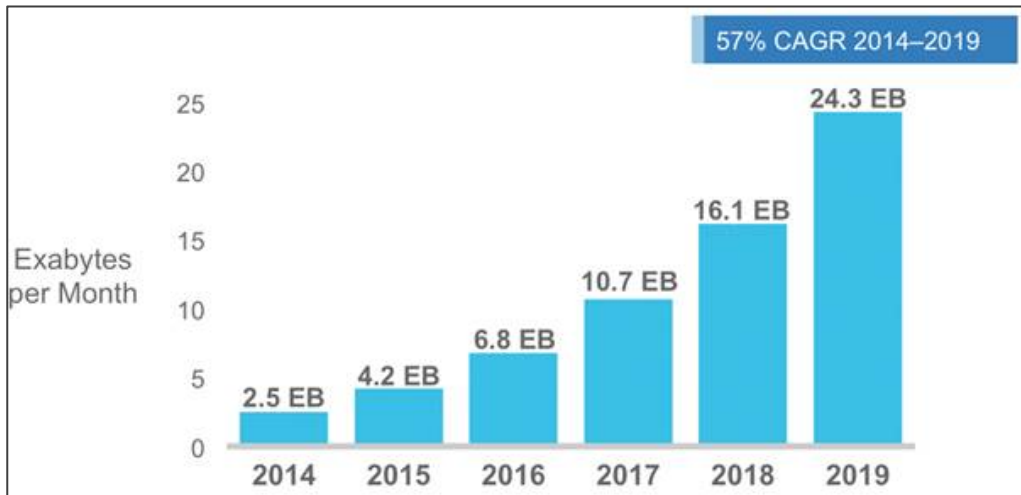
Cisco, a designer and manufacturer of networking equipment and research firm, develops a forecast of global mobile data traffic annually. The 2015 update released in February forecasts mobile data traffic through to the year 2019.²⁷ As shown in Figure 4, Cisco predicts that global mobile data traffic will increase nearly tenfold between 2014 and 2019. It also predicts mobile data traffic will grow at a compound

²⁷ Cisco, [Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2014–2019](#), 3 February 2015.

²⁸ Viswanathan, H, [Getting Ready for M2M Traffic Growth](#), TechZine – Alcatel-Lucent, 11 May 2011.

annual growth rate (CAGR) of 57 percent from 2014 to 2019, reaching 24.3 exabytes per month by 2019.

Figure 4: Cisco Forecast of Monthly Mobile Data Traffic to 2019²⁷



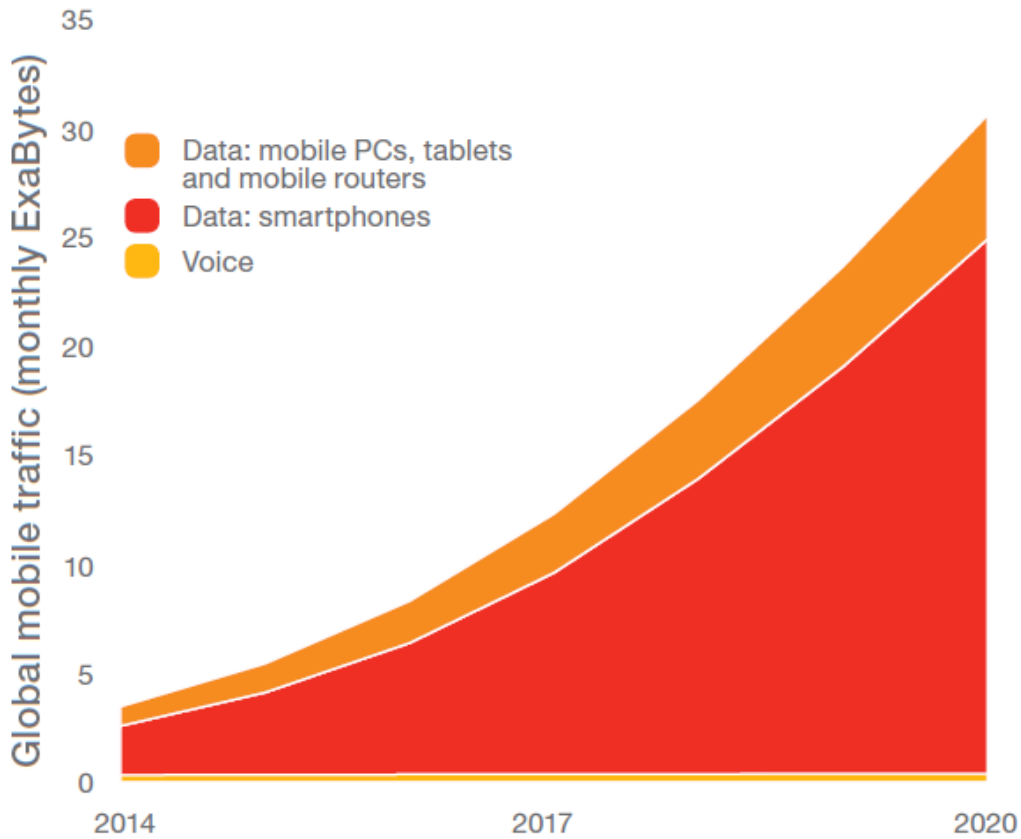
Some of the major trends contributing to the growth of mobile data traffic identified by Cisco include a continuing shift to smarter mobile devices, evolution towards higher-generation network connectivity (increasing use of 3G/4G, decreasing use of 2G) and the growth of machine-to-machine (M2M) connections and the IoT.

Ericsson

Equipment manufacturer Ericsson produces the *Ericsson Mobility Report*, which is updated regularly.²⁹ In the June 2015 update, Ericsson predicted a nine-fold increase in mobile data traffic from 2014 to 2020, as shown in Figure 5. They also predict that mobile data traffic will rise at a CAGR of around 45 per cent from 2014 to 2020.

²⁹ View the latest and previous versions of the [Ericsson Mobility Report](#).

Figure 5: *Ericsson Mobility Report* forecast of global mobile traffic



Ericsson cites the rising number of smartphone subscriptions as the main driver of mobile data traffic growth, with increasing use of video also a large contributor.

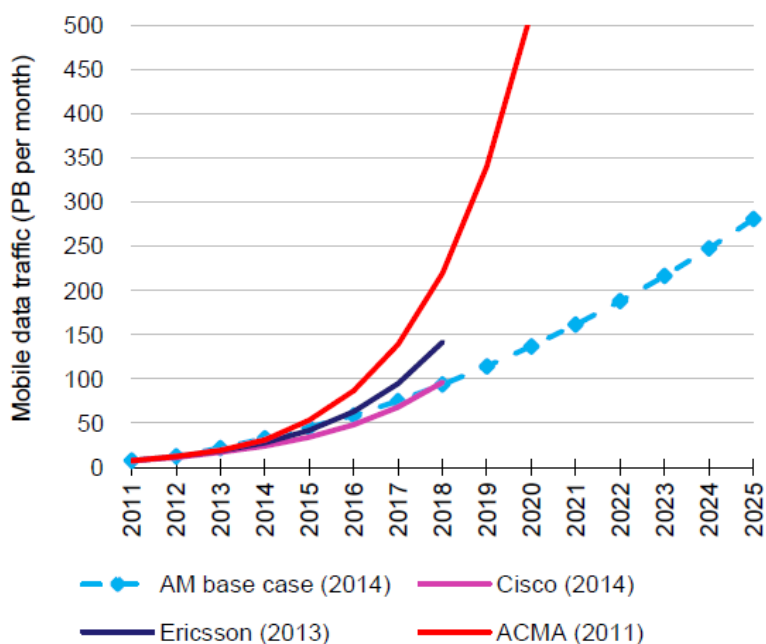
Analysys Mason

In 2013, the ACMA commissioned Analysys Mason to conduct a mobile network infrastructure forecast to examine the mobile infrastructure required for a given amount of mobile spectrum.³⁰

As part of this study, Analysys Mason produced a forecast of total data traffic based on the average of operator forecasts until 2015 and its own forecasts for the period 2016–2025. The forecast is shown in Figure 6. Analysys Mason predicted mobile data traffic would increase around 4.5 times from 2014 to 2020.

³⁰ Available on the [ACMA website](#).

Figure 6: Mobile data traffic in Australia, 2011–2025



Commentary on traffic forecasts

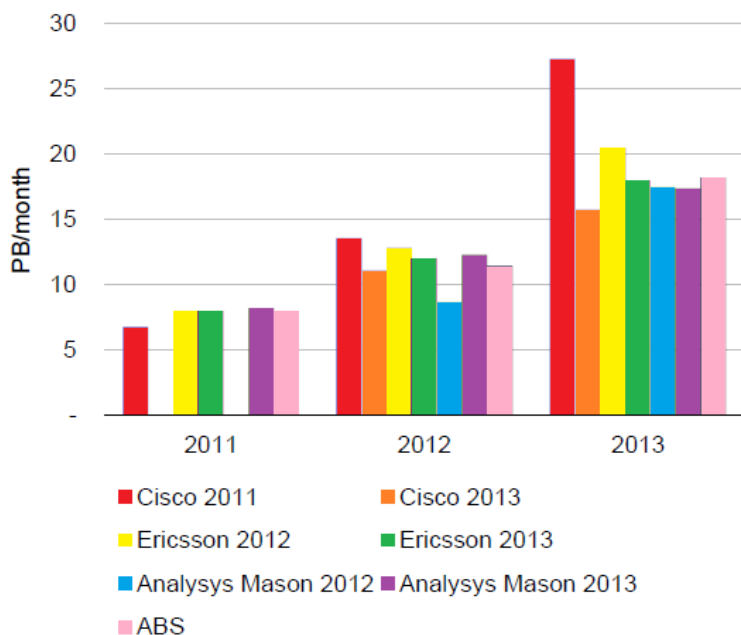
Whilst not directly commenting on the Australian specific growth case, both the Cisco and Ericsson forecasts illustrate the widespread predictions that mobile data will continue to grow at an increasing rate into the foreseeable future. However, it should be acknowledged that estimates have moderated in recent times.

The Australian growth forecasts in the Analysys Mason work illustrate that the global trend is expected to be reflected in the Australian environment, with traffic continuing to grow into the foreseeable future. While predictions indicate that the rate of growth will increase, these forecasts are subject to the uncertainties inherent in predicting the future progress based on a limited set of historical data and a set of associated assumptions.

As part of their research, Analysys Mason compared forecasts for the years 2010–13 with actual traffic figures to inform a judgement on how much reliance can be placed on traffic forecasts. Figure 7 shows the Australian Bureau of Statistics (ABS) estimate of actual monthly traffic alongside the country-specific estimates for Australia from Cisco and Analysys Mason’s research division. Ericsson does not provide a country-specific forecast so the effect of applying Ericsson’s global growth rates to the ABS starting point for 2011 is shown.

In Figure 7, if the ABS data (shown in pink) is taken as the ‘actual’ figure, then it can be seen that the Cisco 2011 prediction (shown in red) underestimated mobile traffic for 2011 by around 15 per cent, but the forecast for 2012 was nearly 20 per cent too high and the estimate for 2013 nearly 60 per cent too high. However, Cisco’s 2013 estimate (shown in orange) for 2013 was around 13 per cent too low. Ericsson’s 2012 global growth rates (shown in yellow) appear slightly high when applied to Australia, but the 2013 figures (shown in green) are very close to the actual outcome. Meanwhile, the 2012 Analysys Mason estimate for 2012 (shown in blue) was 24 per cent too low and both the 2012 (shown in blue) and 2013 (shown in purple) estimates for 2013 are about four per cent too low.

Figure 7: Estimates of Australian mobile traffic for 2011-2013



From this analysis by Analysys Mason, it can be concluded that there are challenges inherent in trying to predict mobile broadband traffic too far into the future. Even estimates that are only looking 18 months to two years into the future show a noticeable variance, both at the global level and at the country level, to what actually occurred as represented by the ABS figures. Such variations either over or under estimate the actual future traffic growth and, when used in studies, can be further compounded by uncertainties in other key modelling assumptions (including busy hour traffic, impact of Wi-Fi offload and data performance strategies).

Nonetheless, these forecasts as well as the ABS data support the assumption that mobile traffic growth will continue to grow into the future, more than likely at an increasing rate in (at least) the medium term.

Estimates of spectrum requirements

Three studies estimating future spectrum requirements for mobile broadband services are outlined below, including international and Australian studies. Estimating spectrum requirements is challenging for a number of reasons, including that:

- > one of the key inputs into any spectrum requirement prediction is mobile broadband traffic forecasts which, as discussed above, are subject to uncertainties
- > prediction and modelling of network topologies can be complex and vary across different areas
- > prediction and modelling of the rollout of new technologies and the subsequent improvements in spectral efficiency is difficult
- > variation across geographical areas and requirements across different frequency bands is also difficult to model
- > the trade-off between infrastructure, technology and spectrum is highly complex and may vary across geographies and carriers.

Another issue is that quantitative estimates do not capture the qualitative characteristics of the spectrum required to support growth in mobile broadband capacity. For example, estimates do not take into account requirements for a range of

frequency bands, or the level of international spectrum harmonisation and uptake needed for a frequency band to generate economies of scale for equipment and roaming benefits.

Recommendation ITU-R M.1768-1³¹

Recommendation ITU-R M.1768-1 describes a methodology for the calculation of terrestrial spectrum requirements estimation for International Mobile Telecommunications (IMT). This methodology was created in 2006 and revised in the ITU's studies towards WRC-15 Agenda item 1.1.

The model uses a range of input data, including market forecast information, from ITU studies including Report ITU-R M.2243³² and Report ITU-R M.2072³³, and predictions on improvements in radio technology aspects from ITU studies including Report ITU-R M.2074.³⁴ Using this model in combination with input data, the demand for spectrum in 2020 is estimated to be between 1340 MHz and 1960 MHz (in low and high demand situations respectively).

It is noted that these estimates are based on global data requirements and not representative of any particular country. It has been claimed in some reports that the ITU Model has overestimated spectrum needs.³⁵

Real Wireless—Study on the future UK spectrum demand for terrestrial mobile broadband applications

As part of their preparatory work for WRC-15 Agenda item 1.1, the United Kingdom (UK) spectrum regulator Ofcom commissioned Real Wireless to provide an estimate of UK mobile data traffic, and the resulting UK spectrum requirement, for the period from 2015 to 2030.³⁶ The estimates are based on market data and use the ITU-R spectrum estimation methodology specified in ITU-R Recommendation ITU-R M.1768-1. The results are shown in Figure 8.

³¹ Recommendation ITU-R M.1768-1 [Methodology for calculation of spectrum requirements for the terrestrial component of International Mobile Telecommunications](#), 2013.

³² Report ITU-R M.2243 [Assessment of the global mobile broadband deployments and forecasts for International Mobile Telecommunications](#), 2011.

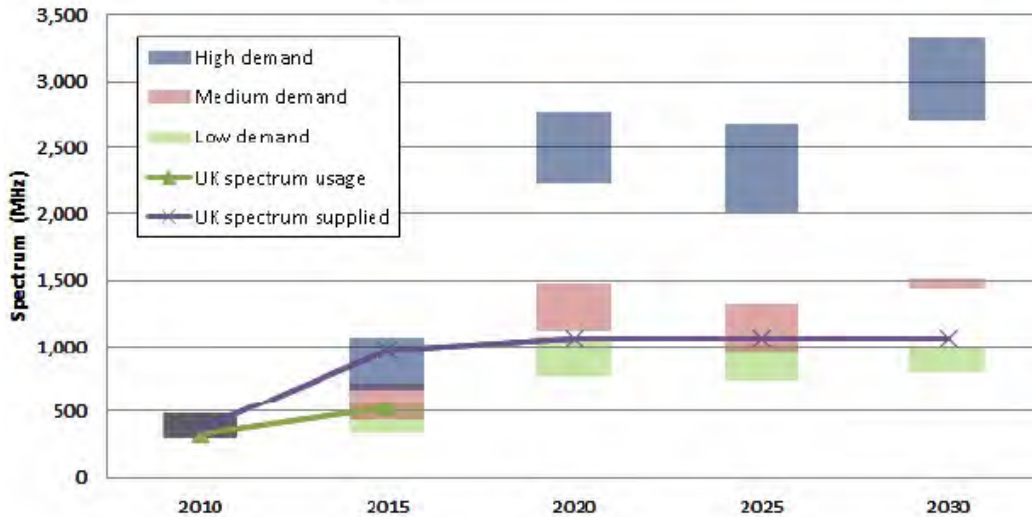
³³ Report ITU-R M.2072 [World mobile telecommunication market forecast](#), 2006.

³⁴ Report ITU-R M.2074, [Radio aspects for the terrestrial component of IMT-2000 and systems beyond IMT-2000](#), 2006.

³⁵ LS Telcom, [Mobile Spectrum Requirement Estimates: Getting the Inputs Right](#), 8 September 2014.

³⁶ Real Wireless, [Study on the future UK spectrum demand for terrestrial mobile broadband applications- Final Report](#), 27 June 2013.

Figure 8: Real Wireless low, medium and high demand baseline licensed spectrum estimate results (MHz) against UK spectrum usage in 2010 and 2015 and anticipated UK spectrum supply over time without future allocations of mobile broadband spectrum at WRC-15



Spectrum(MHz)		2010	2015	2020	2025	2030
High demand	Shared	295	665	2,230	2,010	2,710
	Dedicated	490	1,070	2,770	2,675	3,325
Mid demand	Shared	295	440	1,120	950	1,445
	Dedicated	490	720	1,475	1,315	1,515
Low demand	Shared	295	340	775	740	805
	Dedicated	490	575	1,080	1,015	995

Between 2015 and 2020, the estimated growth in spectrum requirements is driven by the estimated growth in traffic demand, along with the limited impact of small cell deployments and the initial deployment of LTE-A networks in 2020. LTE-A networks can accommodate more demanding services than LTE networks, but these services have higher overheads leading to larger overall spectrum requirements even at low initial demand estimates. Note also that there is a requirement to sustain sufficient capacity for LTE and LTE-A networks in parallel as the LTE-A networks roll out.

Analysys Mason—Mobile network infrastructure forecasting model

Within Australia, the ACMA engaged Analysys Mason to design a mobile network infrastructure forecasting model. An outcome of this engagement was a spreadsheet model³⁰, which uses the Analysys Mason mobile network traffic forecast (discussed above) and varying assumptions on spectrum availability to model the associated number of base stations required to satisfy the resulting demand for capacity.

The amount of spectrum allocated to mobile broadband services is considered as an independent variable in this model. The model calculates the number of sites required for a given set of assumptions about network traffic, spectrum availability, spectral efficiency and the extent of cellular coverage.

When traffic on a network increases to the point that congestion is caused at certain sites, the model assumes an operator will typically respond by utilising any additional carrier frequencies available to the operator at those sites. Once the spectrum available to the operator is fully utilised, the operator has three options (see *Addressing mobile broadband capacity growth*):

- > acquiring additional spectrum
- > network densification—deploying additional sites reduces the number of users per cell and hence increases the average amount of spectral resource available to each user in a cell
- > using more spectrally efficient technologies (for example, re-farming 2G or 3G spectrum for 4G, adding MIMO technology).

The model serves as a further indicator that attempting a definitive estimate of the total amount of spectrum required at a particular point of time in the future is both challenging and fallacious. Further, estimates of spectrum requirements tend to fluctuate significantly with each revision. They are therefore of limited value.

The most obvious indicator is that the ACMA's own estimates of additional mobile broadband spectrum requirements have not been realised. The ACMA had estimated the requirement for an additional 150 MHz of mobile broadband spectrum between 2010 and 2015. However, the spectrum already available/planned for mobile broadband in 2010 (which included digital dividend spectrum in the 700 MHz and 2.5 GHz bands) appears to satisfy the current (as of the first half of 2015) spectrum requirements of telecommunications operators in metropolitan areas at least.

Additional spectrum may be required in other areas where the total quantum of spectrum currently available for mobile broadband is lower. However, it is acknowledged that demand is potentially lower in these areas. This may be able to be met through expansion of current arrangements in metropolitan areas into regional and remote areas (such as the release of spectrum in the 1800 MHz band in regional areas via auction later this year). One of the factors that has contributed to the ACMA's own estimates of additional mobile broadband spectrum requirements not being realised, is that they were based on industry estimates of mobile traffic, which ended up being higher than both actual growth and more recent forecasts. This further reinforces the unreliability of discrete quantitative estimates of future traffic and consequently spectrum requirements for setting policy targets.

The technical network parameters used in the Analysys Mason model, such as network traffic and spectral efficiency, are highly variable and also have a high degree of associated uncertainty. However, the extra step between a mobile network traffic forecast and a spectrum requirement forecast involves the introduction of another uncertainty (that is even more difficult to model)—the commercial considerations that drive decisions by mobile operators regarding their preferred combination of measures to satisfy their network capacity requirements and the impact on the broader economy.

Overall, this model provides an indication of the spectrum-infrastructure trade-off for the mobile broadband industry in Australia. This model is just one of a number of tools used by the ACMA to inform its mobile broadband strategy.

Conclusions regarding mobile broadband growth

Forecasts of mobile broadband traffic growth, and subsequent estimates of spectrum requirements for mobile broadband, provide useful insights into general trends in mobile broadband growth. However, these studies vary significantly and therefore there are challenges in relying upon them for an exact quantitative assessment of future mobile broadband growth. From this discussion, it can be concluded that:

Demand for mobile broadband services (and therefore capacity) will continue to increase for the foreseeable future, though the rate of this increase is difficult to determine.

Strategies to address mobile broadband capacity growth internationally

The issue of addressing demand for mobile broadband capacity is being considered by countries around the world. A number of international regulators have developed strategies to address this issue, as outlined below.

Ofcom (United Kingdom)

In May 2014, Ofcom published its long-term strategy to address the increased use of data by mobile devices (the Statement).³⁷ This followed a consultation process in November 2013.³⁸

In the Statement, Ofcom notes that there are a number of ways to increase the capacity of mobile networks to deal with growth in the use of data, such as more efficient technology and greater use of small cells, but use of additional spectrum is likely to be part of the solution. The Statement also identifies and prioritises additional spectrum bands for potential mobile use.

Ofcom published a Call for Input on spectrum above 6 GHz for future mobile communications in January 2015.³⁹ The Call for Input (CFI) asks for stakeholder input on spectrum bands above 6 GHz that might be suitable for future mobile communication services, often referred to as 5G (the 5th generation of mobile services). In April 2015, Ofcom published an update on their 5G work considering bands above 6 GHz, which summarised the responses to the CFI, sets out Ofcom's current views on bands, and outlines next steps.⁴⁰

FCC (United States)

In March 2010, the Federal Communications Commission (FCC) released the National Broadband Plan.⁴¹ The Plan recommended that the FCC make available 500 MHz of new spectrum for wireless broadband, including 300 MHz for mobile flexible use within the next five years. In addition, on 28 June 2010, the US President via Presidential Memorandum directed the National Telecommunications and Information Administration to work with the FCC to make available 500 MHz of new spectrum for mobile and fixed broadband use.

In October 2014, the FCC released a Notice of Inquiry⁴² to explore industry's interest in using millimetre wave (mmW) spectrum for wireless mobile services. In particular, the FCC asked whether mmW spectrum above 24 GHz band could be used for 5G wireless mobile broadband services.

³⁷ Ofcom, [Mobile Data Strategy \(Statement\)](#), 28 May 2014.

³⁸ Ofcom, [Mobile Data Strategy \(Consultation document\)](#), 21 November 2013.

³⁹ Ofcom, [Spectrum above 6 GHz for future mobile communications](#), 16 January 2015.

⁴⁰ Ofcom, [Laying the foundations for next generation mobile services: Update on bands above 6 GHz](#), 20 April 2015.

⁴¹ FCC, [National Broadband Plan](#), 17 March 2010.

⁴² FCC, [Notice of Intention \(NOI\) to examine use of bands above 24 GHz for mobile broadband](#), 17 October 2014.

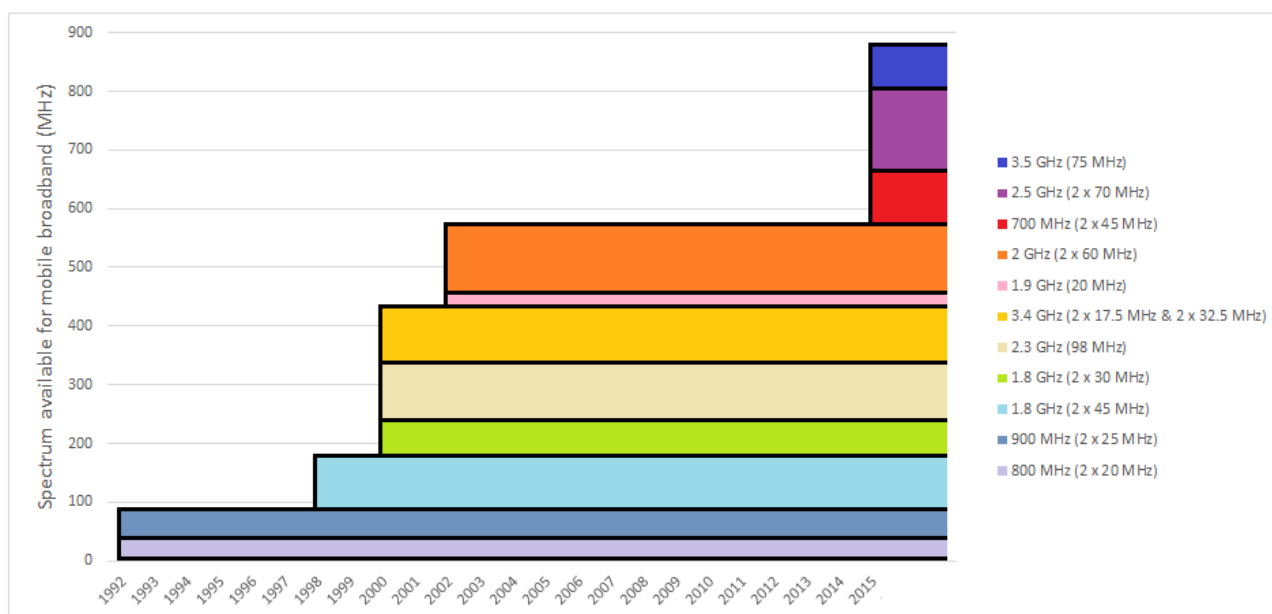
Industry Canada

In March 2013, Industry Canada released the Commercial Mobile Spectrum Outlook⁴³ to provide stakeholders with an overview of its overall approach and planned activities to ensure appropriate spectrum resources are available to meet the demand for commercial mobile services over the next five years. In the Outlook, Industry Canada set an objective of allocating a total of 750 MHz (including existing holdings) of spectrum to commercial mobile services by the end of 2017.

Currently available spectrum suitable for mobile broadband

The evidence suggests Australia currently has sufficient spectrum available for mobile broadband services in the short to medium term. Figure 9 shows the release of spectrum for mobile broadband services⁴⁴ over time in Australia by the ACMA and its predecessors. The vast majority of this spectrum has been made available in a manner that is harmonised with international arrangements and consistent with international standards such as those of 3GPP.

Figure 9: History of release of spectrum suitable for mobile broadband services in metropolitan areas in Australia⁴⁵



Harmonised spectrum arrangements support economies of scale, equipment/vendor choice and roaming opportunities. The ACMA, along with its predecessors, has been a strong supporter of spectrum harmonisation due to the substantial benefits to domestic spectrum management, including benefits to end users.

Appendix A—Currently available spectrum for mobile broadband purposes provides a comprehensive breakdown of currently available spectrum for mobile broadband.

⁴³ Industry Canada, [Commercial Mobile Spectrum Outlook](#), 7 March 2013.

⁴⁴ Spectrum is considered available for mobile broadband use if it is both allocated (or available for allocation) and suitable (based on international harmonisation/technology standardisation i.e. 3GPP) for mobile broadband.

⁴⁵ Note that 125 MHz of spectrum in the 3.6 GHz band was released in 2009 in regional and remote areas.

Table 1 below provides a high level summary of spectrum available by geographic area.

Table 1: Spectrum available for mobile broadband in Australia

Area	Available spectrum for mobile broadband (MHz)
Metropolitan (i.e. the five largest state capitals)	883
Regional	888
Remote	718

International comparison

In a recent study⁴⁶, Analysys Mason, on behalf of the GSMA, reviewed the spectrum currently used for provision of mobile services in eight Asia–Pacific countries. Australia was assessed as having ‘some need for additional spectrum’ (the lowest urgency measure used in the study—other categories were ‘significant need for more spectrum’ and ‘urgent need for more spectrum’). Australia was the only country in the study given the lowest rating.











This benchmark study was based on a metric of 3G and 4G spectrum per connection (Hz per connection). Australia was identified in the study as having 14.38 Hz/connection, getting close to twice the figure for Korea at 7.79 Hz/connection (the closest country to Australia in the table). While a simplistic metric, it does indicate that Australia is, at least by this metric, well ahead of other Asia–Pacific nations in terms of provision of spectrum for mobile broadband services, and supports the argument that Australia currently has sufficient spectrum available for mobile broadband services in the short to medium term.

In February 2013⁴⁷, the FCC released a white paper providing information on how much spectrum is being made available in the United States and other countries, including Australia, to support mobile broadband. Figure 10 summarises the results of the FCC analysis.

⁴⁶ Analysis Mason (on behalf of the GSM Association and Huawei), [Today, tomorrow and the future—managing data demand in the Asia Pacific](#), 19 November 2014.

⁴⁷ Federal Communications Commission, [The Mobile Broadband Spectrum Challenge: International Comparisons](#), Wireless Telecommunications Bureau, Office of Engineering and Technology, 26 February 2013.

Figure 10: Summary of total licensed spectrum available for mobile broadband in selected countries

Country	Current	Pipeline	Current + Pipeline
USA 	608	55+	663+
Australia 	478	230	708
Brazil 	554	0	554
China 	227	360	587
France 	555	50	605
Germany 	615	0	615
Italy 	540	20	560
Japan 	500	10	510
Spain 	540	60	600
U.K. 	353	265	618

Note: US pipeline numbers do not include the significant amount of spectrum that will be made available for mobile broadband from incentive auctions and federal repurposing.

The FCC analysis showed that Australia had the most spectrum available and ‘in the pipeline’ at the time. While this analysis is now two years old, Australia remains similarly well positioned in terms of the quantity of spectrum available to support mobile broadband.

However, direct comparison of the quanta of spectrum available in different countries does not take into account externalities such as demand for mobile broadband in each country, mobile broadband penetration rates, coverage, quality of service, technologies used and technology mix (for example, supply of service by other methods such as Wi-Fi or fixed-line infrastructure). The quantum of spectrum available for mobile broadband services does not provide an indication of the quality of the spectrum available, including the degree of international harmonisation of the bands available. It also does not demonstrate the optimality of the mix of bands (that is, bands at a range of different frequencies). Therefore, these types of comparisons cannot be used in isolation.

Conclusions regarding spectrum availability in Australia

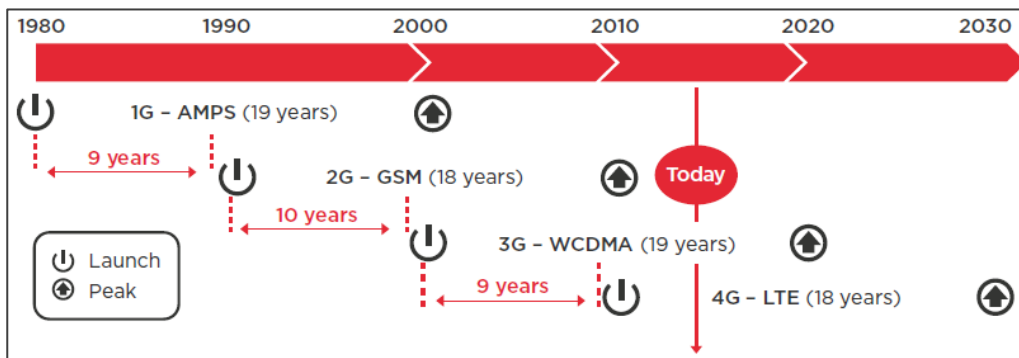
International comparisons and an assessment of the current environment within Australia suggest the following:

Australia currently has adequate spectrum available for mobile broadband purposes in the short to medium term, but it is likely that in the medium to long term, additional spectrum will be necessary.

Timeline for technology growth and spectrum availability

Historically, a new generation of mobile technology has been developed around every 10 years, with the first 1G system introduced in 1981, the first 2G system commencing rollout in 1991, the first 3G system introduced in 2001 and the first 4G (LTE) system appearing in around 2009. This technology evolution is illustrated in Figure 11.

Figure 11: Evolution of mobile technology by generation, 1980 onwards⁴⁸

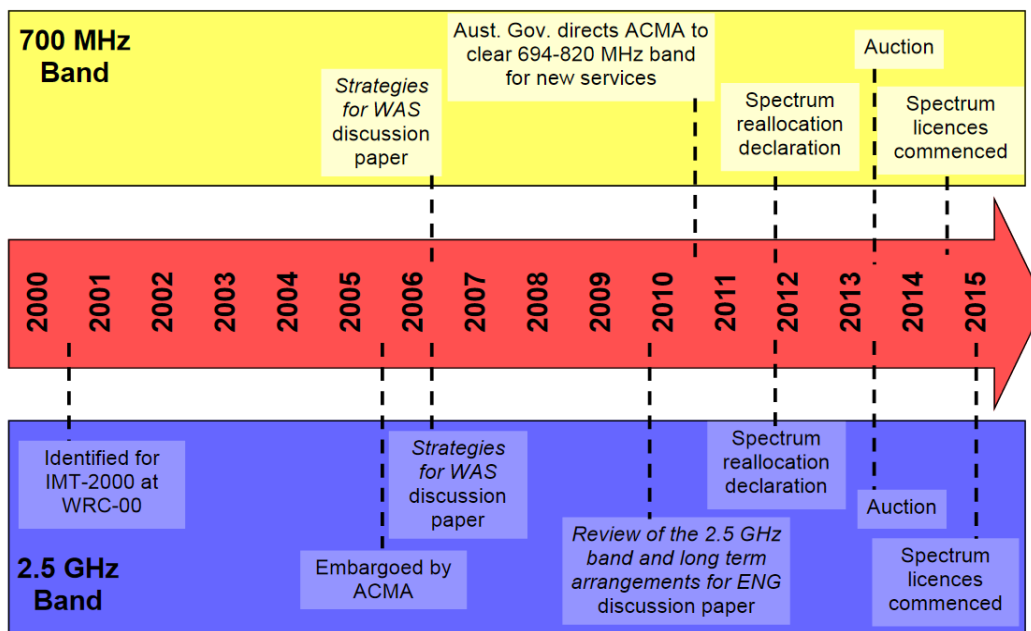


Further, in the past it has taken around 10 years from the commencement of standardisation to the launch of a new mobile generation technology. Additionally, another 18 to 20 years lapses historically after launch before the peak of a particular technology generation.

The international and Australian spectrum planning process for mobile broadband services has also historically taken a number of years. Figure 12 shows a timeline for the planning and eventual release of spectrum for mobile broadband in the 700 MHz and 2.5 GHz bands. It took nearly 15 years from international identification to the release of the 2.5 GHz band for mobile broadband services in Australia, and eight years from first considerations domestically to the release of the 700 MHz band in Australia.

⁴⁸ [Understanding 5G: Perspectives on future technological advancements in mobile](#), GSMA Intelligence, 8 December 2014.

Figure 12: Planning and release of spectrum for mobile broadband in the 700 MHz and 2.5 GHz bands



Therefore, while there are indications that there is not a critical need for additional spectrum for mobile broadband services at the present time, it can be concluded that:

Long lead-times will often remain for making additional spectrum available domestically for mobile broadband due to the timeframes for mobile broadband technology development and standardisation, international spectrum harmonisation and the domestic re-farming of spectrum.

Preparatory or contingency planning work needs to be undertaken in order to maintain options and to allow for timely reaction if and when additional spectrum becomes necessary. However, as discussed in the section *Addressing mobile broadband capacity growth*, additional spectrum is only one way in which the growth in mobile broadband capacity can be addressed.

Implications for other spectrum users

A major implication of spectrum management decisions in support of the growth in mobile broadband services is the potential impact on other spectrum users. The spectrum sought for expansion of mobile broadband services is in large part already used by other services. Therefore, if a particular band is found suitable for mobile broadband use in Australia and then identified and re-farmed for this purpose, coexistence and sharing arrangements, or alternative spectrum or methods of providing services, need to be sought for incumbent users. This can have large financial repercussions as well as affect service delivery and, therefore the benefits that these other services accrue for the nation.

The ACMA therefore needs to balance the requirements of, and impacts on, competing users and uses of the spectrum when considering how to address the growth in demand for mobile broadband capacity. In undertaking this balancing exercise, the ACMA will seek the outcome that maximises the overall public benefit derived from the use of the spectrum, consistent with the Act, the Principles and the ACMA's spectrum management decision-making framework.

An important conclusion from this discussion is:

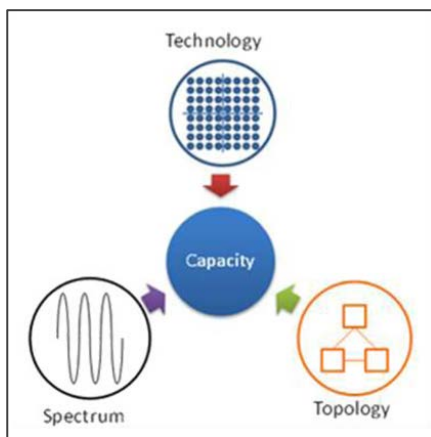
Spectrum will continue to be a key enabler for many other, non-mobile broadband, services that provide economic and societal benefits to Australia. The associated requirement for spectrum to enable these services will continue but may vary over time.

Addressing mobile broadband capacity growth

Overview—spectrum, infrastructure/topology and technology

Access to additional spectrum, or improved use of existing spectrum holdings, is only one of three factors that enable increases in mobile broadband capacity. Other factors that enable increases in mobile broadband capacity are the use of increasingly spectrally efficient technologies and deployment of appropriate network infrastructure and topologies. These three factors, depicted in Figure 13, are partially substitutable. Combinations of the three factors have been used to meet the growth in demand for mobile broadband capacity to date. It is therefore important to have a good understanding of these three factors, and the varying roles of industry and the ACMA in facilitating each of them.

Figure 13: Delivering capacity⁴⁹



Advances in technology

A number of new technologies and improvements to existing technologies are envisaged over the next decade that will assist in addressing mobile broadband capacity growth. These technologies have been widely discussed in detail elsewhere so are simply acknowledged (along with reference if further details are sought) below:

- > *Advanced antenna techniques*³⁸—including Multiple Input Multiple Output (MIMO) antenna techniques that allow multiple streams of data to be sent simultaneously. Other antenna related techniques, such as adaptive antennas and beam-forming techniques, are also set to improve capacity.
- > *Coordinated multipoint (CoMP)*—a tool to improve coverage, cell-edge throughput and system efficiency^{46,49,50,51}

⁴⁹ Real Wireless, [Techniques for increasing the capacity on wireless broadband networks](#), March 2012.

⁵⁰ Singh, S et al, [Coordinated Multipoint \(CoMP\) Reception and Transmission for LTE-Advanced/4G](#), International Journal of Computer Science and Technology, Vol. 3, Issue 2, April–June 2012.

⁵¹ Irmer, R et al, [Coordinated Multipoint: Concepts, Performance, and Field Trial Results](#), IEEE Communications Magazine, February 2011.

- > *Carrier aggregation*⁵²—where operators aggregate the spectrum they hold in one or more different frequency bands to achieve greater throughput to individual users. While it is acknowledged that this may only provide modest gains in spectral efficiency, this technique does provide flexibilities important in spectrum considerations.
- > *5G technologies*⁵³—while there is no set consensus on a definition of 5G, in general it is a combination of mobile technologies that support the throughput, latency and scalability requirements of next generation applications. 5G technologies are expected to exploit advanced MIMO technology with wider bandwidths and higher frequency bands.

Appendix B—Mobile broadband terminology describes some of the common terms used when discussing mobile broadband technologies.

By using the most advanced technologies, operators are ensuring they are getting the most out of their existing spectrum allocations. However, there are a number of practical considerations to take into account. These include considering the time lag for new handsets and other devices that utilise these technologies to be adopted by consumers, maintaining services to devices using older technology until newer technology penetration is sufficiently high, and facilitation of global roaming to and from other countries with less technologically advanced networks.

Spectral efficiency⁵⁴

While the technology advancements outlined lead to an overall effective improvement in spectral efficiency, specific techniques, including higher order modulation schemes and other coding techniques, are also an important consideration for spectrum planning into the future. Although it is not certain whether continued increases in spectral efficiency can be relied upon in the long term, improvements in the medium term appear likely.

⁵² [Carrier Aggregation in LTE-Advanced](#), Sequans Communications, 22 July 2013.

⁵³ [The LTE, LTE-Advanced & 5G Ecosystem: 2015-2020](#), SNS Research, 2015.

⁵⁴ Rysavy, P, [Challenges and Considerations in Defining Spectrum Efficiency](#), Proceedings of the IEEE, Volume 102, Issue 3, 14 February 2014.

What is spectral efficiency?⁵⁴

Spectral efficiency is a general measure of the data speed that can be realised with a given spectrum bandwidth, typically expressed in bits per second per Hz (bps/Hz). Spectral efficiency is often measured by reference to either peak spectral efficiency or average spectral efficiency.

Peak spectral efficiency is determined by the highest throughput a radio technology can deliver using a given amount of spectrum. This generally results from having a strong signal from the cell tower or the phone (depending on whether uploading or downloading data—in general use terms, it is a combination of the two). In 4th Generation (4G) technology terms, a high signal strength means the radio link is afforded the highest-order modulation scheme available and a low amount of coding overheads, which maximises the data speed. This is generally a best case scenario.

Average spectral efficiency on the other hand is a more 'real world' measure that considers the aggregate cell throughput in a deployed configuration of multiple cell sites. Therefore, average spectral efficiency is arguably a better measure of how a technology will serve a subscriber base and in determining the overall capacity of a network.

There have been several studies around the world claiming various figures for improvement in spectral efficiency. In Report ITU-R M.2290⁵⁵, the ITU-R expects that by 2020, a unicast area spectral efficiency of 7.3 bps/Hz/cell will be achievable. ITU-R spectral efficiency estimates appear to represent the high end of available estimates, with Analysys Mason assuming a lower figure of 2 bps/Hz/sector⁵⁶ for LTE/LTE-A in 2020⁵⁷. Real Wireless⁵⁸ also suggested reduced spectral efficiency values, and refer to area spectral efficiency values from the WINNER II study⁵⁹:

- > for RATG1⁶⁰, spectral efficiency is constant until 2020, at 0.4-0.7 bps/Hz/cell (depending on cell type)
- > for RATG2⁶¹ (LTE-A), spectral efficiency increases to 3-8 bps/Hz/cell (depending on cell type) in 2020.

Real Wireless assumes that spectral efficiency will improve by around 1.6 to 1.8 times (per five-year period) between 2015 and 2030.

Figure 14 plots an approximation of the average spectral efficiency for different systems, along with the peak efficiency required for operation at their maximum rates. An obvious trend is the widening gap between average and peak spectral efficiency. Earlier technologies were deployed operating at their maximum rates. This was because these systems were designed to operate at their maximum rates at the cell

⁵⁵ Report ITU-R M.2290, [Future spectrum requirements estimate for terrestrial IMT](#), December 2013.

⁵⁶ Spectrum efficiency per cell is equivalent to the spectrum efficiency per sector multiplied by the number of sectors in a cell. In this case, there are three sectors in a macrocell. Therefore, the equivalent spectrum efficiency is 6 bps/Hz/cell. Note that this is still less than the ITU-R figure.

⁵⁷ Analysys Mason assumed that the average spectral efficiency of a network increases in a linear fashion, between 1.0 bps/Hz/sector in 2012 to 2.6 bps/Hz/sector in 2025, for 4G (i.e. LTE/LTE-Advanced).

⁵⁸ Real Wireless, [Study on the future UK spectrum demand for terrestrial mobile broadband applications](#), June 2013.

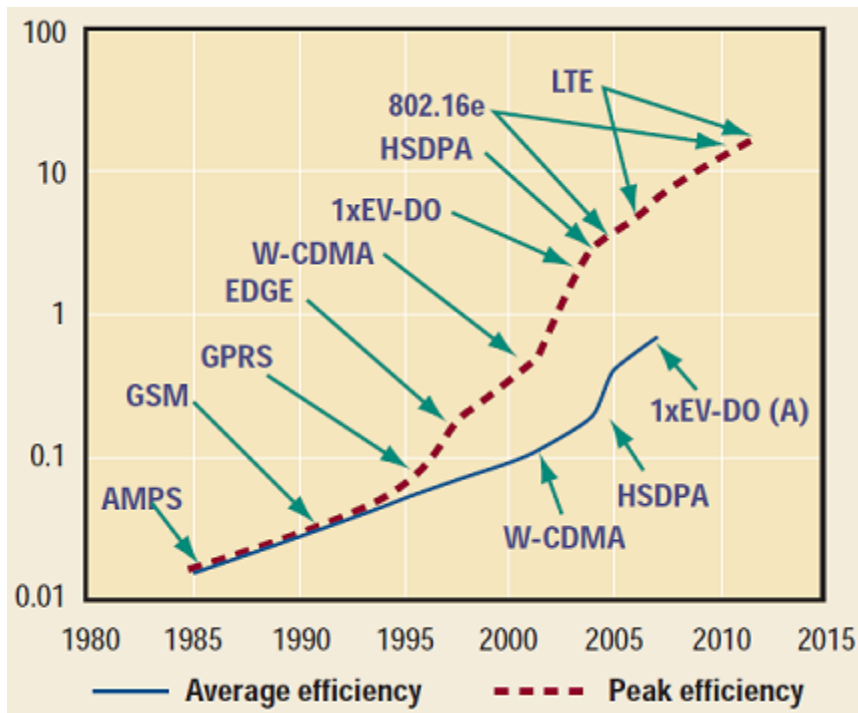
⁵⁹ Ojala et al, [IST-4-027756 WINNER II D5.10.2 v1.0—Spectrum requirements for systems beyond IMT-2000](#), March 2007.

⁶⁰ RATG1—Cellular mobile standards up to and including LTE.

⁶¹ RATG2—Cellular mobile standards LTE-A and beyond.

edge. Newer technologies employed reduced channel coding then higher-order modulation, which increased the peak user data rate but required a better signal-to-noise ratio (SNR) than was available at the cell edge.

Figure 14: Average versus peak spectral efficiency over time⁶²



Therefore, while improvements in spectrum efficiency are expected to contribute significantly to addressing the increasing demand in mobile broadband capacity, improvements will not necessarily be proportional to the increase in peak efficiency. Further, migration to newer technologies takes time, with legacy systems in operation often up to a decade or more after their introduction. While there is room for improvement in the rates of adoption of newer technologies, limiting factors including legacy user equipment will always present challenges.

Use of new technologies by Australian operators to increase capacity

Australian mobile broadband operators are in general relatively early adopters of new technologies. This has helped them to continually improve the spectral efficiency and capacity of their networks, even in the absence of new spectrum allocations.

Australian carriers have been some of the earliest adopters of LTE internationally. Telstra launched LTE services in all eight capital cities and 30 regional centres in September 2011⁶³ using spectrum in the 1800 MHz band. Telstra was also amongst the first carriers in the world to trial LTE in early 2010. Optus launched its 4G network using the 1800 MHz band in the Hunter region in April 2012.⁶⁴ Vodafone Hutchison Australia (VHA) activated LTE services in parts of Sydney, Perth, Melbourne, Adelaide, Brisbane, Newcastle and Wollongong in June 2013, using spectrum in the

⁶² Rumney, M, *What Next for Mobile Telephony?*, [Agilent Measurement Journal, Issue Three, 2007](#), Pg. 32–37.

⁶³ Taylor, J, [Telstra's 4G LTE goes public](#), ZDNet, 26 September, 2011.

⁶⁴ [Optus launches 4G network across Newcastle and Hunter region](#), Optus media release, 26 April 2012.

1800 MHz band.⁶⁵ In all cases, carriers migrated from 2G to 4G technologies within their 1800 MHz spectrum holdings and improved spectral efficiency.

In 2014, VHA expanded its use of LTE into the 850 MHz band⁶⁶, while Telstra and Optus expanded use of LTE into the 700 MHz⁶⁷ and 2.5 GHz⁶⁸ bands. Optus has also rolled out LTE in the 2.3 GHz band⁶⁸ and tested LTE in the 3.5 GHz band as part of its 'Gigasite' trial.⁶⁹

Telstra, Optus and Vodafone have also rolled out LTE-A carrier aggregation. Telstra initially used the 900 MHz and 1800 MHz bands, later using the 700 MHz and 1800 MHz bands⁷⁰. Optus initially used multiple carriers within the 2.3 GHz band⁷¹ and most recently trialled carrier aggregation in the 2.3 GHz and 2.5 GHz bands.^{68 72} Vodafone combines the 850 MHz and 1800 MHz bands.⁷³ Telstra⁷⁴, Optus⁷⁵ and Vodafone⁷⁶ all support LTE-A user equipment category 6 devices.

Optus and Vodafone have migrated from 2G to 3G within their holdings in the 900 MHz band, with Telstra announcing it will switch off its GSM network by the end of 2016.⁷⁷ In past years, carriers have also continuously extended and improved the performance of existing 3G networks by upgrading to high speed packet access (HSPA) and HSPA+, as well as rolling out dual carrier HSPA+ (DC-HSPA+)^{78 79} and smart antennas.⁸⁰

Overall, there has been good use of technological improvements to address the growth in mobile broadband demand and increase mobile broadband capacity. This has been a combined effort by the mobile broadband carriers in their early adoption of new technologies, and the development of technology flexible arrangements by the ACMA, which has allowed migration with minimal regulatory intervention.

Network infrastructure and topology

A standard trade-off in industry is between spectrum and infrastructure. Where insufficient spectrum is available, yet demand for capacity is high, additional infrastructure is needed to reduce or spread the number of users per cell. There have been a number of developments that have made increased use of infrastructure and

⁶⁵ [Vodafone Australia Launches LTE](#), Telegeography, 12 June 2013.

⁶⁶ Swan, D, [Vodafone turns on 4G in Adelaide](#), ITWire, 6 October 2014.

⁶⁷ Bender, A, [Better coverage, faster speeds expected across Australia](#), Computer World, 7 January 2015.

⁶⁸ Bender, A, [Optus clocks 480 Mbps in 4G carrier aggregation trial](#), Computer World, 2 March 2015.

⁶⁹ [Optus' Gigasite Trials Exceed 2.3 Gbps on the World's Biggest and Fastest Mobile Sites](#), Optus media release, 28 February 2014.

⁷⁰ Jennings, M, [We know a lot about firsts when it comes to Carrier Aggregation](#), Telstra Exchange, 23 September 2014.

⁷¹ Withers, S, [Optus claims carrier aggregation first](#), ITWire, 22 September 2014.

⁷² Connolly, B, [Vodafone boosts 4G capability](#), CIO, 12 March 2015.

⁷³ Healey, N, [Optus and Vodafone continue rollout of new 4G services](#), CNET, 17 November 2014.

⁷⁴ Volard, A, [Introducing the future of 4G: Telstra 4GX](#), Telstra Exchange, 3 November 2014.

⁷⁵ [Optus introduces world's first TD-LTE Advanced Carrier Aggregation Network](#), Optus Media Release, 19 December 2013.

⁷⁶ Healey, N, [Best smartphones for the Vodafone 4G+ network](#), CNET, 9 February 2015.

⁷⁷ Wright, M, [It's time to say goodbye old friend](#), Telstra Exchange, 23 July 2014.

⁷⁸ [Realising the LTE vision](#), Jane van Beelen, Telstra, 2013.

⁷⁹ [Vodafone outlines plans to give customers improved coverage, better reliability and higher speed Vodafone 3G+ and 4G services](#), Vodafone media release, 26 June 2012.

⁸⁰ [Telstra Mobile Smart Antenna](#), Telstra fact sheet.

topology techniques to address capacity growth more feasible, though some practical constraints remain.

The mechanisms that can be employed to utilise infrastructure and topology to address the growth in demand for mobile broadband capacity include:

- > *Traditional network densification*—increasing the number of macro level sites has traditionally been used to increase capacity.
- > *HetNets (Heterogeneous Networks)*—a combination of strategically placed small cells, Wi-Fi access points and distributed antenna systems to cost effectively offload coverage and capacity from traditional macrocell networks.
 - > *Small cells*—use of cells of reduced radius in innovative ways such as attaching small cells to billboards and bus stops.⁸¹
 - > *Advances in Wi-Fi technology*—Wi-Fi’s multiple access control techniques enable a high degree of spectrum sharing between multiple users of data services where latency and security may not be particularly critical. The use of techniques known as ‘Wi-Fi offload’ and ‘Wi-Fi backhaul’ can potentially play an important role in easing pressure on key spectrum bands.

Use of network infrastructure and topology by Australian operators to increase capacity

An analysis of the growth in the number of physical sites in the inner Sydney area was conducted to investigate the current use of network infrastructure by Australian operators as a means of addressing the growth in mobile broadband capacity. This analysis is presented in *Appendix C—Use of infrastructure to address capacity demand growth*. The number of sites used overall has remained relatively steady, however there has been growth in the number of sites using different frequency bands. This suggests that carriers are favouring deployment of additional frequency bands on existing sites rather than constructing new sites. The analysis also suggests that there is opportunity for carriers to make greater use of their existing spectrum holdings in some cases. Further, there is potentially opportunity for capacity growth through the sharing of sites across carriers. However, quantifying the level of growth available overall is difficult.

Subjectively, there are a number of areas where Australian operators could increase their use of network infrastructure and topology to increase capacity. For example, while some carriers are increasing their use of Wi-Fi^{80, 81} and small cells^{78, 82, 83}, carriers are not at this stage automatically offloading traffic from their mobile networks to their Wi-Fi networks.

Spectrum

As Australia’s spectrum regulator, the ACMA has responsibility for spectrum arrangements for mobile broadband services. There are three broad dimensions to the ACMA’s role in the supply of spectrum for mobile broadband services:

1. Ensuring spectrum management arrangements for bands expected to be used by mobile broadband services are made under suitable conditions including sufficient licence tenure and technology flexibility.

⁸¹ Ramli, D, [Vodafone partners with JCDecaux to boost inner-city mobile coverage](#), The Sydney Morning Herald, 16 February, 2015.

⁸² Seneviratne, C, [Small cell with big reward](#), Telstra exchange, 21 November, 2014.

⁸³ Gedda, R, [Optus releases femtocell mobile 3G ‘base station’](#), TechWorld, 28 July 2011.

2. Optimisation of arrangements for spectrum already available for mobile broadband services.
3. Re-farming (as appropriate) additional spectrum for potential use by mobile broadband services.

Spectrum management arrangements

Tenure and technology flexibility

As a general philosophy, the ACMA attempts to avoid establishing spectrum management arrangements that are limited to a specific technology type. In other words, the ACMA attempts to be technology flexible. This is particularly relevant when identifying and designing arrangements for mobile broadband services.

When the ACMA has formed the view that the highest value use of a particular frequency band has changed, or is expected to change to mobile broadband, arrangements for the future use of that band are optimised for the technologies that are likely to be employed in the foreseeable future. So while the ACMA's frameworks do not explicitly restrict the use of a band to a particular type of mobile broadband technology, in order to develop planning frameworks that optimise the efficient use of the spectrum, certain assumptions need to be made.

When demand is greater than supply for a band (as is the usual case where mobile broadband is determined to be the highest value use), the ACMA usually allocates spectrum via a market-based process (an auction). Successful bidders have flexibility to deploy whichever technology they choose as long as they remain within the boundaries of the technical framework. This technology flexibility not only provides scope for the use of a broad range of technologies, but also, ideally, the opportunity to migrate to newer technologies without regulatory intervention.

The ACMA also aims to provide a solid basis for investment by providing certainty of tenure. The ACMA does this in many cases by providing information about when arrangements in particular bands are being re-considered and may change. Services in bands that are not subject to a replanning process would have usual expectations regarding certainty of tenure. The majority of new spectrum for mobile broadband is made available by allocating spectrum licences. This provides licensees certainty of tenure for up to 15 years. In both cases, this gives users the long-term certainty required to invest in, maintain and eventually upgrade their networks.

From this it can be concluded that:

The use of technology flexible technical frameworks and provision of sufficient tenure will remain fundamental when designing spectrum management arrangements, including for mobile broadband services.

International harmonisation and standardisation

Ensuring spectrum made available for mobile broadband in Australia is internationally harmonised and consistent with technology standards is important to the ultimate success of a frequency band. International spectrum harmonisation and technology standardisation generates economies of scale, reducing the price of equipment. This is important for almost all radiocommunications services, but in particular for mobile broadband services and end-user devices such as handsets. Greater availability of reasonably priced and standardised end-user equipment means increased benefits for the broader economy.

International spectrum harmonisation is particularly important to a relatively low-population country like Australia. Australia can influence and encourage harmonised spectrum management arrangements by participating in international fora such as the Asia-Pacific Telecommunity (APT) and the International Telecommunication Union-

Radiocommunication Sector (ITU-R). Through this participation, Australia can shape harmonised spectrum arrangements that provide suitable options for domestic mobile broadband and associated co-existence arrangements, and also encourage development of arrangements that suit as many countries as possible to maximise the benefits from economies of scale. A balance must be pursued so that the benefits of international harmonisation are not diluted by too many options being identified.

From this it can be concluded that:

International spectrum harmonisation and technology standardisation will continue to play an important part in delivering equipment economies of scale, consumer choice and international roaming opportunities. International spectrum harmonisation and technology standardisation will continue to be considered when developing domestic arrangements.

Optimising existing spectrum releases

While the ACMA endeavours to plan spectrum arrangements to be as technology flexible as possible, technologies evolve and change, which can result in pre-existing spectrum management arrangements becoming less than ideal for new generations of technology. It is therefore important that existing arrangements are reviewed, and where necessary optimised, to allow mobile broadband operators to make the best use of the spectrum resources that are already available.

An example is the 890–915 MHz/935–960 MHz band, which was released in the early 1990s and planned for 2G GSM technology. Two of the operators with licences for this spectrum have begun to change the use of this spectrum by migrating to 3G technologies in some areas. However, the operators are limited by the spectrum arrangements, which provided 8.4 MHz paired to Optus and Telstra, and 8.2 MHz paired to VHA. This quantity of spectrum is not optimal for 3G and 4G technologies that operate most efficiently on channels 5 MHz (or multiples thereof) wide. In circumstances like these, arrangements need to be reviewed to determine how best to support new technologies into the future as older technologies are decommissioned. In the case of the 890–915 MHz/935–960 MHz band, reconfiguration into 2 x 5 MHz lots would result in an effective 2 x 10 MHz paired increase in 3G or 4G capacity.

From this it can be concluded that:

The review of established frameworks for spectrum already in use for mobile broadband services will continue to be necessary so that the efficient use of the spectrum is able to be maximised.

Re-farming of additional spectrum for use by mobile broadband services

When the demand for mobile broadband services is not met through the initial planning and optimisation of existing allocations, additional spectrum may be required. The challenge inherent in making additional spectrum potentially available for mobile broadband services is that there is very little spectrum appropriate for mobile broadband services that is not already used by other services.

While in some cases there are alternative non-wireless means of providing that service (for example, fixed point-to-point links can be transitioned to fibre in some cases), or that service can be provided in another frequency band, there are some services that have no alternative means of providing that service (for example, monitoring of the 'fingerprints of nature').

Even where alternatives are available, incumbent operators have often invested heavily in equipment and other systems that sometimes need to be replaced when shifting to another frequency band or non-wireless technology.

Therefore, identifying and releasing more spectrum to address mobile broadband capacity growth is a complex and time intensive task, given the potential impact on the broader community and incumbent services. As discussed in *Implications for other spectrum users*, the ACMA needs to balance the requirements of, and impacts on, competing users and uses of the spectrum when considering how to address the growth in demand for mobile broadband capacity.

Additional issue—Backhaul spectrum

To address the growth in mobile broadband capacity holistically, it is recognised that backhaul capacity is required to support cellular networks. Spectrum is required where backhaul is delivered wirelessly. Therefore, as part of its rounded approach to supporting mobile broadband capacity growth, the ACMA is monitoring and addressing this issue as required.

In July 2014, the ACMA consulted on proposed changes to channel arrangements for microwave fixed point-to-point services outlined in Radiocommunications Assignment and Licensing Instruction FX3 Microwave Fixed Services Frequency Coordination (RALI FX3). The aim of these changes was to provide new spectrum options capable of supporting demand for increased data rates in backhaul networks. As a result, a revision of RALI FX3 was published in October 2014.

The ACMA will continue to monitor developments in fixed service technologies, including in higher frequency bands to ensure that channel arrangements and technical requirements can support these technologies. Emerging trends in the use of in-band backhaul and class licensed bands will also be monitored, particularly as they relate to the use of small cells.

Conclusions regarding factors to address mobile broadband capacity growth

Based on the above discussion, it can be concluded that:

Increases in mobile broadband capacity will continue to be met through a combination of additional spectrum, improved technologies providing increased spectral efficiency, increased network infrastructure and new network topologies.

The ACMA, in its role as the national spectrum manager, has an important role to play in facilitating the continued growth in mobile broadband capacity and the provision of the associated benefits by establishing and maintaining appropriate spectrum management settings. This includes both facilitating spectrum moving to its highest value use by enabling re-purposing of bands, and in optimising existing spectrum management arrangements to ensure that spectrum already available for mobile broadband can be used as efficiently as possible. The tools and processes with which the ACMA manages the spectrum may be improved by changes to Australia's spectrum policy and management framework as a result of the implementation of the recommendations of the Spectrum Review.

Importantly, however, the ACMA is not alone in its responsibility and ability to facilitate growth in mobile broadband capacity. Providers of mobile broadband services have the ability and should face appropriate incentives to use other mechanisms that increase capacity, such as increases in network infrastructure and deployment of the latest spectrally efficient technology.

While to some extent there is a trade-off for providers between the cost of spectrum and the cost of infrastructure, the value of spectrum to providers of mobile broadband services appears to be higher than simply the cost of the infrastructure that acquiring additional spectrum offsets. Based on recent auction results, in some cases operators appear to be willing to pay for access to spectrum at amounts well above the cost of new infrastructure that could deliver an equivalent volume of traffic. This may be due to the fact that there is significant uncertainty around mobile traffic forecasts, spectral efficiency improvements, and the timing and quantum of additional spectrum releases. Spectrum can be quickly deployed in the event that a mobile network operator experiences unanticipated increases in mobile traffic, base station costs, or a slowdown in spectral efficiency, and this confers an option or insurance value to spectrum. In this way, ownership of spectrum can confer a value even when it is not in use. It is important that this source of value is recognised and taken into account in decision-making processes around spectrum management settings.

Proposed mobile broadband strategies and work program

Basis for action

The ACMA is of the view that supporting the continued growth of mobile broadband services would promote the object (section 3) of the Act, including the maximisation of the overall public benefit derived from using the radiofrequency spectrum, and would be consistent with the Principles. However, as required under the Act and the Principles, ACMA spectrum management decisions in support of mobile broadband need to be balanced with the impacts on other spectrum users.

ACMA assumptions

In reviewing its mobile broadband strategy, the ACMA has identified a number of assumptions to guide its considerations. These are outlined below and are used in the subsequent development of proposed mobile broadband strategies and an associated work program.

Assumptions

1. The highest value use of spectrum will vary between bands and geographic areas over time. As such, mobile broadband will only sometimes be the highest value use of a particular spectrum band (see *ACMA role*).
2. Mobile broadband services will continue to deliver societal and economic benefits to Australia and these benefits will increase with greater use of mobile broadband services made possible through increased network capacity (see *The importance of mobile broadband*).
3. Demand for mobile broadband services (and therefore capacity) will continue to increase for the foreseeable future, though the rate of this increase is difficult to determine (see *Drivers of mobile broadband growth*).
4. Australia currently has adequate spectrum available for mobile broadband purposes in the short to medium term, but it is likely that in the medium to long term, additional spectrum will be necessary (see *Currently available spectrum suitable for mobile broadband*).
5. Long lead-times will often remain to make additional spectrum available domestically for mobile broadband due to the timeframes for mobile broadband technology development and standardisation, international spectrum harmonisation and the domestic re-farming of spectrum (see *Timeline for technology growth and spectrum availability*).
6. Spectrum will continue to be a key enabler for many other, non-mobile broadband, services that provide economic and societal benefits to Australia. The associated requirement for spectrum to enable these services will continue but may vary over time (see *Implications for other spectrum users*).
7. The use of technology flexible technical frameworks and provision of sufficient tenure will remain fundamental when designing spectrum arrangements including for mobile broadband services (see *Tenure and technology flexibility*).
8. International spectrum harmonisation and technology standardisation will continue to play an important part in delivering equipment economies of scale, consumer choice and international roaming opportunities. International spectrum harmonisation and technology standardisation will continue to be considered when developing domestic arrangements (see *International harmonisation and standardisation*).

9. The review of established frameworks for spectrum already in use for mobile broadband services will continue to be necessary so that the efficient use of the spectrum is able to be maximised (see *Optimising existing spectrum releases*).
10. Increases in mobile broadband capacity will continue to be met through a combination of additional spectrum, improved technologies providing increased spectral efficiency, increased network infrastructure and new network topologies (see *Conclusions regarding factors to address mobile broadband capacity growth*).

The ACMA seeks comments on these assumptions. Do you agree? Why/Why not?

Proposed strategies

Taking into account both the assumptions and the spectrum management framework outlined in the section *ACMA role*, as well as the context of mobile broadband capacity growth and demand discussed earlier in this paper, the ACMA has developed a set of proposed strategies to address the growth in demand for mobile broadband capacity. A key part of these strategies is the articulation of a spectrum management process for the release of additional spectrum for mobile broadband.

Consistent with the Act and Principles, these proposed strategies are intended to guide the ACMA in its actions. While many of these strategies have been implicit in actions taken up to this point and/or otherwise adopted in the *Towards 2020 paper*, they are stated here to provide stakeholders with increased clarity on the ACMA's approach to managing mobile broadband related spectrum management issues.

These strategies are outlined below and subsequently discussed in greater detail:

1. Encouraging a holistic approach to addressing the outcome of mobile broadband capacity growth that balances the available inputs of spectrum, technology and network infrastructure/topology.
2. Articulation of a transparent spectrum management process for identifying potential future spectrum options for mobile broadband. This includes the identification of a pool of potential spectrum options at varying stages of consideration. This will provide the ACMA with capacity to react to demand requirements on a contingency basis if, and when, needed, and when the evidence suggests that mobile broadband is, or is becoming, the highest value use of a particular band.
3. Where possible, utilisation of the often long lead-times to assist in reducing the effect on incumbents arising from re-farming of spectrum to mobile broadband.
4. Exploration and, where appropriate, the adoption of opportunities for greater sharing between mobile broadband services and other services.
5. Engagement in international deliberations to influence the development of domestically suitable internationally harmonised spectrum options.

The ACMA expects the tools and processes with which it manages the spectrum to be improved by changes to Australia's spectrum policy and management framework as a result of the implementation of the recommendations of the Spectrum Review. To that end, the ACMA expects to review the strategies for addressing the growth in mobile broadband capacity following the implementation of the recommendations of the Spectrum Review.

Strategy 1: Holistic approach to mobile broadband capacity growth

The ACMA proposes to adopt a holistic approach to addressing mobile broadband capacity growth that seeks the balanced use of available mechanisms for delivering

capacity growth. The ACMA will focus on the desired outcome—that is, delivery of mobile broadband services enabled by mobile broadband capacity, with provision of spectrum being one of several inputs to delivering this outcome.

As mandated in the object of the Act, the ACMA must manage the radiofrequency spectrum to ‘encourage the use of efficient radiocommunication technologies so that a wide range of services of an adequate quality can be provided’.⁸⁴ In determining whether further re-farming of spectrum for mobile broadband is appropriate, the ACMA will consider the current state of advanced, spectrally efficient technologies uptake, as well as network infrastructure and topology deployments in efforts to deliver greater mobile broadband capacity using currently available spectrum.

Examples of the questions likely to be asked by the ACMA in this regard include:

- > Are all existing mobile broadband spectrum holdings being utilised (and if not, why not)?
- > Have existing mobile broadband spectrum holdings been (or in the process of being) re-purposed for newer technologies—such as evolution from 2G, to 3G or 4G—in order to increase network capacity?
- > Have mobile broadband network operators deployed adequate network infrastructure? For example, in high demand areas has the density of base stations deployed in one or more bands increased over time in order to increase network capacity?
- > Have mobile broadband network operators adopted capacity increasing network topologies, such as small cells and heterogeneous networks (including Wi-Fi offload)?

The ACMA acknowledges that discrete metrics may not be available to inform these questions and that a degree of subjective analysis and judgment may be necessary. However, the ACMA believes that identifying these expectations and seeking input from the mobile broadband industry will serve an important purpose in focusing consideration on the broad range of factors available to addressing growth in capacity demand.

Strategy 2: Transparent spectrum management planning process

The ACMA does not intend to identify, as part of its mobile broadband strategy, specific quantitative metrics or targets for the amount of spectrum that is required for mobile broadband services over time. As discussed in the *Estimating spectrum requirements to support mobile broadband growth* section, the models used in these estimates are highly sensitive to inputs and variables, which are difficult to accurately predict too far into the future. This makes long-term estimates useful as a guide for trend analysis, rather than for determining specific spectrum targets.

Importantly, quantitative estimates provide no insight into the frequency band required and do not capture other important qualitative aspects. These aspects include properties such as the desired characteristics of the spectrum (for example, whether high or low band spectrum is appropriate), international spectrum harmonisation and technology standardisation factors. Instead, the ACMA will not concentrate its efforts solely on quantity but also quality, and rather than focus on arbitrary and simplistic targets, seek to provide the right spectrum at the right time to address the growth in demand for mobile broadband capacity.

⁸⁴ Paragraph 3 (d) of the [Act](#).

In lieu of quantitative metrics, and as a measure to provide transparency and greater certainty to all spectrum holders, the ACMA intends to adopt a strategy that identifies a process for the consideration of potential bands for re-allocation to mobile broadband. This would include a criteria based assessment for when bands should (or should not) progress along the various stages of the process. In concert with this process, the ACMA would identify a range of bands at varying stages of consideration for potential re-farming for mobile broadband.

The intention of this strategy is to develop a contingency plan by identifying a pool of potential spectrum options available for mobile broadband at various stages in the process. In line with Principle 4—to the extent possible, promote both certainty and flexibility—this will provide the ACMA with the ability to be agile and flexible. It will also enable the ACMA to respond in a timely manner to demand requirements if and when decisions are made that the highest value use of a band warrants re-farming for mobile broadband. This will provide transparency to all stakeholders, including incumbents who will have a clear understanding of what steps are to be taken and what issues are to be considered in potentially re-farming. It would also provide certainty to the mobile broadband industry as to what spectrum may become available and under what broad conditions.

Importantly, such a strategy acknowledges the often long lead-times often associated with re-farming spectrum by ensuring that long-term work continues on potential future options, even if in the near term there is no need for additional spectrum releases.

Stages and considerations for band re-farming

The process of replanning a band can be broken down into three broad stages. These three stages could be applied to any band replanning exercise. However, they are detailed here as general guidance on the process to be adopted in the context of repurposing a band for mobile broadband services.

The stages of replanning are outlined in Table 2.⁸⁵

⁸⁵ Under the Act, the minister and the government have a policy-making role that is independent of the ACMA.

Table 2: Stages of the process for consideration of additional spectrum for mobile broadband services

Stage	Description
0 Monitoring	'Business as usual' monitoring of international and domestic mobile broadband spectrum trends.
1 Initial investigation	Initial investigation and scoping of potential options for domestic re-farming of a band informed by preliminary technical assessment. If initial scoping and technical assessment shows potential, preliminary assessment of highest value use of the spectrum undertaken.
2 Preliminary replanning	Identification of replanning/re-farming proposals (including mechanisms to address incumbent issues) informed by detailed technical sharing studies and analysis of ongoing incumbent spectrum needs. A comprehensive assessment of the highest value use of the band undertaken.
3 Re-farming	Decisions made on preferred re-farming proposal.
3a Replanning	Detailed band/channel replanning undertaken to support the change in the use of the spectrum to mobile broadband. Where possible, long-term transition arrangements put in place, allowing incumbents to transition voluntarily over time (incumbents retain their rights during the replanning stage in accordance with the Act). In this scenario, a change of spectrum use commences at this stage with final implementation concluded in stage 3b via an allocation of spectrum to specific mobile broadband users. However, in some cases it may be appropriate for spectrum already available for mobile broadband to be replanned in order to better support new mobile broadband technologies. In this scenario, a change of use of spectrum and subsequent allocation is not necessary, hence stage 3b is not required and the process stops here.
3b Allocation (to mobile broadband users)	Development of final technical framework and allocation instruments/tools for near term re-farming. Incumbents are obliged to transition to new arrangements or cease operations in specified time frame (incumbents rights are varied and/or removed in accordance with the Act). Mobile broadband users are given the opportunity to acquire and use re-farmed spectrum.

Stage 0: Monitoring

Initial consideration of additional spectrum bands for mobile broadband begins with the ACMA's business-as-usual monitoring of international and domestic mobile broadband spectrum trends. In this stage, the ACMA would maintain awareness of trends and interest in potential bands for mobile broadband.

In this stage, there would be no direct action required by stakeholders. However, there is an opportunity for stakeholders to keep the ACMA apprised of developments and issues in various bands (either advocating or opposing potential use of mobile broadband services in the band). These bands would be noted within the ACMA's Five year spectrum outlook (FYSO).

Criteria for progressing from Stage 0 to Stage 1

In forming a judgement as to whether a band should progress to the next stage in the process, the ACMA will take into account a range of factors, including:

- > the level of interest or investigation of the band nationally or internationally for mobile broadband services
- > incumbent use of the spectrum, including whether there is any strong reason why the band is fundamentally unsuitable or otherwise not viable for mobile broadband
- > technology standardisation developments (for example, progress within the 3GPP)
- > international spectrum harmonisation considerations such as whether the band is under investigation by the ITU or APT, or in overseas jurisdictions.

Stage 1: Initial investigation

If and when the analysis in the monitoring stage indicates that a frequency band shows some potential for future re-farming for mobile broadband, the band would progress to the initial investigation stage.

The initial investigation will involve scoping of potential planning options for domestic re-farming of a band informed by preliminary technical assessment. Typically, these planning options would be consulted on in a discussion paper. An example of this type of consultation is the ACMA's paper on the 1.5 GHz band released in 2012.⁸⁶

If the initial scoping and technical assessment shows potential, a preliminary assessment of the highest value use of the spectrum will be undertaken. While it is envisaged that at this stage the assessment would be mainly qualitative, quantitative elements could be included. This will be informed by information collected in the consultation process. It will include consideration of issues such as relocation or retuning costs for incumbent users and any detrimental effects to service delivery that a change in use of the band may cause. It should be noted that the highest value use may vary across different geographical areas. For example, the highest value use may be mobile broadband services in metropolitan and regional areas but may be the incumbent service in remote areas. Assessments of highest value use are discussed further below.

In this stage, there would again be no action required by stakeholders. However, there is an opportunity for stakeholders to inform the ACMA about their views and the effects of different options on incumbent and potential new services so the costs and benefits can be accurately gauged and considered. During Stage 1, a spectrum embargo would be considered to ensure that the status of a band remains stable for the duration of the planning process.⁸⁷

⁸⁶ The ACMA discussion paper *Planning for mobile broadband in the 1.5 GHz mobile band* is available on the [ACMA website](#).

⁸⁷ More information on spectrum embargoes is available on the [ACMA website](#).

Criteria for progressing from Stage 1 to Stage 2

The broad criteria for progression to Stage 2 is the result of the preliminary assessment indicating that the highest value use of the band may be, or soon will be, for mobile broadband.

Stage 2: Preliminary replanning

If the preliminary assessment of highest value use of the band indicates that mobile broadband may be, or soon will be, the highest value use of the frequency band in all or some areas, the band would progress to Stage 2 to commence preliminary replanning. This stage will involve identification of proposals (including mechanisms to address incumbent issues) informed by detailed technical studies and analysis of ongoing incumbent spectrum needs. Responses to the consultation process undertaken in Stage 1, including preferred planning options and approaches to accommodating incumbent services, will be used to inform this analysis.

Once developed, these proposals will be consulted on in a discussion paper. An example of this type of consultation is the ACMA's second discussion paper in the review of the 803–960 MHz band.⁸⁸

As part of Stage 2, a comprehensive assessment of the highest value use of the spectrum will be undertaken. While not all costs and benefits are easy to quantify, the quantitative value of costs and benefits will be determined to the extent possible at this stage. The assessment of the highest value use will be informed by information collected during both the consultation processes in Stage 1 and Stage 2, including information on any relocation or retuning costs of incumbent users, and any detrimental effects to service delivery changes described in the proposals may cause. Assessments of highest value use are discussed further below.

The immediate effect on stakeholders in Stage 2 is unlikely to be greater than in Stage 1. However, there is again an opportunity for stakeholders to inform the ACMA about the effects of different options on incumbent and potential new services so the costs and benefits can be accurately gauged and considered. In this stage, transition plans and associated timeframes will start to be discussed so stakeholders will have increased clarity on the timeframes for potential changes.

Criteria for progressing from Stage 2 to Stage 3

The broad criteria for progression to Stage 3 is the result of the comprehensive assessment indicating that the highest value use of the band may be, or soon will be, for mobile broadband.

Stage 3: Re-farming

If the comprehensive assessment of highest value use of the band indicates that mobile broadband is expected to be the highest value use of the frequency band in all or some geographic areas, then this band would progress to Stage 3 to commence re-farming. In re-farming, the ACMA takes decisions and actions to effect the change in use of the spectrum from its current use to mobile broadband.

There are two potential sub-stages of re-farming that could be pursued: replanning and allocation. In general, replanning and allocation would occur sequentially as part of the re-farming stage where the use of the band is transitioned to mobile broadband from another, pre-existing use. However, it is possible that the use of a band is already for mobile broadband and therefore re-farming between uses is not required. In this

⁸⁸ The ACMA discussion paper *The 803–960 MHz band: options for future change* is available on the [ACMA website](#).

case, however, it may be desirable for the planning/licensing arrangements already in place to be revised and updated to better support changes in mobile broadband technology.

The two sub-stages of re-farming are outlined below:

- > *Stage 3a: Replanning*—Detailed band/channel replanning would be undertaken by the ACMA with long-term transition arrangements and no immediate allocation of spectrum to mobile broadband users. This would allow affected incumbents to migrate to new arrangements voluntarily over a longer time frame. Under the replanning sub-stage, incumbents retain their rights for the short to medium term. However, in some cases it may be appropriate for spectrum already available for mobile broadband to be replanned in order to better support new mobile broadband technologies. In this scenario, a change of use of spectrum and subsequent allocation is not necessary, hence Stage 3b is not required and the process stops here.
- > *Stage 3b: Allocation*—Final technical framework and allocation instruments/tools are developed for the near-term re-farming of spectrum to mobile broadband and allocation of licences to mobile broadband users. Incumbents would be obligated to transition to new arrangements or cease operations in a comparatively short time frame. At this sub-stage, incumbents' rights are varied and/or removed, in accordance with the Act.
- > The ACMA normally uses a price based allocation (an auction) when demand for spectrum is greater than supply. The ACMA also normally allocates spectrum licences for wide area, high value type spectrum uses such as mobile broadband. In this scenario, re-allocation of a band from apparatus to spectrum licensing is usually utilised and requires a spectrum re-allocation declaration (section 153B).

Stage 3 is where incumbent users are affected. However, the timeframes for transition, and therefore the timing between replanning and allocation, will vary depending on circumstances. An example of Stage 3 re-farming where only replanning (3a) is being undertaken is the optimisation of the 3.4 GHz technical framework for use by internationally harmonised next-generation mobile technologies.⁸⁹ An example of Stage 3 re-farming where both replanning (3a) and allocation (3b) are being undertaken is the release of an additional 2 x 60 MHz of spectrum in regional Australia in the 1800 MHz band.⁹⁰

Assessments of highest value use

As part of Stages 1 and 2 of the proposed process for consideration of additional spectrum for mobile broadband services, assessments of highest value use are set to be undertaken. As outlined above, the ACMA uses a total welfare standard as its overarching framework when assessing the optimal approach to individual spectrum management issues. As such, in considering the highest value use for a given spectrum band, the ACMA considers the impact that a change in use would have on all parties in the economy. Importantly, this will include not only an assessment of those costs and benefits that can be readily quantified monetarily, but also those costs/benefits that are more intangible and may be harder to quantify.

⁸⁹ More information is available on the [ACMA website](#).

⁹⁰ [Re-allocation declaration and competition limits for regional 1800 MHz spectrum band](#), The Hon Malcolm Turnbull MP, Minister for Communications, 29 May 2015.

Therefore, when considering the potential change of use of spectrum to mobile broadband, the ACMA is likely to include an assessment of:

1. The incremental costs imposed on firms providing services using the spectrum that is to be refarmed. Technical constraints may even prevent the service currently provided by incumbents on that spectrum from being provided.
2. The increase in the price of services provided by incumbent spectrum users. This will depend on :
 - > whether the prices rise or consumers incur incremental costs in accessing the service or a substitute services via an alternative platform
 - > whether other platforms can provide the same services or services that are regarded by consumers as very close substitutes.In some cases, the repurposing of a frequency band may render incumbent services unviable.
3. The increase in producer surplus for producers providing new services using the repurposed spectrum.
4. The increase in consumer surplus if it enables:
 - > new valuable services to be rolled out in Australia or reduces the cost of those services being brought to market, or increases competition in the provision of services
 - > consumers to capture the benefits of global economies of scale in the production of equipment for utilisation in the bands
 - > consumers to reap the benefits of global roaming that is possible in part because of international standardisation.
5. The wider costs and benefits, including those that are more intangible and may be harder to quantify.

This approach is being increasingly adopted internationally. An example is the cost-benefit analysis of changing the use of the 700 MHz band to mobile services conducted by Ofcom, published on 28 May 2014.⁹¹

The ACMA will conduct further work to develop a framework for conducting these assessments of highest value use. To that end, comment is sought on the aspects that should be included in the framework for conducting assessments of highest value use.

What factors should be taken into account in assessing the highest value use of a spectrum band? What particular costs and benefits should be taken into account? Is there a recognised measure of these costs and benefits?

Strategy 3: Utilising the often long lead-times to reduce effect on incumbents

Overall, it appears that Australia currently has sufficient spectrum available for mobile broadband services in the short to medium term (see *International comparison* section).

The identification and release of spectrum for mobile broadband services is usually a long-term process, which can occur over the space of a decade. The ACMA acknowledges, and will continue to make use of, the often long lead-times for spectrum identification and release. As outlined above in the new proposed mobile

⁹¹ Ofcom, [Consultation on the future use of the 700 MHz band- Cost-benefit analysis of changing its use to mobile services](#), 28 May 2014.

broadband spectrum management planning process, the ACMA will endeavour to provide extended timeframes for the transition of incumbents and implementation of new arrangements, where possible.

This will include performing the ground work for identification and release of spectrum early to reduce the time required to re-allocate spectrum and therefore increase flexibility and agility to make spectrum available for mobile broadband if and when required. This will include development of alternatives for incumbent services to enable early and long-term transition to reduce the effect on these services, and provide greater investment certainty by allowing equipment changes or replacement due to re-farming to be more closely aligned with normal business cycles.

Strategy 4: Exploring opportunities for increased spectrum sharing

Spectrum sharing is at the heart of spectrum management and a key tool in maximising the utility achieved through use of the spectrum resource. Spectrum sharing is consistently advocated by the ACMA as outlined in Principle 4 of the Principles.

However, given the nature of mobile broadband services, sharing has traditionally been limited to the establishment of co-existence arrangements between mobile broadband and other services at geographic and spectral boundaries. In effect, in a specific geography and frequency band, mobile broadband has been provided exclusive access to the spectrum.

So far, this form of exclusive spectrum access for mobile broadband, with sharing limited to geographic and spectral boundaries, has been deemed appropriate both in Australia and around the world. This is because of the complexity and compromises inherent in ubiquitous services, such as mobile broadband sharing with other services in the same spectrum space.

Emerging technologies and regulatory approaches (such as licensed shared access (LSA), authorised shared access (ASA)⁹², licence assisted access (LAA) and LTE in unlicensed spectrum (LTE-U)⁹³) may, however, offer new opportunities for more finessed forms of sharing between mobile broadband and other spectrum uses in the same spectrum space. In line with Principle 5—to balance the cost of interference and the benefits of greater spectrum utilisation—these new techniques will, however, need to be carefully assessed to determine if the increased spectrum utility delivered by this type of sharing is on balance worth the resulting cost, complexity and compromises.

The ACMA will therefore continue to investigate, and pursue where practical, opportunities for new and innovative forms of spectrum sharing to both provide greater flexibility of spectrum access to mobile broadband and reduce or remove impacts on existing spectrum users.

Strategy 5: Influencing international spectrum harmonisation

As discussed earlier in this paper (see *International harmonisation and standardisation* section), international mobile broadband technology standardisation and spectrum harmonisation enable economies of scale (providing both cheaper devices and a larger choice in devices for both network operators and consumers) and international

⁹² LSA and ASA are concepts that allow spectrum that has been licensed to another user to be used by more than one entity in areas or at times when it is not being used by the incumbent or primary user.

⁹³ LTE-U refers to the use of LTE technology in unlicensed (or class licensed in Australia) spectrum. LAA is a term used by some vendors to describe the same technology.

roaming benefits. The ACMA considers these outcomes to be beneficial and able to be influenced.

Section 3 of the Act states that it is a goal of the management of the radiofrequency spectrum to promote Australia's interests concerning international agreements, treaties and conventions relating to radiocommunications or the radiofrequency spectrum.

The ACMA will therefore continue to facilitate Australia's participation in regional and international fora including the ITU-R and the APT. The ACMA will seek to influence decisions made in relation to the identification of spectrum bands for mobile broadband (that is, IMT) and associated technical and regulatory arrangements supporting the co-existence of mobile broadband with other services. For relatively small radiocommunications markets like Australia, the value of a frequency band is closely linked to the international device ecology—that is, the availability of a wide range of devices, including lower cost options.

In doing this, the ACMA can promote options that are viable for possible implementation in Australia. While a wide range of IMT identification options (not all of which would necessarily be adopted in Australia) is generally desirable, a balance must be pursued so that the benefits of international harmonisation are not diluted by too many options being identified.

In this regard, it is important to note that an IMT identification, while often desirable, does not mandate use of that band in Australia; nor is it prerequisite for a band's use for mobile broadband in Australia. In other words, the ACMA will take account of a band's IMT status in its domestic deliberations, but the presence or absence of an IMT identification does not dictate its use in Australia one way or another.

In addition, deliberations on the identification of spectrum for IMT must also consider the impacts such an identification may have on other spectrum uses and users. This is because while an IMT identification does provide flexibility and opportunities for the mobile broadband sector, it can also increase uncertainty for existing uses and users or create possible co-existence issues that need to be considered and addressed. Collectively this leads the ACMA to believe that, as always, a balanced approach that considers both the costs and benefits of supporting IMT identification is appropriate.

The ACMA seeks comments on these strategies. In particular, comment is sought on the stages of band replanning and considerations for advancing through these stages.

Proposed work program

Current and ongoing projects

The ACMA intends to continue with current projects as deemed appropriate. Table 3 outlines where each of these projects is positioned within the overall process outlined under *Strategy 2: Transparent spectrum management planning process*, along with some of the frequency bands that are currently in the monitoring stage.

Table 3: Position of current mobile broadband spectrum planning projects

Stage	Current mobile broadband spectrum planning projects
0 Monitoring	600 MHz 2 700–2 900 MHz 5 350–5 470 MHz Above 6 GHz
1 Initial investigation	1.5 GHz 1980–2010 MHz and 2170–2200 MHz 3575–3700 MHz
2 Preliminary replanning	850 MHz expansion band 900 MHz
3 Re-farming	3.5 GHz PTS release 700 MHz unsold lots 1800 MHz rural/remote

Stage 0: Monitoring

Bands that are currently in the monitoring stage of the process for consideration of additional spectrum for mobile broadband services are the 600 MHz band, the 2 700-2 900 MHz band, the 5 350–5 470 MHz band and frequencies above 6 GHz.

The 600 MHz band is being allocated or considered for allocation in countries such as the United States and Canada. While this band is being monitored by the ACMA, it is likely to remain at the monitoring stage for the long-term, given Australia’s current use of the band for terrestrial broadcasting of digital television.

The 2 700–2 900 MHz band is also being monitored by the ACMA. This is currently being considered as part of the deliberations around WRC-15 Agenda item 1.1. Coexistence issues with radar use of the band is a major issue to be addressed when considering potential use of the band for IMT. In addition to possible band segmentation approaches, this band may have the potential for innovative regulatory approaches such as LSA or ASA, where radar users remain primary licensees and mobile broadband licensees are allowed access when and where it is not used for primary services. The ACMA will continue to closely monitor this issue and engage with stakeholders via the international preparatory process.

The 5 350–5 470 MHz band has been considered as part of the deliberations around WRC-15 Agenda item 1.1. While it is unlikely that this band will be pursued at WRC-15, there is continued interest in pursuing this band for mobile broadband under a new Agenda item for WRC-19. However, suitable regulatory measures to enable coexistence with the Earth exploration-satellite (active), radiolocation and radionavigation services need to be investigated. The ACMA will continue to closely monitor this issue and engage with stakeholders via the international preparatory process.

The use of spectrum above 6 GHz is being considered internationally for 5G services. This is being pursued as a new agenda item for the WRC-19. The ACMA will continue to closely monitor this issue and engage with stakeholders via the international preparatory process.

Stage 1: Initial investigation

Bands that are currently in the initial investigation stage of the process for consideration of additional spectrum for mobile broadband services are the 1.5 GHz band, the 2 GHz MSS band and the 3575–3700 MHz band.

1.5 GHz

The ACMA released *Planning for Mobile Broadband in the 1.5 GHz mobile band* in May 2012 to gather further information on issues related to the potential use of the 1427.9–1510.9 MHz band (the 1.5 GHz mobile band) for mobile broadband services.⁹⁴ Up to 2 x 35 MHz (1427.9–1462.9 MHz and 1475.9–1510.9 MHz) of FDD spectrum, or up to 90 MHz (1427–1518 MHz) of TDD or unpaired mobile downlink (UMD) spectrum, could potentially be released from the 1.5 GHz mobile band for mobile broadband services.

In response to the discussion paper, stakeholders noted that the impact on incumbent fixed services could be significant and alternative options and a transition plan would need to be developed before this band could be re-farmed for different services. Since that time, the 1.5 GHz band has been investigated as part of WRC-15 Agenda item 1.1.

The ACMA has identified that the impact on aeronautical telemetry services and fixed services, including the Digital Radio Concentrator System (DRCS) will need to be considered in any re-farming considerations.

Further consideration of this frequency band by the ACMA will not occur until after WRC-15, when international decisions on identification of this band for IMT are made and when international interest in the band becomes clearer.

1980–2010 MHz and 2170–2200 MHz

The use of the MSS in 1980–2010 MHz and 2170–2200 MHz in Australia was formalised in April 2002 in the Mobile-Satellite Service (2 GHz) Frequency Band Plan 2002 (MSS band plan) to support a planned worldwide MSS network under the name ICO-P. The frequencies of operation were subsequently included in the Radiocommunications (Communication with Space Object) Class Licence 1998⁹⁵ to authorise ubiquitous communication with the system.

The system did launch one satellite in 2001, however, follow-up satellites to complete the constellation of 12 did not eventuate and, ultimately, the ITU suppressed the 1980–2010 MHz and 2170–2200 MHz band of the ICO-P filing.

In Australia, there are no space or space receive apparatus licences issued⁹⁶ in this frequency range, and as an outcome of the review of the 2.5 GHz band⁹⁷, the ACMA has developed arrangements to support the introduction of television outside broadcast (TOB) in the frequency ranges 1980–2010 MHz and 2170–2200 MHz on an interim basis.

In March 2012, the *Television Outside Broadcast (1980–2110 MHz and 2170–2300 MHz) Frequency Band Plan 2012* was made that revoked the MSS band plan.

⁹⁴ Available on the [ACMA website](#).

⁹⁵ Available at www.comlaw.gov.au/Details/F2005C00245.

⁹⁶ RADCOM extraction 17 February 2015.

⁹⁷ Refer to www.acma.gov.au/theACMA/25-ghz-band-review.

The frequency ranges remain subject to Embargo 23⁹⁸ to support TOB and future replanning activities.

The 2 GHz MSS bands are already subject to a global IMT identification via footnote 388 of the *Australian Radiofrequency Spectrum Plan 2013*. These bands are directly adjacent to the existing 2.1 GHz band used for mobile voice and broadband services. WP 5D of the ITU-R is currently discussing a possible definition of IMT channel arrangements in the 2 GHz MSS bands.

The ACMA will continue to monitor developments within WP 5D, and globally, on this issue.

3575–3700 MHz

In November 2009, the ACMA released arrangements for fixed and mobile broadband services in the 3575–3700 MHz band in regional and remote Australia. At the time, the band was not released in capital cities (except Hobart) to preserve future planning options within these areas.

Since that time, the 3600–3700 MHz band has been investigated as part of WRC-15 Agenda item 1.1. In addition, Australia has indicated its interest in adding its name to existing footnotes in the ITU Radio Regulations identifying the 3400–3600 MHz band for IMT.

Similarly to the 1.5 GHz band, further consideration of this frequency band by the ACMA will not occur until after WRC-15, when international decisions on identification of this band for IMT are made and when international interest in the band becomes clearer.

Stage 2: Preliminary replanning

Bands that are currently in the preliminary replanning stage of the process for consideration of additional spectrum for mobile broadband services are the 800 MHz and 900 MHz bands.

The ACMA commenced a review of arrangements in the 803–960 MHz band in May 2011 with the release of the discussion paper *The 900 MHz band—Exploring new opportunities*.⁹⁹ The second discussion paper in the review, *The 803–960 MHz band—Exploring options for future change*, was released in October 2012.¹⁰⁰

The review has revealed an opportunity to expand spectrum licensed segments at 825–845/870–890 MHz (the ‘850 MHz band’) by up to 15 MHz (paired) for mobile broadband use. This proposed mobile broadband spectrum (referred to as the 850 MHz expansion band) could be used by commercial or emergency services networks or a combination of both. The spectrum licensed segments at 825–845/870–890 MHz are currently used by Telstra 3G services and Vodafone Hutchison Australia (VHA) to provide both 3G and 4G services. The spectrum from 803–820 MHz is part of Australia’s digital dividend and could be easily repurposed. 855–870 MHz is used by fixed services, land mobile services and some outmoded technologies, which would need to be relocated to allow for mobile broadband use.

The 890–915 MHz/935–960 MHz band is an example of replanning pre-existing mobile broadband spectrum (rather than replanning of spectrum used for other

⁹⁸ Embargo 23 is available from www.acma.gov.au as in force and last revised September 2013.

⁹⁹ Available on the [ACMA website](http://www.acma.gov.au).

¹⁰⁰ Available on the [ACMA website](http://www.acma.gov.au).

services). Spectrum arrangements in this band are currently not optimal for 3G and 4G technologies. Optus and Telstra hold 2 x 8.4 MHz and VHA holds 2 x 8.2 MHz when 3G and 4G technologies operate most efficiently on channels 5 MHz (or multiples thereof) wide. As discussed in *Optimising existing spectrum releases*, reconfiguration into 2 x 5 MHz lots would result in an effective 2 x 10 MHz paired increase in 3G or 4G capacity.

The ACMA is currently finalising decisions on the 803–960 MHz band, including the 850 MHz expansion band. It is likely that some re-farming will arise from this review, which will mean that parts of this band will elevate to Stage 3.

Stage 3: Re-farming

Bands that are currently in the re-farming stage of the process for consideration of additional spectrum for mobile broadband services are 700 MHz unsold lots, the 1800 MHz band in rural and remote areas and spectrum in the 3.5 GHz (3400–3425 MHz and 3492.5–3542.5 MHz) band for use by fixed and mobile broadband services. In these cases, the decision has been made to allocate the band to mobile broadband services and final technical frameworks and re-allocation instruments have been or are being prepared.

700 MHz unsold lots

Between 23 April and 7 May 2013, the ACMA conducted the digital dividend auction, offering nine 2 x 5 MHz lots of 700 MHz spectrum and 2.5 GHz spectrum for sale. Telstra bought four of the nine lots of 700 spectrum and Optus bought two lots at the \$1.36 MHz/pop reserve price, at a total cost of around \$1.9 billion. The remaining three lots of 2x5 MHz are referred to as the ‘unsold lots’.

The former minister directed¹⁰¹ the ACMA to report on the appropriate procedures for the allocation of the unsold lots having regard to:

- A. the prices achieved for spectrum licences allocated as a result of the auction
- B. prevailing market circumstances that may have an impact on the value of the relevant spectrum.

The ACMA reported to government in September 2014. As is the case for unallocated spectrum generally, interested parties can make expressions of interest in the unsold spectrum to either the ACMA or the government.

1800 MHz

There is increasing demand for access to spectrum in the 1710–1785 MHz and 1805–1880 MHz frequency ranges (the 1800 MHz band) from various industry sectors to deploy mobile broadband services in regional and remote Australia. In 2012, the ACMA commenced a review of the current arrangements for the 1800 MHz band. This review considered both the short- and longer-term planning for the band. The initial focus was on settling short-term arrangements for access for mobile broadband services to the band. The current regulatory arrangements limit the ability for prospective users to access the 1800 MHz band for mobile services. Within regional and remote Australia, the band has historically been used by fixed services.

In response to the review, the ACMA proposed to allow coexistence arrangements for fixed and mobile services in remote areas utilising Public Telecommunication Service (PTS) apparatus licences. A review on the effectiveness of these arrangements will be undertaken in 2017. In regional Australia, the ACMA is of the view that a price-based

¹⁰¹ [Australian Communications and Media Authority \(Spectrum Allocation – Post-Auction Review\) Direction No. 1 of 2013](#)

allocation of spectrum licences would resolve some of the current concerns regarding access to the 1800 MHz band in regional areas. Furthermore, the ACMA considers this to be a key long-term objective for the band and is looking to streamline any re-allocation process to provide access to the regional 1800 MHz band as soon as possible.

A draft recommendation to the minister to identify those parts of the 1800 MHz band not already identified in regional areas for spectrum licensing was released by the ACMA on 10 February 2015.¹⁰² The ACMA sent the final recommendation to the minister in May 2015. On 29 May 2015, the minister announced that an additional 2 x 60 MHz of spectrum would be made available in 1800 MHz band in regional Australia.¹⁰³ The ACMA is planning to hold an auction for the spectrum in late November 2015.

3.5 GHz

On 20 October 2014, the Minister for Communications directed the ACMA¹⁰⁴ to make available 75 MHz of spectrum in the 3400–3425 MHz and 3492.5–3542.5 MHz frequency ranges (3.5 GHz band) for use by the NBN. The ACMA was required to have licensing arrangements in place to support this by the end of April 2015.

In April 2015, the ACMA implemented new licensing and technical arrangements to support fixed and mobile broadband services in the 3.5 GHz band. The revised arrangements for this band aim to optimise its use for time division duplex (TDD) technologies.

While this spectrum has been made available for the NBN (to deliver fixed wireless broadband), the spectrum is also suitable for mobile broadband and is included here for that reason.

Transparency on the mobile broadband process

The ACMA intends to use the Five year spectrum outlook (FYSO) as a tool to keep stakeholders informed on the suite of mobile broadband spectrum planning projects. As discussed, frequency bands identified for monitoring, as well as those frequency bands in the later stages of the process for consideration of additional spectrum for mobile broadband services, will be noted in the FYSO.

As outlined, once a frequency band moves into the initial investigation phase and beyond, the ACMA will release discussion papers and engage with stakeholders in the usual fashion.

The ACMA seeks comments on the proposed work program. Are there any frequency bands or other projects which should/should not be included in the current work program? Why/Why not?

¹⁰² Available on the [ACMA website](#).

¹⁰³ 'Residual lots' of spectrum that are currently subject to spectrum licensing, but are not allocated, in Adelaide, regional South Australia and Cairns/Townsville will also be allocated.

¹⁰⁴ [Australian Communications and media Authority \(3.5 GHz frequency band\) Direction 2014](#), 20 October 2014.

Invitation to comment

Making a submission

The ACMA invites comments on the issues set out in this discussion paper or any other issues relevant to the ACMA's spectrum management strategy on mobile broadband matters. Submissions should be made:

By email: freqplan@acma.gov.au

By mail: The Manager
Spectrum Planning Section
Spectrum Infrastructure Branch
Australian Communications and Media Authority
PO Box 78
Belconnen ACT 2616

The closing date for submissions is COB, Friday 23 October 2015.

Electronic submissions in Microsoft Word or Rich Text Format are preferred.

Media enquiries should be directed to Emma Rossi on 02 9334 7719 or by email to media@acma.gov.au. Any other enquiries may be directed by email to freqplan@acma.gov.au.

Effective consultation

The ACMA is working to enhance the effectiveness of its stakeholder consultation processes, which are an important source of evidence for its regulatory development activities. To assist stakeholders in formulating submissions to its formal, written consultation processes, it has developed [Effective consultation—a guide to making a submission](#). This guide provides information about the ACMA's formal written public consultation processes and practical guidance on how to make a submission.

Publication of submissions

In general, the ACMA publishes all submissions it receives. The ACMA prefers to receive submissions that are not claimed to be confidential. However, the ACMA accepts that a submitter may sometimes wish to provide information in confidence. In these circumstances, submitters are asked to identify the material over which confidentiality is claimed and provide a written explanation for the claim.

The ACMA will consider each confidentiality claim on a case-by-case basis. If the ACMA accepts a claim, it will not publish the confidential information unless authorised or required by law to do so.

Release of submissions where authorised or required by law

Any submissions provided to the ACMA may be released under the *Freedom of Information Act 1982* (unless an exemption applies) or shared with certain other Commonwealth Government agencies and certain other parties under Part 7A of the *Australian Communications and Media Authority Act 2005*. The ACMA may also be required to release submissions for other reasons including for the purpose of parliamentary processes or where otherwise required by law (for example, under a court subpoena). While the ACMA seeks to consult submitters of confidential information before that information is provided to another party, the ACMA cannot guarantee that confidential information will not be released through these or other legal means.

Privacy

The [Privacy Act 1988](#) imposes obligations on the ACMA in relation to the collection, security, quality, access, use and disclosure of personal information. These obligations are detailed in the [Australian Privacy Principles](#) that apply to organisations and Australian Government agencies.

The ACMA may only collect personal information if it is reasonably necessary for, or directly related to, one or more of its functions or activities.

The purposes for which personal information is being collected (such as the names and contact details of submitters) are to:

- > contribute to the transparency of the consultation process by clarifying, where appropriate, whose views are represented by a submission
- > enable the ACMA to contact submitters where follow-up is required or to notify them of related matters (except where submitters indicate they do not wish to be notified of such matters).

The ACMA will not use the personal information collected for any other purpose, unless the submitter has provided their consent or the ACMA is otherwise permitted to do so under the Privacy Act.

Submissions in response to this paper are voluntary. As mentioned above, the ACMA generally publishes all submissions it receives, including any personal information in the submissions. If a submitter has made a confidentiality claim over personal information which the ACMA has accepted, the submission will be published without that information. The ACMA will not release the personal information unless authorised or required by law to do so.

If a submitter wishes to make a submission anonymously or use a pseudonym, they are asked to contact the ACMA to see whether it is practicable to do so in light of the subject matter of the consultation. If it is practicable, the ACMA will notify the submitter of any procedures that need to be followed and whether there are any other consequences of making a submission in that way.

Further information on the Privacy Act and the ACMA's privacy policy is available at www.acma.gov.au/privacypolicy. The privacy policy contains details about how an individual may access personal information about them that is held by the ACMA, and seek the correction of such information. It also explains how an individual may complain about a breach of the Privacy Act and how the ACMA will deal with such a complaint.

Appendix A—Currently available spectrum for mobile broadband purposes

The table below shows the frequency bands that are currently available and/or used for mobile broadband services. Spectrum is considered available for mobile broadband use if it is both allocated (or available for allocation) and suitable (based on international harmonisation/technology standardisation i.e. 3GPP) for mobile broadband.

Band	3GPP band #	Frequency range (MHz)	Duplex type	Paired BW (MHz)	Unpaired BW (MHz)	Total BW (MHz)	Metro BW (MHz)	Regional BW (MHz)	Remote BW (MHz)	Additional information
700 MHz	28	703–748 paired with 758–803	FDD	45	-	90	90	90	90	Spectrum licensed Australia-wide Used for mobile broadband (4G)
800 MHz	5	825–845 paired with 870–890	FDD	20	-	40	40	40	40	Spectrum licensed Australia-wide Used for mobile broadband (3G/4G)
900 MHz	8	890–915 paired with 935–960	FDD	25	-	50	50	50	50	Apparatus licensed Australia-wide Used for mobile telephony and broadband (2G—GSM900 and 3G—WCDMA/HSPA)
1800 MHz	3	1710–1785 paired with 1805–1880	FDD	75	-	150	150	30	0	Spectrum licensed Australia-wide (restricted to the lower 2 x 15 MHz in regional areas) Used for mobile broadband (4G and GSM-R)
1900 MHz	33	1900–1920 unpaired	TDD	-	20	20	20	20	20	Spectrum licensed in capital cities only Not currently used in cities Apparatus licenced in regional and remote areas Used for broadband

Band	3GPP band #	Frequency range (MHz)	Duplex type	Paired BW (MHz)	Unpaired BW (MHz)	Total BW (MHz)	Metro BW (MHz)	Regional BW (MHz)	Remote BW (MHz)	Additional information
2.1 GHz	1	1920–1980 paired with 2110–2170	FDD	60	-	120	120	120	120	Spectrum licensed in metro areas and 2 x 20 MHz in regional areas Used for mobile broadband (3G/4G) Apparatus licensed in regional and remote areas. (2 x 40 MHz regional, 2 x 60 MHz remote) Used for 3G/4G mobile telephony and broadband
2.3 GHz	40	2302–2400 unpaired	TDD	-	98	98	98	98	98	Spectrum licensed in capital cities and regional areas Used for mobile and fixed broadband (4G)
2.5 GHz	7	2500–2570 paired with 2620–2690	FDD	70	-	140	140	140	140	Spectrum licensed Australia-wide Used for mobile broadband (4G)
3.5 GHz	42	3400–3575 unpaired	TDD	-	175	175	175	175	35	100 MHz spectrum licensed in capital cities and major regional centres. 65 MHz spectrum licensed in regional areas. 75 MHz apparatus licensed in capital cities, 110 MHz in regional areas and 35 MHz in remote areas Used for fixed and mobile broadband.
3.6 GHz	42 & 43	3575–3700 unpaired	TDD	-	125	125	0	125	125	Apparatus licensed in regional and remote areas Used for broadband.
TOTAL						1008	883	888	718	

Appendix B—Mobile broadband terminology¹⁰⁵

IMT

International Mobile Telecommunications (IMT) encompasses IMT-2000 and IMT-Advanced, and defines the requirements of 3rd generation (3G) and 4th generation (4G) technologies. It is expected that IMT will continue to evolve towards 5th generation (5G) technologies with IMT-2020.¹⁰⁶

IMT-2000

IMT-2000 is the standard developed by the International Telecommunication Union Radiocommunication Sector (ITU-R) covering 3G technologies. Various radio technology options have been included in the IMT-2000 standard. These include WCDMA (Wideband Code Division Multiple Access), HSPA (High-speed packet access), LTE (Long Term Evolution) and WiMAX (Worldwide Interoperability for Microwave Access).

Operators and equipment vendors have marketed some IMT-2000 technologies (including LTE and WiMAX) as 4G, even though they are strictly included in the IMT-2000 technology group.⁴⁸

IMT-Advanced

IMT-Advanced is the ITU standard for 4G technologies. IMT-Advanced only identified two technologies as meeting the criteria laid out by the ITU-R for 4G. These are:

- > LTE-A (Long Term Evolution-Advanced)
- > WiMAX Release 2.

As noted above, there has been some blurring of the definition of IMT-Advanced and its correlation to 4G, with some operators and equipment vendors marketing IMT-2000 technologies as 4G.

IMT-2020¹⁰⁶

The ITU-R began a program to develop IMT-2020¹⁰⁶ in early 2012. IMT-2020 sets the stage for 5G research activities. 5G is still in early development and is therefore not defined at this stage.

Wi-Fi

Wi-Fi is a brand name used to market wireless local area network (WLAN) technology based on the 802.11 family of standards developed by the Institute of Electrical and Electronics Engineers (IEEE).

¹⁰⁵ [The spectrum policy dictionary](#), GSMA, February 2014.

¹⁰⁶ The use of the term 'IMT-2020' is a placeholder terminology and the specific nomenclature to be adopted for the future development of IMT is expected to be finalized at the Radiocommunication Assembly 2015.

See the [ITU website](#) for more details.

Appendix C—Use of infrastructure to address capacity demand growth

The number of sites in an area in inner-Sydney from November 2007 to November 2014 was used to analyse the use of infrastructure by Australian carriers to address the growth in demand for mobile broadband capacity.

The area analysed is shown in Figure C1. The area is a 20 kilometre circle around the point with coordinates 33°53'0.06"S, 151° 7'47.85"E. This area was selected as it is heavily populated and therefore would have been largely covered by each of the three major Australian operators' mobile networks at November 2007. Therefore, any significant increase in the number of sites in this area after that time can be assumed to be attributable to capacity in-fill.

Figure C1: Area analysed in infrastructure study



The analysis was limited to the three major Australian mobile network operators—Optus, Telstra and VHA. It was also limited to the 850 MHz band, the 900 MHz band, the 1800 MHz band and the 2.1 GHz band. Details of the quanta of spectrum currently held by each carrier in these four frequency bands are shown in Table C1.

Table C1: Spectrum holdings in Sydney

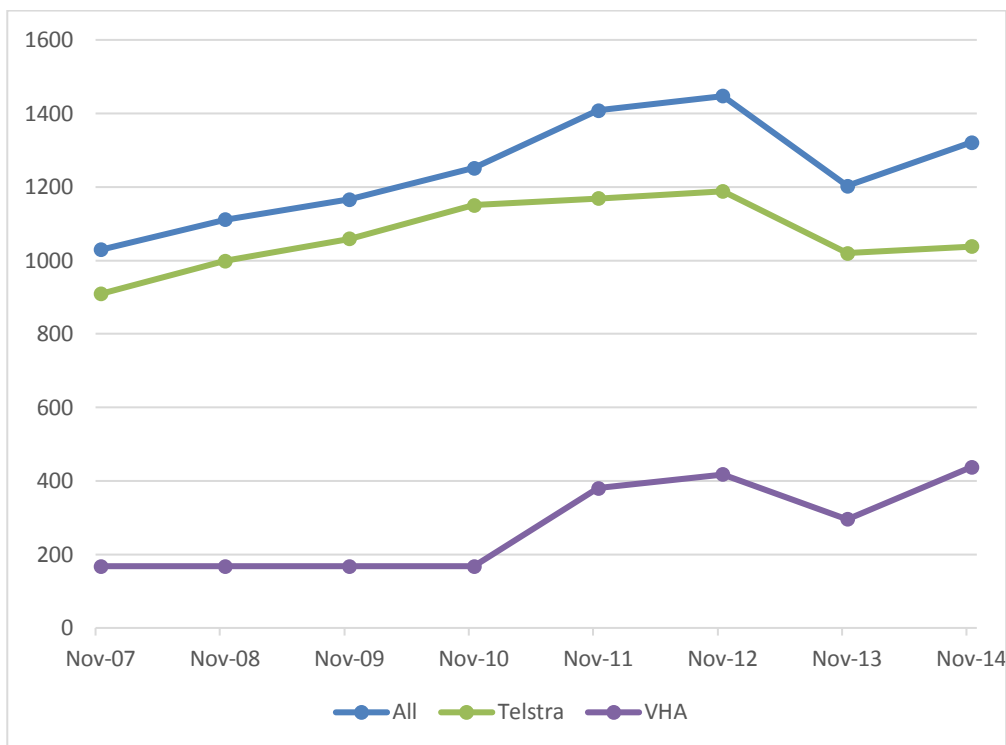
Frequency band	Amount of spectrum in each frequency band in Sydney (MHz)		
	Optus	Telstra	VHA
850 MHz	0	2 x 10	2 x 10
900 MHz	2 x 8.4	2 x 8.4	2 x 8.2
1800 MHz	2 x 15	2 x 15	2 x 30
2.1 GHz	2 x 20	2 x 15	2 x 25
TOTAL	2 x 43.4	2 x 48.4	2 x 73.2

Analysis by frequency band

850 MHz

Figure C2 shows a graph of the number of unique sites with registrations in the 870–890 MHz band in the inner-Sydney area (refer to Figure C1). While there is growth in the number of sites used by both Telstra and VHA, there was a dip in registrations in 2013 due to the re-registration of sites at the renewal of the 850 MHz spectrum licences. The re-registration of devices allowed licensees to ‘clean-up’ the database and remove registrations no longer in use. Therefore, it is difficult to quantify the growth in the use of infrastructure in this band. However, as lower frequencies such as the 850 MHz band are typically used for coverage, significant growth would not be expected as a result of capacity in-fill.

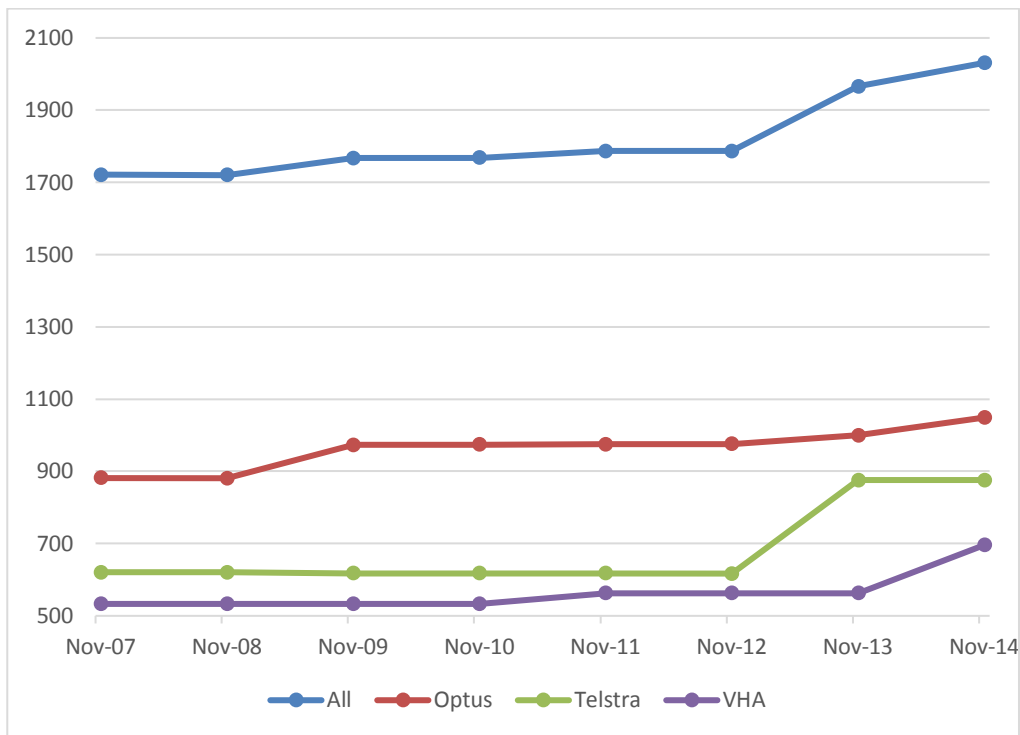
Figure C2: Number of sites with registrations in the 870–890 MHz band in Sydney



900 MHz

Figure C3 shows a graph of the number of unique sites with registrations in the 935–960 MHz band in the inner-Sydney area (refer to Figure C1). There has been some overall growth in the number of sites used by all carriers, with some sites used by more than one carrier. Optus use a greater number of sites in this spectrum compared with Telstra and VHA, potentially because it does not hold any spectrum in the 850 MHz band. However, as lower frequencies such as the 900 MHz band are typically used for coverage, significant growth would not be expected as a result of capacity in-fill.

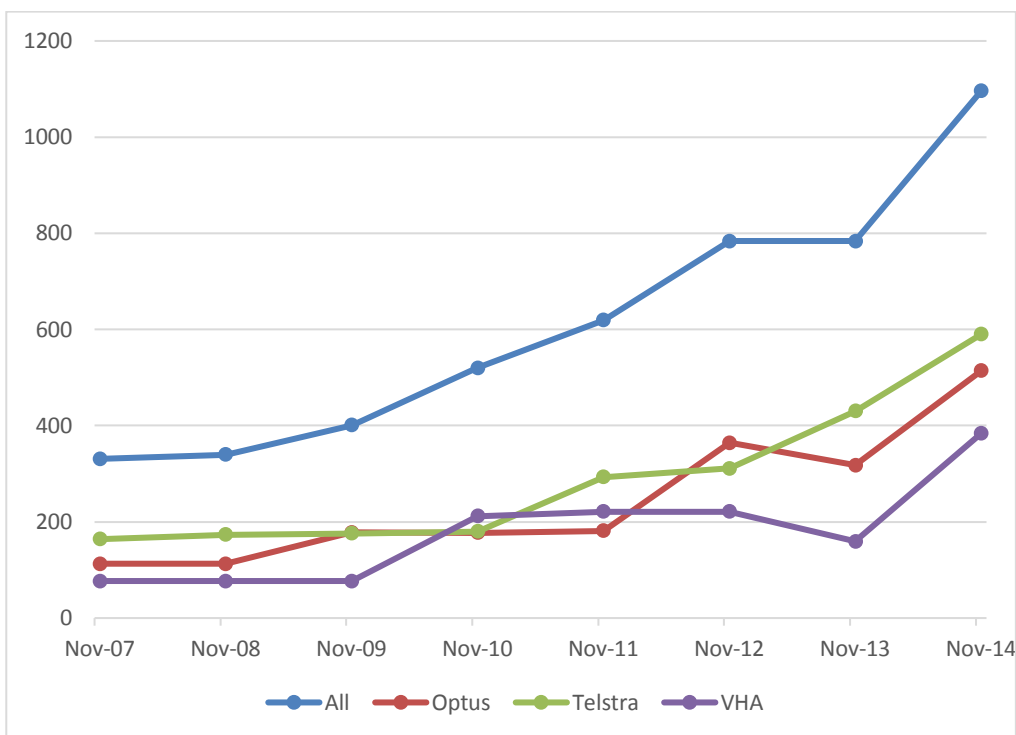
Figure C3: Number of sites with registrations in the 935–960 MHz band in Sydney



1800 MHz

Figure C4 shows a graph of the number of unique sites with registrations in the 1805–1880 MHz band in the inner-Sydney area (refer to Figure C1). There has been significant overall growth in the number of sites used by all carriers, with some sites used by more than one carrier. This is to be expected in this frequency range, which is more appropriate for capacity in-fill than the 850 MHz and 900 MHz bands, and also due to its rise in popularity as a 4G band internationally over the past three years. Over the period analysed, the three operators have experienced similar growth in the number of sites used in this frequency range, with the difference in the number of sites used by each carrier widening in recent years.

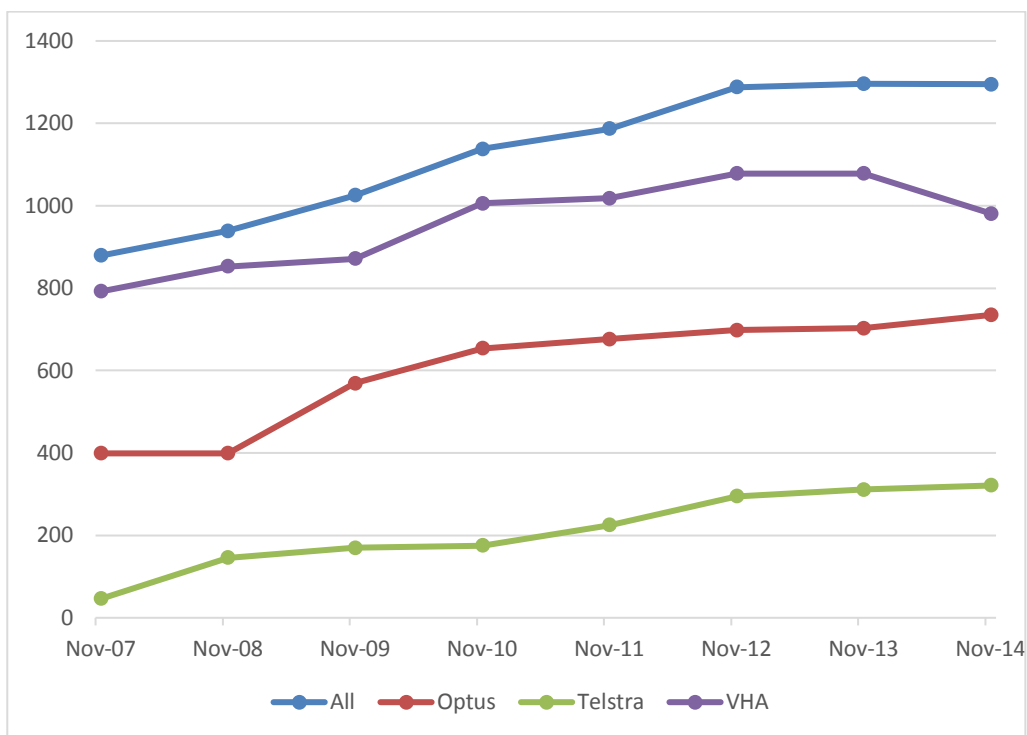
Figure C4: Number of sites with registrations in the 1805–1880 MHz band in Sydney



2.1 GHz

Figure C5 shows a graph of the number of unique sites with registrations in the 2110–2170 MHz band in the inner-Sydney (refer to Figure C1). There has been overall growth in the number of sites used by all carriers, with some sites used by more than one carrier. This is to be expected in this frequency range, which is more appropriate for capacity in-fill than the 850 MHz and 900 MHz bands. The growth in the number of sites used in this band appears to have plateaued in recent years. This is likely due to a shift in investment from 3G services (which the 2.1 GHz band is currently largely used for) to 4G services in other bands such as 700 MHz, 850 MHz, 1800 MHz, 2.3 GHz and 2.5 GHz.

Figure C5: Number of sites with registrations in the 2110–2170 MHz band in Sydney

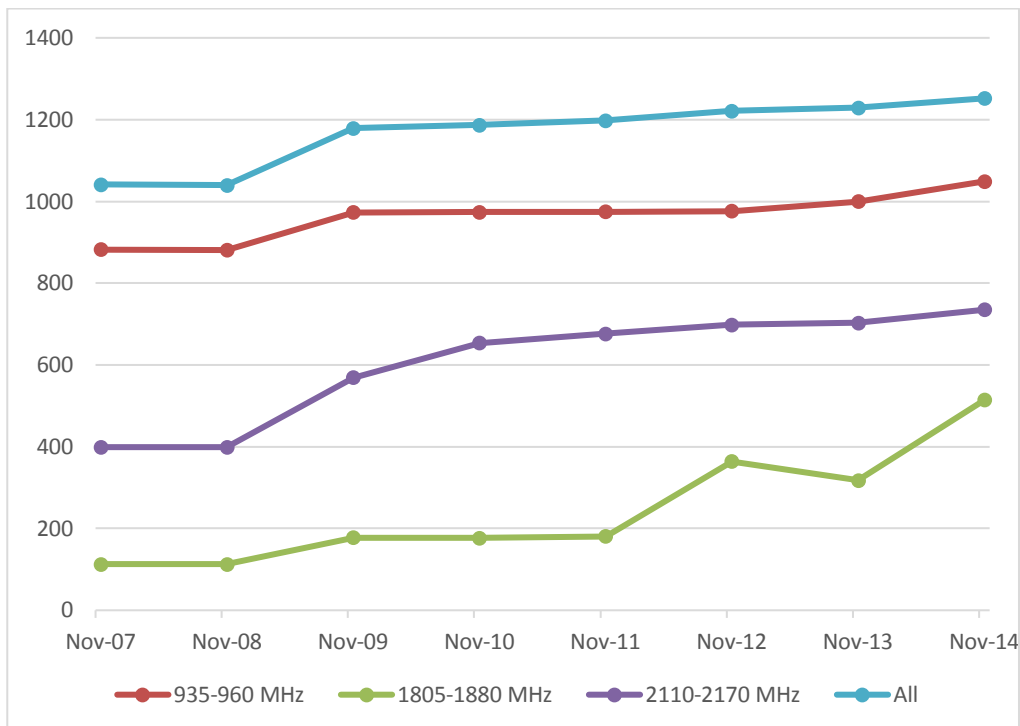


Analysis by operator

Optus

Figure C6 shows a graph of the number of unique sites with Optus registrations across the 900 MHz, 1800 MHz and 2.1 GHz bands in the inner-Sydney area (refer to Figure C1). There has been growth in the number of sites used by Optus, with most sites using more than one frequency band. The 900 MHz band uses the greatest number of sites, followed by the 2.1 GHz band and the 1800 MHz band.

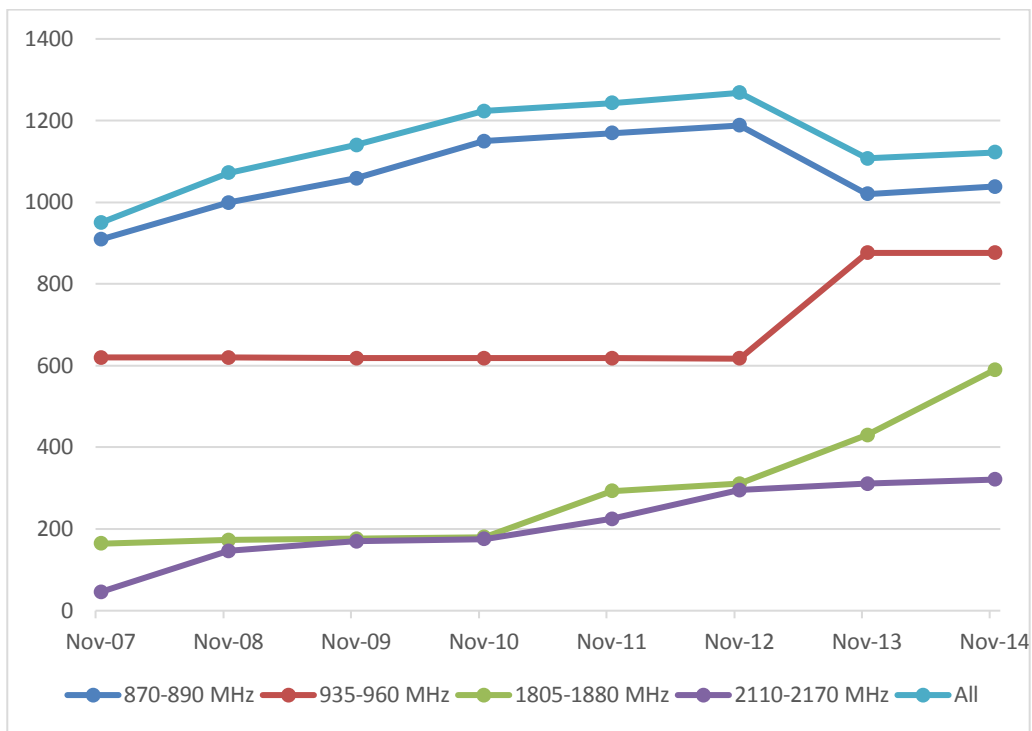
Figure C6: Number of sites with Optus registrations in the 900 MHz, 1800 MHz and 2.1 GHz bands in Sydney



Telstra

Figure C7 shows a graph of the number of unique sites with Telstra registrations across the 850 MHz, 900 MHz, 1800 MHz and 2.1 GHz bands in the inner-Sydney area (refer to Figure C1). There has been growth in the number of sites used by Telstra, with most sites using more than one frequency band. The 850 MHz band uses the greatest number of sites, followed by the 900 MHz band, then the 1800 MHz band and the 2.1 GHz band.

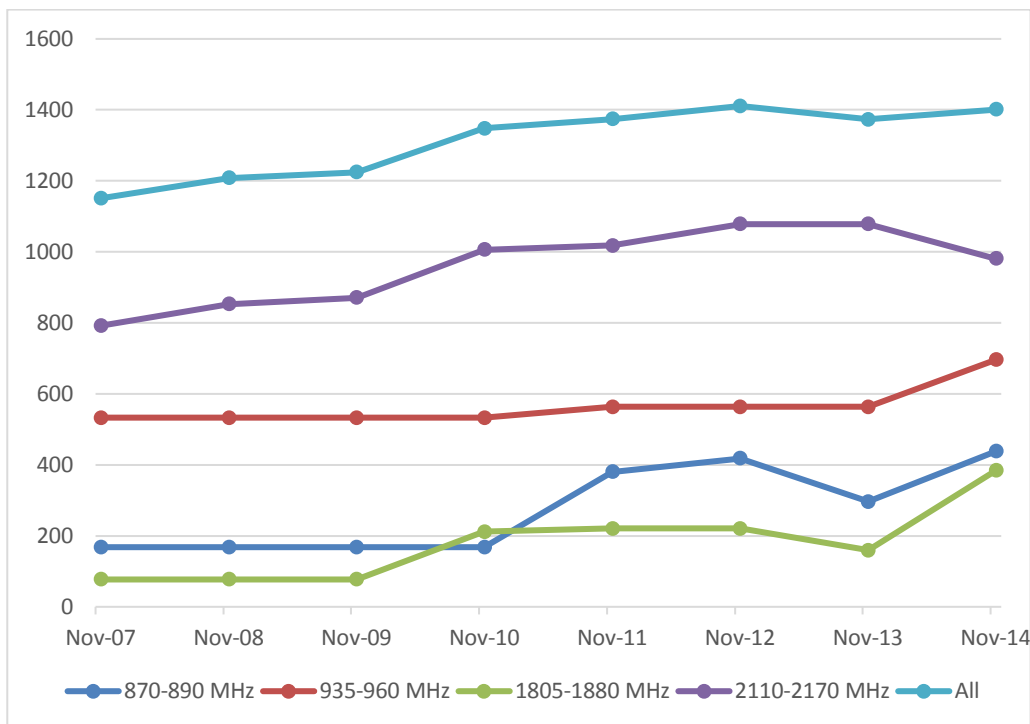
Figure C7: Number of sites with Telstra registrations in the 850 MHz, 900 MHz, 1800 MHz and 2.1 GHz bands in Sydney



VHA

Figure C8 shows a graph of the number of unique sites with VHA registrations across the 850 MHz, 900 MHz, 1800 MHz and 2.1 GHz bands in the inner-Sydney area (refer to Figure C1). There has been growth in the number of sites used by VHA, with most sites using more than one frequency band. The 2.1 GHz band uses the greatest number of sites, followed by the 900 MHz band, then the 850 MHz band and the 1800 MHz band.

Figure C8: Number of sites with VHA registrations in the 850 MHz, 900 MHz, 1800 MHz and 2.1 GHz bands in Sydney



Overall

Figure C9 shows a graph of the number of unique sites across the 850 MHz, 900 MHz, 1800 MHz and 2.1 GHz bands in the inner-Sydney area (refer to Figure C1) with Optus, Telstra and/or VHA registrations. The overall number of sites has remained relatively steady, with only a five per cent growth from November 2007 to November 2014. This suggests that expansion of the use of individual frequency bands and individual carriers has been through a combination of:

- > the use of existing sites to support services in multiple bands
- > the use of infrastructure-sharing between operators rather than construction of more sites.

Comparing carriers, the number of sites used is relatively similar, with no carrier using more than 57 per cent of the overall number of sites used. This suggests there is potential for growth in the number of sites used through infrastructure-sharing between carriers, as well as across frequency bands. However, the potential growth is difficult to quantify without analysing the relative locations of each of the sites (for example, some sites may appear with different site IDs in the ACMA database but only be a matter of metres apart).

Figure C9: Number of sites across the 850 MHz, 900 MHz, 1800 MHz and 2.1 GHz bands with Optus, Telstra and/or VHA registrations in Sydney

