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Australian Communications and Media Authority

Additional Submission to the Parliamentary Joint Committee on Law Enforcement *Inquiry into Spectrum for Public Safety Mobile Broadband (PSMB)*

Australian Communications and Media Authority (ACMA)

JULY 2013

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Executive Summary

This further submission responds to the invitation by the Committee Chairman at the end of our evidence :

> *"... if you have some additional points you want to put in, in light of additional evidence, please feel free to do so."*

Upon reflecting on both the detail and tenor of much of the discussion heard during the Inquiry, including some of the lines of questioning from the Committee to us, the ACMA has taken the view that there is potential value in providing some additional context and information. We hope that this will assist the committee in its deliberations.

By way of overall observation, it is clear from the testimony of a number of witnesses, and from the committee's own questioning, that an underlying issue for the inquiry has been how to deal with issues many of which have a high technical component, and where there seem to be competing claims. The Committee's frustration with this aspect of the debate arose during the ACMA's own testimony

> ***Mr McClelland**: ...We are sitting here and ACMA has given its report from October. We are seeing a joint submission from all states and territories; we are seeing evidence provided from each and every police commissioner around Australia; we are seeing other evidence, such as the Motorola practical examination bid criticised, or otherwise, for the parameters of it; we are seeing the evidence of Deloitte from overseas. And they are saying that the 10 megahertz allocation, the five plus five, effectively, as determined in October, is not adequate for their business-as-usual practices, let alone the once in a generation event, of which they say there have been six in the last four years. This is something that we need to get our heads around.*

Such frustration is understandable. As the regulator of a finite, yet high demand resource such as radiofrequency (RF) spectrum we often face situations of robust debate which occurs in a largely technical environment. This involves making sometimes nuanced judgements that are often based on a complex – and, importantly, evolving – matrix of engineering and economic considerations. This is particularly the case when it comes to broadband networks utilising quite new technologies such as LTE, which do have some significant capabilities and modes of operation that are qualitatively different from earlier technologies.

The ACMA certainly understands the issues facing the PJCLE and remains ready to assist in advising the committee on any technical issues or questions the committee may have. We make these kinds of judgements very regularly, and the issues are not straightforward and are if anything becoming more complex as demand for spectrum increases and technologies continue to evolve. Both are trends that the ACMA has had to work at in acquiring and maintaining relevant engineering and economic expertise.

This may have been a factor in explaining why some of the important testimony presented to the Committee was, as we indicated in our opening statement to the committee, materially factually incorrect. Some of the inaccuracies seem to be based on a perhaps understandable lack of visibility by some submitters as to the actual state of play internationally and in particular within international forums that are developing public protection and disaster relief (PPDR) standards and recommendations. Others reflect incorrect understandings about the way LTE networks operated, and seem from the way they were discussed to perhaps be based on extrapolating past ways of designing data networks onto an LTE environment in a manner that is simply not correct.

Accordingly, this further submission provides considerable further detail on some matters that appear to have been of interest to the committee, or contentious. Our aim is to provide some clarity around what should be a largely technical matter but seems to have become an emotive one.

A related reason for this additional submission is formally to advise the Committee that the ACMA has not taken a final decision on the quantum of 800 MHz band spectrum that is appropriate for a dedicated PSMB capability. We want to do this given the repeated proposition put by the Committee Chairman to us last week that our consideration of the matters was "all over, red rover". As Mr Cheah intimated at the time, the point of our opening statement and subsequent evidence to the Committee, including this submission, has been primarily

- to explain the processes, reasoning and evidence base on which the decision last year was taken – and in so doing to explain how the ACMA views and treats evidence in reaching decisions on spectrum allocations;
- to point out some important inaccuracies about some matters that are central to the Committee's terms of reference that were presented in testimony and submissions from other witnesses, particularly as some of that directly challenged ACMA work and because Committee members seemed to have found some propositions persuasive; and
- to offer to assist the committee further in exploring relevant matters, particularly those that have a strong technical.

This further submission focuses on two key areas. The first is the international situation. Comparisons have been drawn between spectrum provisions made in Australia and other countries, but the validity of such comparisons must be tested rather than simply accepted at face value. For example, technical studies undertaken in other countries have been referred to as 'evidence' in these deliberations, however the ACMA has found many of the parameters used in these studies to be significantly different than what is accepted in Australia for PSMB, to the extent that applying the Australian accepted parameters would significantly alter the spectrum recommendations made in those studies.

In truth, there are a wide range of technical, operational, geographic and economic factors that determine how individual administrations provide spectrum for emergency services, and it is not reasonable to attempt to map one country's set of requirements to another's. Differing population densities and distributions, crime/disaster rates, technology types and availability of complimentary facilities mean that there is no one-size-fits-all approach to spectrum for public safety.

Questions were raised in the ACMA's Inquiry hearing about the need for international spectrum harmonisation of public safety radio services (referred to as *PPDR* in international spectrum harmonisation parlance). International harmonisation is highly important to Australia both domestically and internationally, providing for equipment economies of scale, interoperability/cross-border roaming and spectrum efficiency, and ensures that the myriad of radio technologies used in all aspects of society can coexist without interfering with one another.

The International Telecommunication Union (ITU) has identified the 800 MHz band for PPDR communications in Australia, Asia and the Pacific (AAP). In contrast, the 700 MHz band plan that has been adopted in this region and an increasing number of countries further abroad has not been identified for PPDR. Both bands are supported by appropriate standards for Long Term Evolution, or LTE equipment, which has been selected as the radio technology platform for PSMB, so LTE equipment will be manufactured for both bands. However, public safety-specified equipment is more likely to be manufactured in the 800 MHz band, given that that band is harmonised for PPDR.

International planning for broadband PPDR in the 800 MHz band is well advanced in the various international forums that the ACMA is engaged with; however no such planning has been undertaken for the 700 MHz band. A different variant of the 700 MHz band plan has been adopted for both narrowband and broadband PPDR operations in the US and Canada, which is not harmonised with that of the AAP. As a result, PSMB equipment in the US market will not be able to be used in Australia.

The second key area that we have provided further information on relates to issues concerned with LTE networks. As the committee knows, one of the key aspects of this issue is that the proposed PSMB capability will be based on LTE, which is an evolved, 4th generation (4G) radio access technology. This technology is a significant departure from older technologies in that it is an all IP radio network, as opposed to older generation circuit-switched technologies. This necessitates a different way of thinking when considering many of the technical aspects of PSMB, as the nature of this technology type will have significantly different implications for planning, capability, robustness and spectrum usage than older technologies.

Unfortunately, much of the testimony provided to date seems to have been based on the characteristics and considerations of older technology types, such as earlier generation cellular and narrowband land mobile radio (LMR) systems, and the ACMA feels that this has confused the issue. One aim of this submission is to hopefully draw out the differences between 4G and older technologies and their implications for this issue.

One example of thinking in terms of older technologies is that it has been put to the Inquiry that the PSMB network would use large cells (*'20 to 30 km'* to quote Mr. Waites from the Police Federation of Australia (PFA)). This is more reflective of an LMR-based topology and is both at odds with the PSMBSC's own modelling and somewhat defeats the purpose of deploying an LTE network. In fact, this approach would not be realisable under the current standards for LTE[1] systems operating in Australian frequency bands.

There have been linkages discussed between network density (ie. spacing between base stations, determined by cell size) and spectrum bandwidth. It has been argued that larger cells/fewer base stations (and lower cost) necessitate a larger provision of spectrum to meet the PSMB capacity requirement within the coverage area. To that end, it appears that much of the push for bandwidth over and above the 10 MHz provided has been based on this large cell model, which could be interpreted as an attempt to offset deployment costs.

From a technical perspective, *capacity,* rather than *spectrum,* is the most important requirement in planning a radio network. Ensuring that the capacity requirement is met within the PSMB coverage area will mean that emergency responders will be able to access the data throughput they need to do their job, and the truth is that capacity is determined by both the amount of spectrum provided and the density of the network layout – all stakeholders are in agreement on that.

However, the argument that spectrum and cell size can be traded against each other only applies to appropriately *dense* network topologies, ie. networks with reasonably closely spaced base stations, and not the abovementioned large cell topology. To increase the cell size beyond that which was determined by the PSMBSC (4 and 9 km for urban and regional coverage respectively) would require that the mobile devices in the network employ higher transmission power than is permitted in either the LTE standard or the ACMA technical frameworks that will apply to those frequency bands.

There are in fact, significant advantages to deploying an LTE network that is properly dimensioned without large cells. One benefit will be improved data handling, so highly concentrated data traffic (common around an incident site) can be more readily served. Contrary to some testimony (including that of Mr. Hewitt of ACT Emergency Services), denser networks are more robust that

[1] Developed by the 3rd Generation Partnership Project, or '3GPP'

their large cell-based counterparts, as they can more readily recover coverage when a base station is rendered unserviceable. An unserviceable base station in a large cell network is more likely to result in a coverage black spot.

1. Overview

The ACMA welcomes the opportunity to make this further submission to the *Inquiry into spectrum for public safety mobile broadband*. It should be read in conjunction with the previous submission made to the Inquiry[2]. This previous submission contained information on:

- The ACMA's role, responsibilities and powers under legislation;
- ACMA engagement with – and spectrum provisions for – Public Safety Agencies (PSAs);
- Overview of the Public Safety Mobile Broadband Steering Committee (PSMBSC) process; and
- Individual responses to each of the Inquiry's Terms of Reference.

The aim of this submission is to provide additional information to the Parliamentary Joint Committee on Law Enforcement (PJCLE) that may be useful in its deliberations, and to clarify – and in some cases correct – some of the evidence that has previously been provided in both submissions and Committee hearings. Broadly speaking, this submission covers matters of spectrum harmonisation and technical considerations, honing in on certain aspects that have perhaps not been clearly articulated during the Inquiry.

[2] See: http://www.aph.gov.au/Parliamentary_Business/Committees/Senate_Committees?url=le_ctte/spectrum_mobile_broadband/submissions.htm

2. Spectrum harmonisation and international matters

Two of the key themes that have emerged through the course of the Inquiry are matters concerning international spectrum harmonisation and the applicability of spectrum allocations for PSMB by individual administrations. While related, these are essentially separate issues, as harmonisation ensures that there is a market for equipment that can coexist with other systems and operate across borders, while bandwidth provisions are dependent on the local operating environment and are considered a matter for individual administrations.

This chapter explores both the importance and implications for international spectrum matters to the domestic radiocommunications environment.

2.1. Why should spectrum be harmonised?

Spectrum is harmonised internationally for a number of reasons, and it is important for Australia to engage in this process to the extent possible. Some of the benefits of spectrum harmonisation include:

- Economies of scale for equipment are realised by providing common frequency bands for specific purposes.
- Cross-border operation is made possible, including roaming of mobile services, common navigation systems for long-haul aviation and maritime services and interoperability for emergency and defence operations. While cross-border interoperability is not likely to be as important to PSAs as economies of scale, it is not unreasonable to suggest that recent deployments to other Asia-Pacific countries (eg. Japan, New Zealand) for disaster relief operations might have benefitted from having a PSMB capability that was interoperable with local emergency services.
- Spectrum allocations are planned internationally so different services and technology types can coexist, without causing interference to each other.
- Spectrum efficiency is optimised. RF spectrum is a limited, high-demand resource, both in Australia and globally. International harmonisation helps ensure that the radiofrequency spectrum is used as efficiently as possible, so as to maximise the public benefit of its use (an Object of the *Radiocommunications Act 1992*).

The International Telecommunication Union (ITU) Radio Regulations have treaty status, and Article 5 of the Regulations contains a table of international allocations for the entire radiofrequency spectrum. This table is updated at the completion of each World Radiocommunications Conference (WRC) which is the culmination of a three-to-four year study cycle (next WRC is in 2015). The study cycle is intensive and technical in nature, requiring input from many countries, including Australia.

To the extent possible (with some minor deviations), the Australian Radiofrequency Spectrum Plan (ARSP, produced by the ACMA) is harmonised with Region 3 allocations of Article 5 of the Radio Regulations – Region 3 being the Asia-Pacific region as defined in the Radio Regulations. Allocations are made by service, which include mobile (incl. land mobile, cellular, maritime, aeronautical), fixed (eg. microwave links), broadcasting (TV, radio), radiolocation (radar), radionavigation (eg. aeronautical navigation aids), space research, earth exploration, fixed and mobile satellite, radio astronomy and so on. All of these services need to coexist in a congested radiocommunications environment, which harmonisation plays a key role in.

2.2. How are specific technical standards reflected in the Australian radiocommunications environment?

The ACMA also seeks to ensure that the technical frameworks it develops are aligned with accepted international standards, where reasonable to do so. This is also undertaken for the reasons listed above. For example, in bands that are spectrum-licensed for cellular services, the ACMA refers extensively to the appropriate international standards for the latest available technologies (eg. 3rd Generation Partnership Project (3GPP) standards for 4G Long Term Evolution (LTE) technologies). Reasons for doing so are discussed further in Section 3.2 of this submission.

Both the Region 3 700 MHz (3GPP band 28) and 800 MHz expansion bands (3GPP bands 26 and 27) bands have been standardised by the 3GPP telecommunications standard development organisation.

2.3. Why will the 800 MHz band be used for PSMB in Australia, and what is its relationship with the rest of Asia?

While the specific frequencies for Public Safety Mobile Broadband (PSMB) in Australia are yet to be decided (and will be determined as part of the broader 803-960 MHz band review), they will come from within frequencies that are harmonised internationally by the ITU for Public Protection and Disaster Relief (PPDR). These frequencies are 806 – 824 MHz paired with 851 – 869 MHz under ITU-Radiocommunications Sector (ITU-R) Resolution 646. The 700 MHz band is not harmonised for PPDR in the Asia-Pacific region. International harmonisation for PPDR is important for both economies of scale for public safety-grade (which differs from commercial grade) equipment, as well as provisions for interoperability.

Given some of the discussions at the Inquiry's hearings, the ACMA feels that contents of Resolution 646 also need further examination. At one stage during the hearing, Mr. Hill of Motorola Solutions stated that:

> *"The ITU resolution 626 (sic) was drafted many years ago. It was originally drafted to harmonise spectrum for narrowband operations. By narrowband operation I mean voice operations for two-way radio types of operations. In our region at the moment there is no agreement and that is part of the work that ACMA is doing with the APT and the ITU and to which we are also helping to contribute. But there is currently no agreement in the region as to what part of spectrum is to be used for public safety for broadband. So resolution 626 only applies to narrowband operations in that 800 megahertz band."*

ITU-R Resolution 646 (Rev. WRC-12) was first adopted at the World Radiocommunication Conference (WRC) in 2003 to:

> "*... strongly recommend administrations to use regionally harmonised bands for public protection and disaster relief (PPDR) to the maximum extent possible*."

The ACMA is currently involved, through the Asia-Pacific Telecommunity, in developing harmonised frequency arrangements for PPDR applications in the 800 MHz. The ACMA is also proactive in studying the technical and operational issues relating to broadband PPDR so that ITU-R Resolution 646 (Rev. WRC-12) can be amended to better reflect the trend in PPDR applications toward higher bandwidth applications. Significant progress within Region 3 (of which Australia and the majority of Asia are apart) has been made on the development of a regionally harmonised band plan to support broadband PPDR in the 800 MHz band; however, no endorsed band plan is yet in place. No such work is being undertaken to harmonise the 700 MHz band for PPDR.

It is true that spectrum harmonisation work under Resolution 646 initially focussed on narrowband radio. It should be noted that Resolution 646 was made when narrowband radio was the *only* wide-area mobile radio technology used by public safety agencies. Over time, and particularly in recent years, it has been recognised that broadband technologies were becoming important for PPDR operations, and is one of the focuses of the current WRC study cycle[3]. This trend towards broadband PPDR technologies is reflected in Resolution 646 (both the original 2003 resolution and 2012 revision), where it states that:

> "*considering... f) that, although there will continue to be narrow-band requirements, many future applications will be wideband (indicative data rates in the order of 384-500 kbit/s) and/or broadband (indicative data rates in the order of 1-100 Mbit/s) with channel bandwidths dependent on the use of spectrally efficient technologies*"

This is at odds with the assertion that the "*resolution 626 (sic) only applies to narrowband operations in that 800 megahertz band*". ITU-R Recommendation M.2015 "*Frequency arrangements for PPDR radiocommunications systems in UHF bands in accordance with Resolution 646 (Rev. WRC-12)*" contains example frequency arrangements by region in its Annexes. Annex 4 contains such an example plan for the 800 MHz band for Region 3. It should be noted that:

- Again, narrowband services were the first to be harmonised, so the first channel plans in the recommendation were narrowband;
- The current working version of the document[4] contains an example channel plan for broadband PPDR for Region 3 in the 800 MHz band (revision to Annex 4); and
- Any such channel plans, broadband or narrowband, are 'examples' and intended only to guide administrations in their planning, and are as such non-binding.

Narrowband services are not spectrum-intensive. They certainly do not occupy the entire 800 MHz band (currently 2 x 5 MHz used for narrowband in Australia in the 800 MHz band). Contrary to Mr. Hewitt's evidence at the 24th July hearing of the inquiry ("*You can harmonise the 800 band, but most of Asia have already deployed their police and emergency service narrowband voice systems in that space that has been identified by ACMA*") the entire 800 MHz band is not currently encumbered by public safety agencies across most of Asia.

2.4. What are the key differences between the 700 and 800 MHz bands?

As a general observation it would be fair to say that differences between the 700 and 800 MHz bands have been overstated, and in reality, many stakeholders are actually agnostic to which band is used for PSMB. For example, Mr. Bouwmeester from Motorola Solutions stated at the Inquiry hearing on the 24th June that:

> *"From our perspective, whether it is in the 700 or 800 megahertz [band] will make no difference from a commercial perspective."*

Radio propagation distances are very slightly longer in the 700 MHz band than the 800 MHz band for a given transmitted power level. The relationship between propagation distance and frequency is logarithmic. In high density (e.g. urban) areas where networks are capacity-dimensioned, this will make little difference. In lower density (e.g. rural) areas that are more likely to be coverage-dimensioned, this will result in a slight coverage difference.

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[3] *WRC-15 Agenda Item 1.3: "To review and revise Resolution 646 (Rev.WRC-12) for broadband public protection and disaster relief (PPDR), in accordance with Resolution 648 (WRC-12)"*

[4] See Annex 19 to ITU-R Working Party 5A (WP 5A) Chairman's Report for May 2013 meeting: http://www.itu.int/md/R12-WP5A-C-0306/en)

There is a similar difference in building penetration loss, ie. slightly more loss in the 800 MHz band than the 700 MHz band, but considered negligible for cellular planning purposes. To put this into perspective, the Telstra NextG network has good building penetration performance and operates in the 850 MHz band, which has slightly more penetration loss than the 800 MHz band.

The figures in Table 1 were derived from information contained in a report by Ofcom[5], the UK communications regulator, to show the differences in penetration loss between the 700 MHz (specifically at 703 MHz) and 800 MHz (at 810 MHz) bands for different building materials and thickness. Note that the differences in loss are small fractions of a dB, and can therefore be considered negligible.

Material	Loss at 810 MHz (dB)	Loss at 703 MHz (dB)	Loss difference (dB)
Concrete - 100mm	0.847	0.75	0.097
Brick - 80 mm	1.33	1.33	0
Plasterboard – 18mm	0.1	0.09	0.01
Wood – 70mm	0.22	0.19	0.03
Glass – 10mm	0.01	.009	0.001

Table 1: Differences in penetration losses between 700 and 800 MHz frequencies for a range of building materials and thicknesses

The difference in cost between deploying 700 MHz or 800 MHz networks was explored by the PSMBSC, and the relevant paper is available on the DBCDE website[6]. The cost differences identified were small, however the specific figures (expressed as percentage difference) have been redacted from the uploaded documents for security reasons (complete versions of the documents have been provided to the Inquiry).

There has been much discussion about the timeframe of chipset availability in the 700 and 800 MHz bands. 3GPP standardisation of equipment operating in both bands has been ongoing for a number of years now, and standardisation work in bands 26 (814–849/859–894 MHz), 27 (807-824/851-869 MHz) and 28 (703-748/758-803 MHz), the 800 and 700 MHz bands, are at similar stages in development.

2.5. What is the state of play regarding spectrum arrangements for PSMB in other countries?

Much has been made of the amounts of spectrum being provided in other countries and what they mean for Australia, with specific reference to scenarios in the US, Canada and Europe (particularly Germany). The ACMA wishes to provide some commentary on these matters, as it is important to acknowledge that one country's specific requirements cannot be transposed onto another's. While the ITU and regional bodies such as the Asia-Pacific Telecommunity (APT) are concerned with harmonising frequency bands for PPDR, it is acknowledged that actual bandwidths provided are a matter for individual administrations, given that requirements differ from country to country.

[5] Ofcom: *Project SES-2005-08 – Predicting coverage and interference involving the indoor-outdoor interface (final report).*

[6] See Document 2 at: http://www.dbcde.gov.au/about_us/freedom_of_information_disclosure_log/foi_list/foi_logs/reports_from_gibson_quai_-_aas_pty_ltd_on_the_analysis_of_public_safety_mobile_broadband

This section discusses the relevant spectrum harmonisation and bandwidth provisions in the abovementioned countries. Key points of this discussion are:

- Differences between Australia's and the US/Canada's 700 MHz band plan mean existing PSMB equipment cannot be used in Australia:
  - The 700 MHz band plan adopted by the US and Canada is, for a number of reasons, somewhat idiosyncratic and not as spectrally efficient as the 700 MHz plan adopted by Australia. It is therefore unlikely to be adopted outside North America, so economies of scale for PSMB equipment in that market are unlikely to grow significantly.
  - The 700 MHz band plan adopted by the US and Canada does not align with that developed by the Asia-Pacific Telecommunity (the 'APT 700 MHz' plan), which has been adopted in Australia. PSMB equipment designed for the American market will not be able to operate in Australia.
- The implications of US/Canadian spectrum provisions for Australia are not clear cut:
  - The provisions of an additional 10 MHz of spectrum over and above an original provision of 10 MHz in the US was largely politically-driven, rather than a result of demand exceeding capacity on the original 10 MHz provided;
  - Canada have followed the US in allocating the additional 10 MHz for PSMB for cross-border harmonisation reasons; and
  - A study of Canadian bandwidth requirements was based on technical assumptions that differed from those used in Australia, which would result in an overestimate of those requirements.
- Other countries mentioned have not 'allocated' spectrum for PSMB – at this stage only recommendations on bandwidth have been made. One study in Europe has been based, in part, on a notional PSMB capability operating at 750 MHz; however Europe is a long way off making any arrangements to replan the 700 MHz band in the region so any such assumptions are largely hypothetical at this stage.
- Studies undertaken in Europe either modelled scenarios based on a more intensive density of responders in a given area, which is reflective of their different operating environments (specifically Germany), or assumed that traffic load could be served by a combination of dedicated PSMB and commercial networks.
- Spectrum bandwidth provisions are acknowledged as being a matter for administrations, noting the differences between countries in technical, operational, geographic and economic environments (including highly variant population densities and distributions).

United States:

Some public safety equipment exists for use in the United States' 700 MHz band; however, this band is not interoperable with equipment operating on the APT 700 MHz band plan that has been adopted in Australia (see Figure 1). As a result, public safety equipment manufactured for use in the US 700 MHz band would not be able to be used in Australia without significant modification to the radio components in the equipment (probably at a similar cost to modifying to the 800 MHz band).

In 2007, PSAs in the US were allocated 2x5 MHz of dedicated spectrum from their digital dividend (763-768/793-798 MHz in Figure 1) to realise a mobile broadband capability. An adjacent 2x5 MHz of spectrum was also made available for a commercial operator to build and operate a broadband network that would serve both commercial and PSA traffic on a prioritised basis. This second paired block of spectrum was known as the 'D block'. Importantly, this is a similar model to that currently proposed in Australia, except that additional prioritised capacity would not be limited to what can be provided with an extra 10 MHz, and in fact only limited by what can be negotiated with telecommunications carriers. The terms of any such agreement would be determined in the negotiation process.

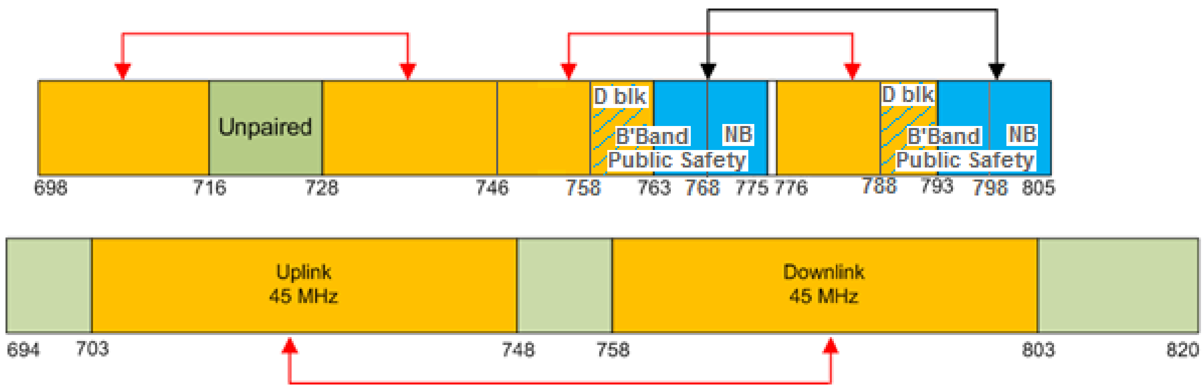

Figure 1: Comparison of US (top) and Australian (bottom) 700 MHz band plans.

An inability to develop the necessary arrangements between commercial operators and PSAs meant that the D block auction in 2008 did not meet the reserve price, and the spectrum was not re-offered. It is believed that the reasons for this were a combination of overly restrictive licence conditions and a very high ($1.3 bn) reserve price. The allocation of the additional 2 x 5 MHz in February 2012 was, in part, due to intense lobbying of Government to release the additional spectrum for PSMB.

Canada:

Canada has adopted the ITU Region 2 plan for the 700 MHz band, and is therefore harmonised with the US. If they were to have allocated D block for commercial use, subscribers would not have been able to roam into the US on these frequencies, as they will be used for PSMB there. Given the large shared border and scale of cross border movement between Canada and the US, roaming is very important, so the utility for commercial services on D block in Canada would have been significantly affected by the US providing it for public safety.

There have been studies undertaken in Canada which made recommendations on spectrum requirements for PSMB[7]. The ACMA reviews all such studies as part of its deliberations and the Police Federation of Australia (PFA) also sought to bring this study to our attention, as it makes a case for more than 10 MHz for PSMB. The study itself projected public safety data demand out to 20 years, and concluded that:

> *"The result of the modeling, taking into account uncertainty factors, shows that the amount of bandwidth required to satisfy the needs of public safety to conduct their missions during commonly re-occurring major emergency situations with modern tools and applications is greater than 20MHz in the near-to-mid term, and likely to also exceed 20MHz in the long term, despite advances in technology. Clearly even with the full 10 + 10 MHz allocated, the community will need to take measures to efficiently manage broadband data communications carefully during periods of peak demand."*

[7] Defence R&D Canada – Centre for Security Science: *700 MHz Spectrum Requirements for Canadian Public Safety Interoperable Mobile Broadband Data Communications*

The study assumed that improvements in technology (such as fractional frequency reuse (FFR) and multiple input/multiple output (MIMO) antenna configurations) to improve spectral efficiency would be implemented in stages over a 20 year timeframe. However, and very importantly, network capacity modelling in the Canadian study assumed that such features would not be implemented in early stages of deployment, therefore a frequency reuse factor of 3 was used (which means that 3 different frequencies are used on a 3 sector base station).

In Australia, the proposed PSMB capability will be based on a network which employs a reuse factor of 1 (same frequency on each sector). In simple terms, a reuse factor of 3 has one third of the spectral efficiency of a factor of one on the uplink (which is the limiting factor in terms of cellular dimensioning), which would equate to a significant overestimation of the spectrum bandwidth needed to meet the capacity requirement.

Europe:

The European Conference of Postal and Telecommunications Administrations (CEPT), through the Electronics Communications Committee (ECC) carried out a detailed analysis of spectrum needs for public safety mobile broadband, recently releasing a draft report on user requirements and spectrum needs[8]. It noted that technical requirements are a matter for individual administrations, and that recommendations therein were made in the interests of achieving harmonisation across Europe to the best degree possible.

Their modelling was based on PSMB networks operating in both the 400 and 750 MHz bands, and, as in Australia, was based on a range of agreed scenarios relevant to their own operational environment. Their bandwidth calculations contained low and medium estimates for “optimistic” and “less optimistic” degrees of spectral efficiency respectively. For the more efficient models (which, from a regulator’s perspective, are the expected norm), they calculated 7.1 + 6.9 MHz for day to day use (for the 750 MHz band, which is most relevant to these deliberations) and 10.3 + 5.8 MHz for large emergency and/or planned events. They noted that in the latter case, temporary additional capacity could be brought in, as has been proposed in the work of the PSMBSC, with the consideration of cells-on-wheels (COWs) as a capacity delivery mechanism.

For both sets of results, the ECC study rounded the spectrum requirements to 10 + 10 MHz (noting that LTE bandwidths are generally quantised into 5 MHz blocks[9]), but noted that individual countries may provide more or less spectrum, depending on their own, individual set of circumstances. From a distance it seems that a similar level of rigour went into producing these findings as has in Australia, and that the differences in bandwidth are simply a matter of scale (more, highly concentrated responders serving much higher population densities). Of particular note was that the report concluded that individual administrations should:

> “*... consider the possible use of commercial networks to meet these needs, while at the same time ensuring interoperability between the different countries as well as maximising economies of scale*”.

In other words, the spectrum demand wasn’t necessarily based entirely on a dedicated PSMB solution, but that commercial services could also be used to absorb some of the demand. The above quote hints at perhaps implementing a “core” dedicated PSMB capability that uses exclusive spectrum, with the ability to roam onto commercial networks for additional capacity or out-of-footprint coverage. It should also be noted that this report made recommendations for European

[8] Electronic Communications Committee: *ECC Report 199 User requirements and spectrum needs for future European broadband PPDR systems (Wide Area Networks), May 2013*

[9] Standard LTE bandwidths are 1.4, 3, 5, 10, 15 and 20 MHz

administrations which do not themselves constitute “allocations” of spectrum for PSMB - the report acknowledges that allocations area a matter for individual administrations.

Germany:

Specific reference has also been made to modelling undertaken in Germany. A study was undertaken by Wik consulting[10] that looked at public safety data needs and extrapolated spectrum requirements based on these needs. They, like Australia, took a multi-layered view of how spectrum for public safety should be provided, noting that:

> *“The wide area network is designed to cater for day-to-day needs (IABG scenario A) and should be able to accommodate typical routine traffic levels wherever they arise in the network coverage area. Local area networks are configured either on a planned basis (to cater for events that are known in advance) or on an ad hoc basis in response to major emergencies that require a high volume of wireless communications”*

On the surface this reflects the anticipated relationship between capabilities operating in the 800 MHz (WAN) and 4.9 GHz (LAN) bands in Australia. The study ultimately recommended that 15 + 10 MHz would be needed for broadband PPDR, which was rounded up from projected requirements of 12.7 + 8 MHz (again due to 5 MHz LTE bandwidth quantisation). This analysis was based on emergency responses to two defined incidents occurring at the edge of a single cell. The figures of 12.7 + 8 MHz were arrived at by simply calculating the spectrum required to support one incident, and then doubling that number. This methodology differed from that used in Australia for PSMB on two fronts:

- In Australia, a far lower population density than Germany means that the two independent incident scenario on the same cell edge would be less likely to occur concurrently. Regardless, the PSMBSC used a very specific (agreed) cell-edge data requirement that is reflective of the operating environment in Australia; and
- Regardless of the likelihood of these scenarios occurring simultaneously, LTE networks are designed in such a way that data traffic at a cell edge can be shared by multiple adjacent cells (being an all-IP technology – see Section 3.7 for more explanation). Simply doubling the bandwidth requirement does not accurately reflect the data-handling capability of 4G networks. Modelling the two incident scenario in a multi-cell LTE network with resource scheduling enabled would not *double* the spectrum requirement of a single incident occurring, and in fact, may even reduce it.

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[10] WIK-Consult: *PPDR Spectrum Harmonisation in Germany, Europe and Globally* http://www.bmwi.de/English/Redaktion/Pdf/ppdr-spectrum-harmonisation-germany-europe-globally,property=pdf,bereich=bmwi2012,sprache=en,rwb=true.pdf

3. Technical and planning considerations

As flagged previously in this submission, many of the issues surrounding PSMB and a supporting spectrum quantum are technical, and the ACMA is concerned that some of the testimony has been either overly simplistic or technically incorrect. This chapter aims to provide some detail about the technical considerations, including network dimensioning and its implications on spectrum quantum and the ability to serve data (including implications for image quality). A summary of the key points in this chapter is as follows:

- *Capacity,* rather than *spectrum,* is the most important variable when dimensioning a radio network. Achieving the required level of capacity to the users is the ultimate goal. Spectrum bandwidth is one input to this, however network layout (in particular base station density – see below) is just as critical.
- PSMB will be based on LTE, which is an evolved, 4th generation (4G) radio access technology. This has significantly different planning implications to older network technologies, and it is not simply a matter of re-using land mobile radio (LMR) base stations to provide PSMB coverage.
- It has been suggested that a dedicated PSMB network would comprise abnormally large cell sizes. This will not be realisable for the following reasons:
    - LTE is a cellular technology which is specified by an international standards body. These standards place limitations on power settings and out-of-band (OOB) emission levels on handset devices, which determine the maximum range of a cell.
    - The result is that there is a maximum cell size that can be deployed, which is much smaller than what has been suggested in testimony from the Police Federation of Australia (PFA).
    - The only way to increase cell sizes beyond this maximum would be to allow power settings greater than that permitted in the standard, which create a range of other technical and spectrum planning issues.
- As a result of the above point, linkages discussed between network density (ie. spacing between base stations, determined by cell size) and spectrum bandwidth are misplaced. Suggestions that deployment costs can be offset by additional spectrum would only be valid if the abovementioned high power device settings were used, which would not be permitted given that domestic technical frameworks are (for reasons mentioned in Section 2.2) aligned with international standards.
- The argument that spectrum and cell size can be traded against each other only applies to *dense* network topologies, ie. networks with reasonably closely spaced base stations, and not the abovementioned large cell topology. The ACMA needs to be careful in terms of over-provisioning spectrum that is not likely to be supported by adequate infrastructure to constitute its efficient use. This is potentially at odds with the ACMA's responsibilities under the *Radiocommunications Act, 1992* ('the Act'), as well as other community expectations.
- Perhaps more importantly, a sufficiently 'dense' network topology would be beneficial to PSAs in a number of ways, as it would improve both the data handling of 'clustered' users and be better able to recover if one or more base stations were to become unserviceable as a result of natural disaster. The ACMA is concerned that some testimony from PSA representatives (including Jim Hewitt of ACT Emergency Services) does not seem to recognise these factors or the significantly different environments that LTE networks represent. It needs to be acknowledged that LTE networks work in a completely different

way to the older technologies that have formed the basis of many arguments presented to the Inquiry.

- Consideration of how different spectrum bandwidths can result in different levels of image resolution need to be taken in the context of capacity, rather than just spectrum. Again, spectrum, along with network density and the specific technology features inherent in LTE are all determining factors in how the requisite capacity can be achieved. A trial that does not include any surrounding cells does not account for the latter two factors, thereby leaving spectrum as the one determining variable, which is not representative of how real world network would handle the image data (see Section 3.5).

3.1. What are the limitations of LTE with regard to cell size?

As a general observation, it is important that, if PSAs are to adopt a 4th generation technology for public safety mobile broadband (PSMB), its characteristics, benefits and constraints need to be acknowledged. This requires an acknowledgement that 4G technologies represent a new paradigm in radio planning, and that all involved stakeholders collectively need to move away from outdated thinking based on narrowband LMR networks. This includes an acknowledgement that extremely large coverage areas will no longer be able to be factored into radio planning. This is not an ACMA 'opinion', rather a fact that is dictated by the nature of the technology itself. This section explores this further.

During the PFA's Inquiry hearing on the 17th June, Mr. Waites mentioned that PSMB towers would provide coverage of "*20 to 30 kilometres depending on atmospheric conditions*". This is at odds with both conventional cellular thinking and the evidence gathered by the Public Safety Mobile Broadband Steering Committee (PSMBSC) through GQ-AAS (UXC) consulting, which was based on a more realistic, calculated cell radius of 4km in an urban area, and 9km in a regional area for handheld device coverage.

This is an important point, as it has a direct impact on the quantum of spectrum needed for PSMB. Certainly, if 20 to 30 km cells were to be deployed, then 10 MHz *would* be insufficient to meet the required capacity (which is a combination of data demand and number of users served in a given area). This is because the larger cell area would incorporate more users; therefore more bandwidth would be needed to provide those users with the required data capacity.

However, the modelling shows that these large cell sizes would not be practically achievable under the LTE standard, so this argument is somewhat moot. To achieve larger cell coverage would not only require additional spectrum, but also higher mobile device power, which would not comply with the current standards for LTE in the 800 MHz band (as well as the APT 700 MHz band), and may require implementation of so-called 'guard bands' in the band plan in order to be accommodated (as described in Section 3.2).

3.2. What would be the spectrum planning implications of permitting high power devices, if they were to be incorporated in 3GPP standards?

It was touched on in Section 2.2 that the ACMA seeks to align technical frameworks for spectrum-licensed commercial mobile services with 3GPP standards, where practical. Economies of scale and spectrum efficiency are key drivers for this. The 3GPP standard provides for this adjacent channel coexistence by specifying spectral envelopes ('masks') for out-of-band (OOB) emissions, as well as upper bounds on device power settings. As mentioned in Section 3.1, permitting device power settings over and above the maximum limits in the 3GPP standards (and by extension, the probable ACMA technical frameworks) could necessitate guard bands being implemented in the 800 MHz band plan.

Given that guard bands are, in essence, wasted spectrum, implementing them would reduce both the efficiency and utility of the band, which goes against the Object of the Radiocommunications Act. This is particularly important in such high value spectrum as the 800 MHz band. This is one of the reasons why the base stations of cellular networks are much closer-spaced ('denser', ie. smaller cells) than the LMR networks that have historically been relied on by PSAs.

3.3. What is the actual coverage limit for cells serving standard-compliant devices?

There has been discussion in the Inquiry about the number of base stations (and associated deployment cost) being inversely proportional to the amount of spectrum provided. However this relationship only exists for networks with cells that aren't *'noise limited'*, ie. not designed to the limit of coverage (large cells). It is important to note that if cells are planned to the limit of their coverage (to the required data capacity level), there is little difference between the coverage provided by 10 and 20 MHz bandwidths, given that the cell is limited by propagation factors (ie. planned to the noise limit).

To illustrate this, Figure 2 shows modelling of uplink[11] coverage from the same site as that used for the PSMB trial undertaken in Midland, WA (more discussion of this trial in Section 3.4). The modelling in Figure 2 was based on the following parameters:

- 800 MHz frequency (trial used US 700 MHz band frequencies);
- 3 sectors using 13.9 dBi panel antennas (same as trial);
- 25m antenna height (same as trial);
- Arbitrary sector azimuths (would likely differ from those use in the trial, but this would not account for any significant differences in coverage distance);
- Hata suburban + ITU-R P.526 propagation models to incorporate representative environment and terrain effects; and
- PSMBSC-accepted requirements including -0.8dB SNIR (signal to noise + interference ratio) for 3 users uploading 725kbps.

The red-coloured areas show where the PSMBSC-defined upload capacity requirements would be met using 5 MHz of spectrum in the uplink (ie. a 10 MHz provision in total), and the light blue shows the same using a 10 MHz of spectrum in the uplink. The dark blue circle shows a 4km radius from the base station.

The uplink coverage distance determines the cell size, given that devices transmit much lower power than base stations and the differences in data throughput (bits/sec/Hz) between SC-FDMA (uplink) and OFDMA (downlink) modulation schemes for a given signal-to-noise-plus-interference (SNIR) ratio.

Figure 2 shows that the notional coverage area where the required capacity is met would roughly be 4km for 10 MHz of spectrum for standard-compliant devices, and only marginally larger for 20 MHz, assuming a network dimensioned for coverage (noise-limited). This is consistent with the PSMBSC modelling, and in simple terms means that if the cell size does not exceed 4km, the agreed capacity requirement can be met using 5 + 5 MHz of spectrum.

[11] Uplink used to define coverage as it is the lower power and therefore limiting factor for cell size. The downlink modelled in isolation would have a larger coverage.

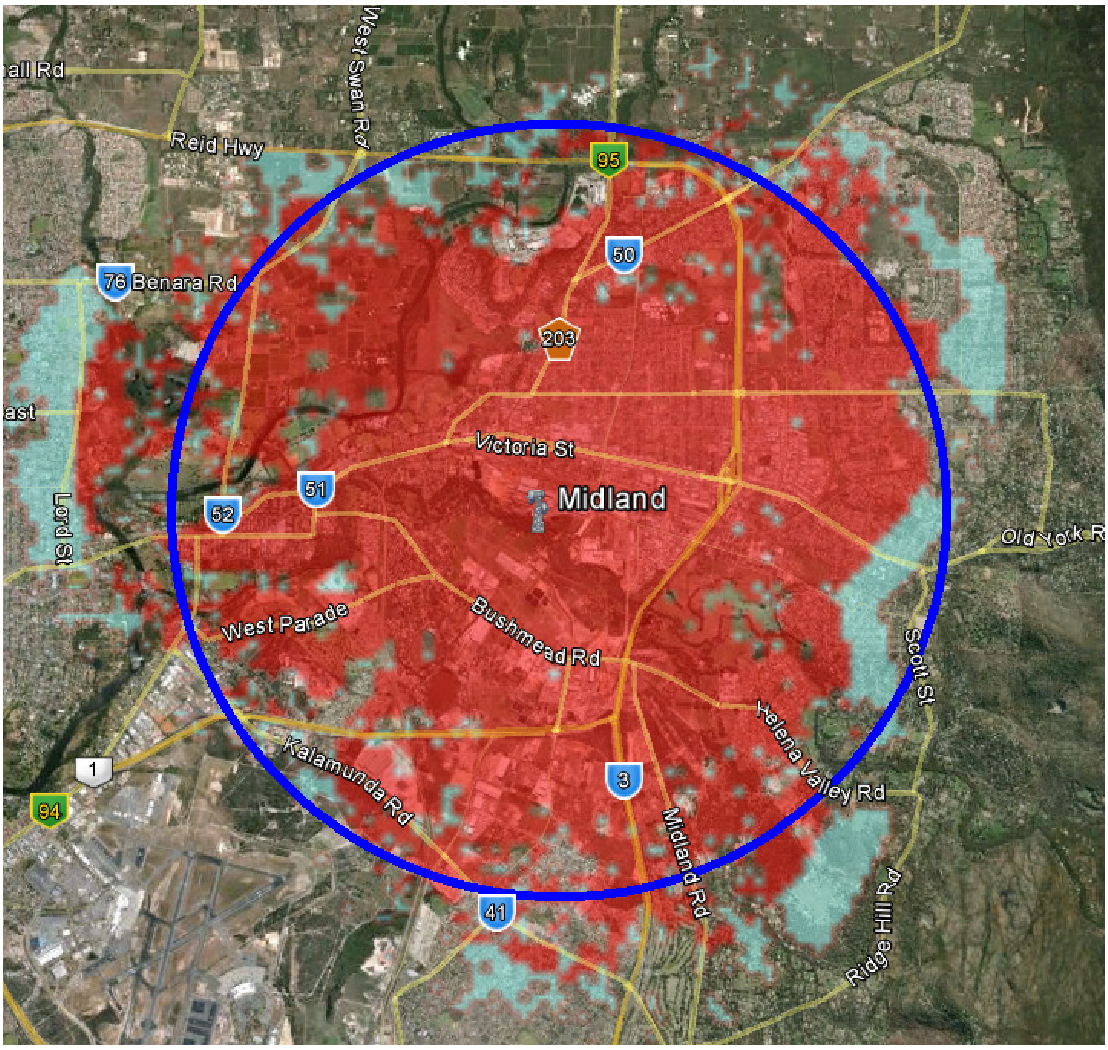

Figure 2: Modelling of coverage difference between 5 MHz (red) and 10 MHz (light blue) uplink bandwidths to meet PSMBSC-agreed capacity requirements, for a noise-limited network. For comparison purposes, this example is modelled using the same site and parameters as the trial conducted by Motorola at Midland, WA.

Figure 3 has been provided simply for context to illustrate the coverage that may be provided by a more realistic network that is served by multiple base stations. It is an extension of Figure 2 that shows how additional base stations (spaced roughly 8km apart, ie. 2 x the coverage limit for 5 + 5 MHz) could be deployed around the one modelled in Figure 2 to provide wide area coverage.

It should be noted that the modelling shown in Figure 3 is provided for example purposes only, and the base station sites selected are arbitrary (ie. not representative of existing tower sites, apart from the Midland trial site). Again, it can be seen that by dimensioning the network in this manner, the coverage difference between 10 MHz (red) and 20 MHz (blue) to meet the required capacity is not significant, and the only way to achieve a greater spacing between base stations would be to increase the device power beyond that permitted in the standard, as previously described.

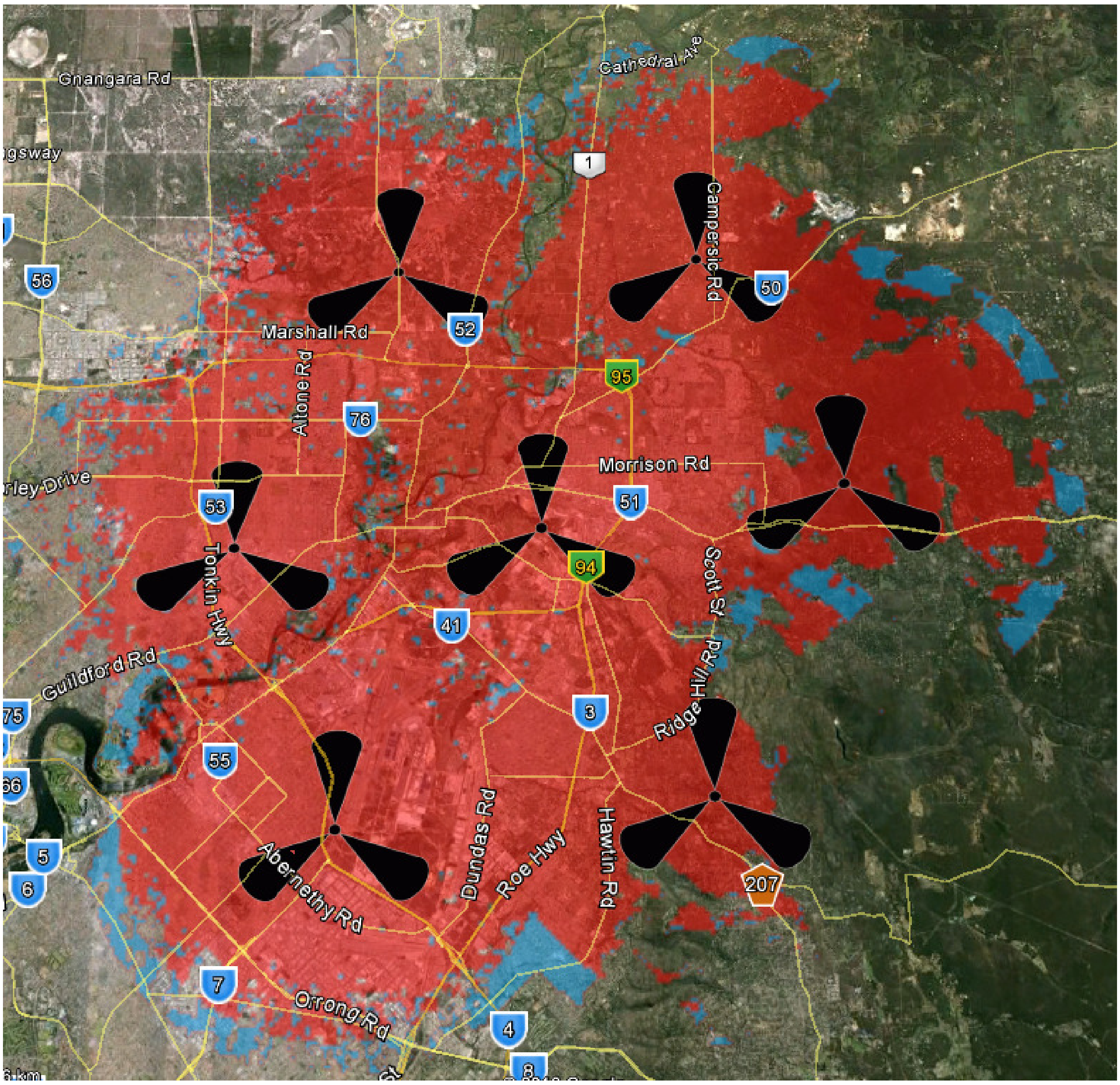

Figure 3: Extension of Figure 2 with added base stations. Unlike the modelling in Figure 2 this assumes 13.9 dBi omni-directional antennas on each base station, rather than sectors (results in minor distortion of PFD depiction at sector edges, but negligible for illustration purposes). The sector beams depicted are therefore also for illustration purposes only.

3.4. What can be read from the trial conducted by Motorola Solutions in Midland, WA?

The Inquiry has clearly taken an interest in a trial conducted last year of the proprietary Motorola Solutions PSMB system at Midland, WA. A number of images were produced at this trial that have been submitted as evidence. The ACMA was aware of this trial occurring, and in fact issued the trial licences to authorise operation and attended the trial on two occasions[12].

The ACMA is of the understanding that the Motorola Solutions PSMB system has the option to transmit up to 33 dBm (2W) from mobile devices, as opposed to the maximum 23 dBm (200mW) permitted in the LTE standard.

[12] ACMA engineers attended over two days, including a demonstration of the technology and discussions of spectrum planning implications of PSMB. Mr. Chris Cheah, an ACMA Authority member, attended on a separate date.

During a visit to the trial by some of the ACMA's engineers, it was proposed by Motorola that the ACMA, as part of its review of the 800 MHz band, should incorporate guard bands of 1 MHz on either side of the uplink frequencies earmarked for PSMB (to facilitate extra power from the device, hence no need for guard bands on the downlink). At the PSMBSC's Overflow Capabilities Sub-Group's (OCSG) Industry Roundtable meeting held in Melbourne on the 7th March, 2013, Mr. Hermang Patel of Motorola (attending via teleconference via the US) specifically asked the ACMA representatives if they would consider provisions for higher power devices in their replanning of the 800 MHz band. This is not a request that has been put to the ACMA by other potential equipment vendors.

Planning for guard bands around the uplink frequencies would mean that the corresponding 1 MHz slots on either side of the downlink would effectively be 'orphaned' – ie. unable to be 'paired' with uplink frequencies and therefore unsuitable for mobile broadband services. This would result in a total of 4 MHz lost to guard or unpaired segments in order to accommodate a large cell system, which would itself require an extra 10 MHz of spectrum to meet the PSMB capacity requirements within its coverage area. This is one of the reasons why mobile broadband networks using higher-than-standard device powers are considered unfavourable from a spectrum planning perspective.

3.5. Is image quality directly attributable to spectrum quantum?

There has also been much discussion of the images submitted to the Inquiry by Motorola Solutions[13] (Figure 2 of their submission), showing *"the difference between 10 MHz and 20 MHz of spectrum".* At face value, this makes a compelling argument, noting that the image produced using 10 MHz is of far lower quality than that produced using a 20 MHz bandwidth. Such imagery is useful as a visual comparison, however regardless of the application (be it still images, videos, mapping, biometrics or other telemetry), what is really important is the *data rate* that the user has available, which goes to the overall *capacity* of the network. A degraded image is an indicator of insufficient *capacity*, of which *spectrum* is only one determining factor.

Meeting data capacity needs is achieved through a well designed balance between spectrum bandwidth and network layout. Ultimately, responders must be able to communicate with the data throughput (measured in bits per second) needed to carry out their duties. In order to calculate the spectrum bandwidth and cell size required to meet the capacity requirement, it is necessary to define what the capacity requirement is, as well as the physical (propagation) limits of the radio technology. This is achieved by determining a baseline data throughput level for a defined number of users operating in 'worst case' conditions (at the 'cell edge', where the bits-per-second-per-Hz is generally at its lowest).

This was, in simple terms, the methodology employed by the PSMBSC, which used an agreed cell edge capacity level as a basis for calculating the maximum cell sizes for different environments (urban, suburban and regional) and spectrum needed to support each of the modelled scenarios. The modelling accounted for three users operating at the edge of a single cell uploading video streams. Uploading was considered as it is the uplink that constrains the cell coverage (for reasons explained in Section 3.3).

Given that image quality is dependent on a number of factors, including cellular density, the fact that the trial demonstrated only one 3-sector base station means that the impact of cellular density on the image quality was not demonstrated. In a single cell demonstration – which is clearly not the norm in a mobile broadband network – spectrum is logically the main input to achieving capacity; however this is not reflective of a 'real world' network.

[13] See Figure 2 from Motorola Solutions' *Submission to the Parliamentary Joint Committee on Law Enforcement Inquiry into Spectrum for Public Safety Mobile Broadband*

While no one would expect an equipment supplier to conduct a wide-area, multi-tower demonstration, the benefits and constraints of a single-tower demonstration need to be considered, as the outcomes can be somewhat subjective. It is important in any trial to be clear about the technical parameters under which it was operating and what this means for the outcomes demonstrated. For example, one could produce a high quality image using 5 MHz on a device operating at a given distance from a base station, and then lower the spectrum bandwidth to 3 MHz to achieve a similar comparison.

The key point is that these images were produced using a single-tower (three cell) demonstration. At the cell edge (which in an isolated trial is also the edge of coverage), it is very easy to contrive examples of the differences in image resolution between any differing amounts of spectrum. However, in an ordinary multi-cell LTE network, being an all-IP network (as opposed to older generation cellular and narrowband networks), the data traffic can be served by multiple base stations when a device is operating at or near a cell edge (worst case condition).

Regardless, the PSMBSC took account of this in their calculations by defining a minimum data throughput requirement that would allow video upload by three users at the cell edge (which was agreed by the PSMBSC membership). This requirement was used to determine the maximum cell sizes used in the modelling of 4 and 9 km for urban and regional areas respectively. So provided the PSMB cell sizes do not exceed those limits, the data capacity will be at – and in most cases well above – that minimum design requirement. In other words, if PSMB is dimensioned in accordance with the modelling shown in the PSMBSC's reports, 10 MHz will be sufficient to achieve the capacity required for still and video images.

3.6 Should spectrum be provided to offset deployment costs?

One of the more obvious implications of balancing cell sizes and spectrum bandwidth is cost. As described in Section 3.3, the relationship between cell size/cost and spectrum bandwidth only holds for non-noise limited ('interference-limited', or 'capacity-dimensioned') networks. This section explores the implications of balancing spectrum and infrastructure provisions to maintain the necessary network capacity. It therefore assumes that the PSMB network has been appropriately dimensioned and cell sizes are within the limits determined by the PSMBSC.

It has been stated on a number of occasions that LTE represents a paradigm shift in how spectrum can be used, and reused. It provides the ability to scale the cellular density of networks so they are tailored to meet the varying levels of data demand within a coverage area, and if necessary, increase data capacity in areas of higher demand by inserting additional base stations (mobile or fixed) without compromising coverage.

Scalability is an important consideration for both operators and spectrum planners. In essence, cellular density is scalable, however dedicated spectrum bandwidth isn't. The ACMA needs to ensure that *sufficient* spectrum is provided to support operator requirements, but with the assumption that operators will deploy them in an *efficient* way, which means taking advantage of the scalability features of the best available technology.

Providing spectrum for any purpose comes down to meeting the data capacity (bits-per-second, or equivalent analogue bandwidth) requirement for the number of users to be served, when and where they need it. In a cellular network topology, meeting a capacity requirement means striking a balance between spectrum bandwidth and infrastructure/base station count (determined by cell size and total coverage area).

For example, within the notional coverage area depicted in Figure 4, the same capacity might be achieved in both the left (which uses 10 + 10 MHz) and right (5 + 5 MHz) scenarios. Again, the bandwidth vs coverage relationship depicted in Figure 4 only holds when cells are dimensioned well within their coverage limits, and there is very little coverage difference between a 10 MHz and 20 MHz bandwidths for noise-limited cells (except if higher power devices are permitted – refer to Section 3.1 for explanation).

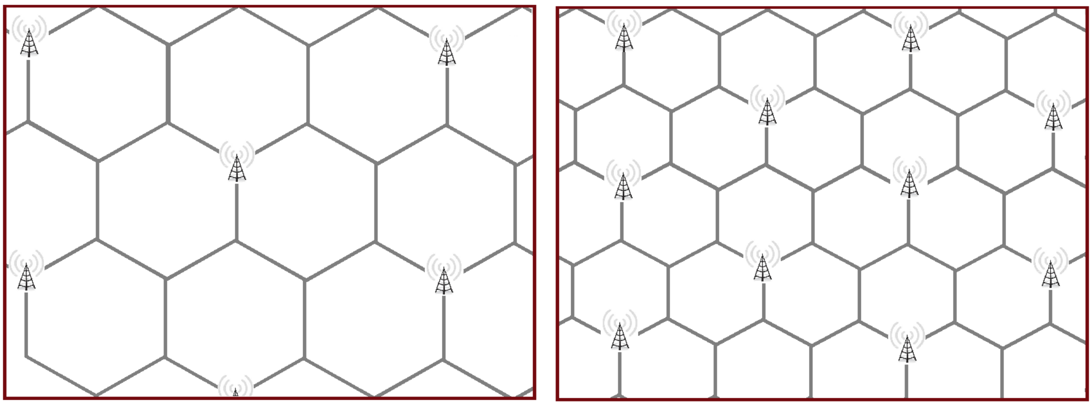

Figure 4: Notional service area for comparison of different cellular densities.

From a whole-of-economy perspective, the lower density, or 'thin' approach minimises build costs for operators (or in the PSMB case, states), however the conventional density approach both frees up the additional spectrum for other uses and minimises underutilisation of the spectrum provided to PSAs. Again, the infrastructure density is scalable; however the bandwidth provided is not – once provided it cannot be used by other services.

In geographic areas that have differing capacity requirements, the cellular density can be varied to reflect that. Conversely, if more spectrum were to be provided to cater for very high demand in small hot spots being served by a thin network, then much of that spectrum would be underutilised everywhere outside of those hot spots. This forms part of the rationale behind the ACMA providing spectrum for all of the scenarios modelled by the PSMBSC (including business-as-usual, planned event and natural disaster responses), but not the urban terrorist attack.

The latter scenario was modelled against events and a response of scale never seen in Australia, and in its deliberations on spectrum, the ACMA took into account the considerable resources available that could be brought to bear to provide the high amount of temporary local capacity needed to respond to such an event. Given the evidence provided through the PSMBSC, to provide the spectrum needed for this contingency (which was, in fact, more than 20 MHz) would mean locking away large amounts of spectrum that would rarely, if ever, be used to its full capacity, and even then only in small, locally-concentrated areas. It is the ACMA's view that this would be both technically and economically inefficient.

Where additional capacity is needed, either on a permanent or temporary basis, a far more efficient use of the available spectrum is to:

- Increase permanent cell tower density to cater for areas of *regular* high demand, eg. CBDs, sports stadiums etc; or
- Deploy an appropriate number of cells-on-wheels (COWs) to cater for *irregular or one-off* demand spikes (eg. due to an emergency) in areas where there would otherwise be a routine level of data demand.

Additionally, there is the ability to access *other* spectrum bands through roaming onto commercial networks and/or deploying local WiFi hotspots and temporary video links using the 4.9 GHz public safety band (see Section 4.1 for further discussion).

Furthermore, providing different amounts of spectrum for different areas (eg. 5 + 5 MHz in suburban/regional areas, 10 + 10 MHz in higher demand areas) is not a viable option as it would significantly reduce the utility of the additional 5 + 5 MHz left in lower density areas. From a spectrum planning perspective, there are other disadvantages to a thin network approach, such as the possible need for higher power devices and guard bands. As described in Section 3.2, this could compound the inefficiency of this approach, as guard bands (and corresponding frequency division duplex pairs) can no longer be used by other LTE systems.

Much of the need for additional spectrum appears to be driven by cost. Spectrum provided by the Commonwealth (at a public interest price) can offset the States/Territories' capital expenditure by reducing the base station count, particularly if there are provisions within ACMA's technical frameworks for higher power devices.

3.7. Are there any advantages to PSAs adopting a 'denser' network approach?

The cost implications of providing spectrum have been well established, however the ACMA maintains that the cell sizes needed for the relationship between spectrum and infrastructure to apply will not be practically realisable. Notwithstanding the spectrum and cost implications, a PSMB network that has been dimensioned to a reasonable density (within the cell size limits determined by the PSMBSC) would have significant advantages for PSAs. The relative merits of the two approaches to network density from a PSA perspective can be described in the Table 2.

Advantages to PSAs of 'thin' approach using 10 + 10 MHz	Advantages to PSAs of conventional approach using 5 + 5 MHz
• Lower capex/opex • (Marginally) less complex • Fewer site/security requirements	• Density is scalable to meet area-specific capacity needs. Reduces unnecessary headroom and therefore far more spectrally efficient • More robust: - Increased redundancy (if a site goes down it is easier for the network to reorganise and recover) - Better data handling (through LTE resource scheduling), particularly at or near the cell edge

Table 2: Advantages to PSAs of different network densities/spectrum quanta

Note that the benefits described of the conventional approach are contrary to some of the evidence given during the inquiry, for example (quoting Mr. Hewitt from ACT Emergency Services at the 24th June hearing). One of the advantages of LTE networks that have been dimensioned with a reasonable density is an increase in robustness and recoverability in the event of a base station outage. At the hearing, Mr. Hewitt suggested that:

> *"The idea of just putting in more sites and having more density to get more capacity is one of the weaknesses in the commercial systems. They put in lots and lots of sites in low-lying areas, so you get lot of good spectral re-use. Unfortunately, during something like the Newcastle floods they are underwater, so they stop working. That is another commercial difference between what we*

do and what they do. What they do is very sensible. They have excellent designs in their networks. They have maximised the spectrum they have available, which is very expensive. It is an expensive resource for them and they maximise it to the greatest degree, and they have great engineers who work out how to do that. But that does not necessarily make it a highly resilient emergency services network."

In actual fact, given the highly configurable nature of LTE networks (including evolving provisions in the standards for self-optimisation), a denser network would be better equipped to recover from an outage resulting from damage to a base station. The resource management functions built into the LTE standard mean that data traffic originating from within the area previously served by the affected base station would more readily able to be served by the surrounding base stations, if the network has been dimensioned appropriately.

As LTE is an IP network, there is no need for a continuous connection with a single eNodeB (LTE cell base station) so hand over to adjacent cells occurs on a "break-before-make" basis. If a base station was to be rendered unserviceable, traffic could be rerouted to another base station that the device can make a connection to. When this occurs, the X2 interface that links eNodeBs allows for a rapid handover time (demonstrated to be less than 50 milliseconds). A thin network would be less likely to be able to recover coverage in such circumstances, given that there would be fewer, if any, adjacent base stations that the device could make a connection with. As a result, the area previously served by the affected base station in a thin network could effectively become a 'black spot'.

Section 3.5 of this submission discussed comparisons of image quality between different spectrum bandwidths which were produced in a single cell scenario. The point was made that LTE, being an all-IP technology, provides that data traffic can be served by multiple base stations, provided the device can make a connection to them. This is a departure from older generation, circuit-based technologies, and means that throughput can be optimised to serve a number of clustered devices. Again, this differs from Mr. Hewitt's testimony:

"When we have an incident it is likely to be on one sector antenna, as in the Mitchell Bridge collapse. That is not a moving incident; it is going to be sitting there on one sector and that is all you are going to get to cover something like the Mitchell Bridge collapse."

On an LTE network, the data traffic arising from a localised, static incident such as this would not necessarily all be served on one sector (depending on location and proximity to surrounding base stations), as would have occurred on an older generation network.

4. Other matters

4.1. What other radiocommunications options are available to Public Safety Agencies?

Different radiofrequency bands have different properties. Bands considered useful for deployable terrestrial communications by operational entities such as Defence and emergency services include high frequency (HF), very high frequency (VHF), ultra high frequency (UHF) and super high frequency (SHF). Each have their own strengths and weaknesses. For example the VHF mobile bands can provide very wide area coverage from a single base station, but with limited capacity. Low UHF frequencies such as the 400 MHz band (used by emergency services for narrowband voice communications) provide a similar combination of coverage and capacity, and at the other end of the scale, SHF bands such as the public safety 4.9 GHz band can provide extremely high amounts of capacity, but only over a short range.

The UHF bands identified for mobile broadband below 1 GHz are a good compromise between coverage and capacity, and are therefore ideal for wide-area broadband networks (eg. Telstra's 850 MHz NextG network). In Australia, these bands comprise the 700, 800, 850 and 900 MHz bands. Much commentary has centred on the 700 MHz band as the 'sweet spot' or 'waterfront' spectrum for mobile broadband, but the reality is all of these bands have favourable properties and differ little in physical characteristics (refer to Section 2.4). If 700 MHz is waterfront property, then the other bands mentioned are as well.

Operators' needs also vary significantly, depending on scenario, environment and nature of their operations. For example, in some geographic areas very high amounts of capacity may be required, and in others only a baseline level of capacity. Telecommunications carriers plan for different user densities by using the lower cellular frequencies (eg. 700, 850 and 900 MHz bands) for wide area cellular coverage and higher frequencies (1800, 2100 and 2500 MHz bands) for higher capacity in built-up areas.

In addition, we have the concept of 'data offload', for example using 2.4 GHz WiFi to transfer large amounts of data through access points to fixed networks. This serves to relieve pressure on mobile broadband networks and is set to become more and more prevalent with the rollout of a National Broadband Network (NBN).

It is often stated that RF spectrum is a highly limited resource that is in high demand, so it is important to use the spectrum provided in the most efficient way possible. The methods described above go to what we mean by 'scalable', ie. using a combination of networks and frequency bands to optimise capacity when and where it's needed. The ACMA places a high degree of importance on providing adequate spectrum to support dedicated networks that optimally support their operations, but maintains that spectrum must be used efficiently by all users.

PSAs have historically relied on – and will continue to rely on – mission-critical narrowband (particularly voice) communications to support their operations, which have been delivered primarily through dedicated land mobile systems. In 2008, the ACMA commenced an extensive examination of PSA needs in this space through a wide-ranging review of the 400 MHz band. This resulted in an expansion of public safety spectrum resources and a framework for national interoperability, for what essentially remains (and will remain) the core communications capability for PSAs.

Broadband radiocommunications are also becoming an important component of future public safety capabilities and will be supported by spectrum in the 800 MHz and 4.9 GHz bands. In October 2012, the ACMA announced various measures that would support public safety communications across a range of frequency bands and technologies. These measures were:

> Provision of 10 MHz of spectrum from the 800 MHz band for wide area PSMB.

> 50 MHz of spectrum from the 4.9 GHz band (internationally harmonised for PPDR) for extremely high capacity, short range, deployable data and video communications (including supplementary capacity for the PSMB network in areas of very high demand).

> Implementation of critical reforms in the 400 MHz band—where spectrum has been identified for the exclusive use of government, primarily to support national security, law enforcement and emergency services.

The diagram in Figure 5 was provided as a conceptual representation of how these provisions could work together to provide a holistic, multi-layered communications capability. It is envisaged that, combined with the agreements with carriers for out-of-area data coverage (recognised as being necessary by both the PSMBSC and internationally), these provisions and reforms will combine to form the basis of a holistic strategy to meet PSAs' voice, data and video communications needs well into the future.

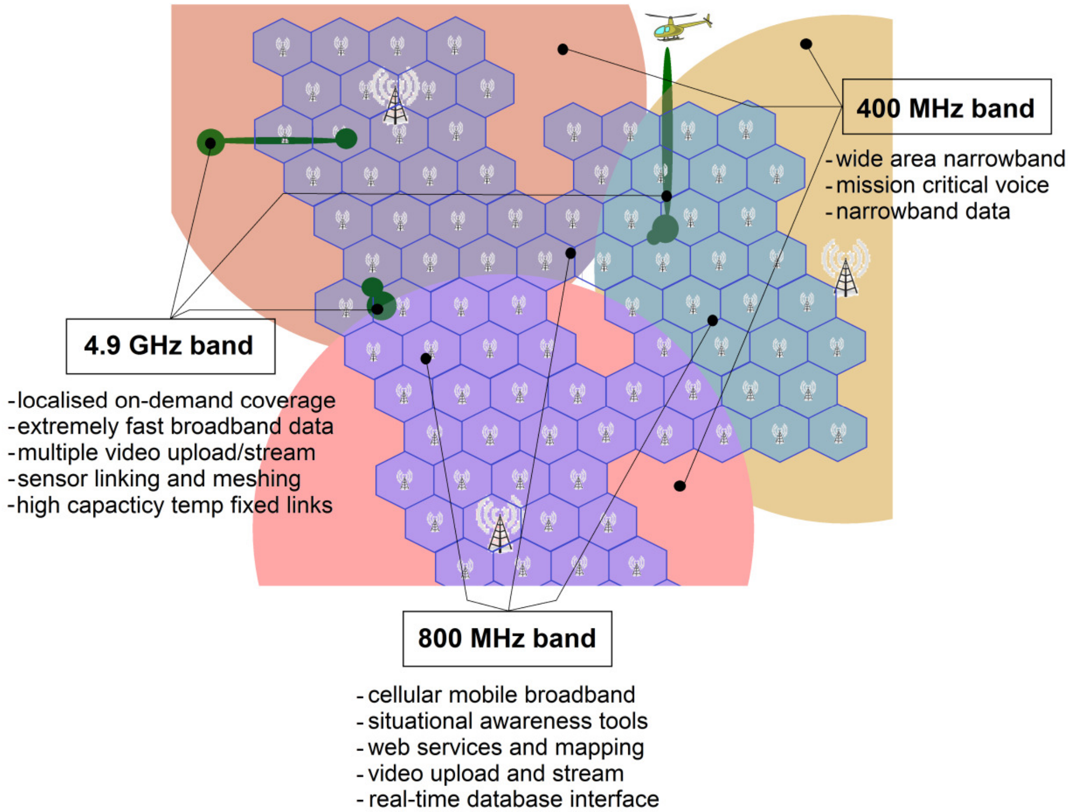

Figure 5: Conceptual depiction of a layered, multi-band strategy for public safety communications

4.2. Additional information

Attachment A contains additional information not contained in the main body of this submission, or the ACMA's original submission that may assist with any further questions the committee may have.

Attachment A – Additional Information

What is the scope and timeframe of the ACMA' review of the 800 MHz band?

The band 803-960 MHz (the 800 MHz band) will be replanned as part of an ongoing review. This frequency range currently supports commercial mobile services, land mobile and studio-transmitter links. It should be noted that the scope of the 800 MHz review excludes the bands 825-845/870-890 MHz currently licensed to Telstra and Vodafone for commercial mobile services.

The review is expected to be completed in late-2013 to early-2014; however, given the importance of making available spectrum to support a PSMB capability, the ACMA made an early decision on providing spectrum from the 800 MHz band. At this stage, it is likely that PSAs will be able to start accessing PSMB spectrum in 2015, around the same time that the 700 MHz band will be available for use.

In order to realise a PSMB capability, the ACMA will be required to clear incumbent licensees on frequencies identified for PSMB and in areas identified by PSAs by giving two years notice for incumbent licensees to cease operation. Identification by PSAs of those geographic areas within which they require a PSMB network will allow the PSMB network to grow in coverage as it matures, while displacing existing users only when necessary to do so.

How much spectrum could be made available as a result of the 800 MHz review?

Mr Hewitt of ACT Emergency Services stated at the Inquiry hearing on the 24th June 2003 that:

> ***Mr Hewitt:*** *... The choices of spectrum in 800 should be looked at quite carefully. If the chunk at the bottom of the 800 is used, the capacity for expansion is quite limited because you are sitting on top of the 700 megahertz allocation, which has already been allocated to commercial operators. It would, basically, snooker you into a corner.*
>
> ***CHAIR:*** *If you only allocated ten from that lower 800?*
>
> ***Mr Hewitt:*** *There is only ten in there. There is nowhere to go after that. You would not be using that piece of spectrum if you were looking at expansion.*

Subject to review outcomes, a decision on the quantum of available spectrum in the 800 MHz at the completion of the 800 MHz review is still to be made; however, there is the potential for up to 2x19 MHz of spectrum to be realised.

How long will the spectrum provided be useful for?

Mr Kelly, President of the Police Federation of Australia stated at the Inquiry hearing on the 17th June 2013:

> ***Mr Kelly:*** *Senator, our submission in relation to the ACMA recommendation is that 10 megahertz is based on business-as-usual projections for only a five-year period. That does not take into account critical incidents, either regionally or in urban centres, and that is the crux of our submission to a large extent, that it is simply not enough. The projections that have been made do not even take into account the likely growth in business as usual operations for police forces as the population grows. So the fact is that we think the recommendation by ACMA is incorrect and needs to be reviewed.*

It is worth reinforcing that the evidence that supported the ACMA's decisions was provided by the PSMBSC through the reports made by GQ-AAS (UXC) Consulting.

The ACMAs recommendation for 2x5 MHz is based on PSMBSC projections out to 2020. This was the date agreed by the PSMBSC and its PSA members. Notwithstanding this, the ACMA's own analysis revealed that a 2x5 MHz allocation would provide headroom for potential demand increases (over and above the 2020 projection) for business-as-usual and planned events.

The ACMA has maintained that it is prepared to review the suitability of spectrum provisions for PSMB once a network has been deployed. If the growth in demand is found to exceed projections, then the ACMA would look at providing additional spectrum to support the capability.

The evolving provisions in the 3GPP standard for LTE carrier aggregation means that any additional spectrum provided in the future will not necessarily need to come from the same frequency band as the original spectrum provided. In fact, it may be beneficial to aggregate carriers from a higher frequency band that is more suited to *capacity* than *coverage*, given the likelihood that, if the capacity of the network is exceeded, it will recur in certain high-traffic areas. PSAs will have a better idea of when and where demand exceeds capacity once a network is operational, but at this stage the evidence suggests that 10 MHz will be sufficient.

Does spectrum for LTE need to be contiguous?

The following testimony was made by Mr Hewitt following a series of questions from Senator Parry at the Inquiry hearing on the 24th June 2013:

> ***Senator PARRY:*** *... To assist me and the committee technically, do the 30 or the 20 need to sit together, or can it be like five here and five over there? It needs to be in one complete bandwidth together, without anything interrupting in between; is that correct?*
>
> ***Mr Hewitt:*** *Yes, you need contiguous spectrum.*

The use of contiguous spectrum allocations to support mobile broadband is representative of an older technology mindset and fails to account for provisions and capabilities, such as multi-carrier aggregation, in the LTE standard.

Whilst additional complexity in the handset and base stations are required to implement multi-carrier aggregation, the LTE standard already supports aggregating spectrum (notionally pairing a lower and higher band) in order to increase capacity/coverage.

How are commercial networks affected by congestion during major emergencies such as the Boston bombings?

The ACMA is not in a position to speculate on if, how or to what extent commercial networks were affected by increased load during such events. There are numerous variables that can contribute to this occurring, in particular the type of radio access network (RAN) technology used. Different RAN types use different modulation and coding schemes, spectrum occupancy and density, some of which are better equipped to handle traffic load than others.

All of the evidence that has been provided of network congestion under load has been based on older generation (pre-4G/LTE) technologies. It needs to be pointed out that 'congestion' on a network is not a 'crash'. In simple terms, when a network reaches its capacity within a cell, other users who seek access will poll the dedicated random access (RA) channel but be rejected because all of the channels are occupied.

For example, in a 2nd generation GSM network, when all of the available channels are occupied, a user will not be able to get onto the RA channel, and the call will fail. In this case the network is 'congested'. Existing traffic will continue to be served but no new subscribers can gain access until capacity is freed up, even if they have a 'priority' status on the network.

As part of the evolution and development in mobile access technologies, it was recognised that congestion and congestion management is an issue that users have particular expectations about. LTE is an all-IP technology (for both voice and data) that partitions data into resource blocks that are dynamically allocated to handle packets from subscribers in a way that optimises throughput and adds resilience. It is expected that LTE will not suffer the congestion issues of previous generations when a priority user (such as PSAs) requires access to the commercial network (based on the PSAs negotiated higher level of access).

More specifically, there are certain functions built into an LTE standard that provide quality of service (QoS) authorisation, which decides how certain data flows will be treated, and ensures traffic handling is in accordance with the users' subscription profile. If a subscription profile was negotiated for PSAs and a priority class identifier (CI) assigned to that user group, their traffic could be given priority over other traffic and even be guaranteed a specific minimum bit rate, regardless of load on the network. As LTE is an all-IP network (as opposed to 3G which is only IP for data and circuit-based for voice), there should always be an opportunity for users to be served that have been assigned a CI with priority status.

Will PSAs maintain a voice communications capability during periods of heavy network loads?

The bedrock of so-called 'mission critical' communications is, and will continue to be, narrow-band voice operations. PSMB is expected to be initially provisioned as a data-only capability, and voice will continue to be carried on narrow-band land mobile radio (LMR) networks, but the expectation is that some voice will be carried on the broadband network when voice services on an LTE network are a mature technology. In Australia, the 400 MHz band is used for public safety LMR communications (except in Tasmania), so congestion of commercial mobile networks around an incident site will have no bearing on the PSA's voice communications capability.