The future deployment of mobile broadband services

2.5GHz in Australia

Network Strategies Report Number 29028. 15 June 2010

NETWORK STRATEGIES

• Telecommunications Strategy •

0 Executive summary

0.1 Introduction

The Australian Mobile Telecommunications Association (AMTA) commissioned Network Strategies Limited to conduct a research project addressing the role of the 2500–2690MHz (2.5GHz – sometimes referred to as 2.6GHz) radiofrequency spectrum band in the future deployment of mobile telecommunications services in Australia.

The study provides evidence of the anticipated economic benefits available through mobile broadband, if sufficient spectrum capacity is available to meet the projected demand.

Data for our analysis has been collected from a wide range of sources, including publicly available material. AMTA members have also assisted us through the provision of proprietary data on a confidential basis. Although this study was commissioned by AMTA, the views expressed within this report are entirely those of Network Strategies.

0.2 Key findings

Mobile data traffic has increased substantially in recent times, and this trend is expected to continue, driven by a combination of increased data allowances, and appealing new mobile applications. Mobile data is now being delivered over smartphones, datacards and USB modems, as well as other mobile-enabled devices and tablet devices, all of which will place further pressure on spectrum capacity.

Rapid growth in mobile broadband

Our projections suggest that by 2020 there will be almost 20 million mobile broadband subscriptions on handsets, together with another 6.3 million datacards (under a moderate growth scenario). Growing machine-to-machine (M2M) communications will create additional revenue streams. Strong growth in traffic, which under a moderate growth scenario will reach 1360 million GB by 2014 (Exhibit 0.1), will reflect the increasing usage of mobile data services and applications.

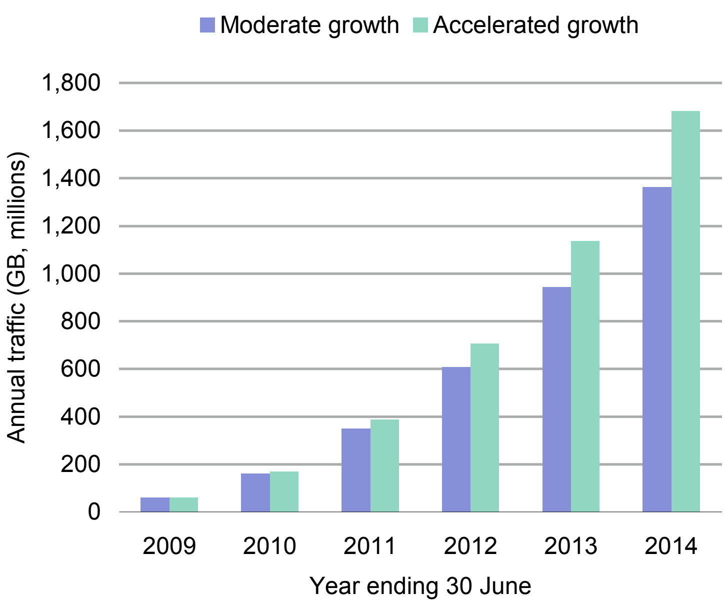

Exhibit 0.1: *Mobile broadband annual traffic projections, Australia, 2009 to 2014 [Source: Network Strategies]*

Macroeconomic benefits

We anticipate that both direct and indirect benefits will accrue to producers and consumers from mobile broadband services. As an indication of potential consumer surplus we estimate that the value derived by consumers from mobile data using 3G handsets increased substantially from AUD911 million in 2008 to over AUD1.5 billion in 2009.

Productivity benefits

We estimated gross productivity benefits for mobile broadband over the period 2013 to 2020 to be around AUD143 billion. From this total benefit we estimate the cumulative productivity benefit for Long Term Evolution (LTE) to be AUD62 billion over this same period, assuming that commercial launch of LTE over 2.5GHz will occur in 2013, with LTE over 700MHz available one year later.

Note that we believe this estimate to be conservative as:

- our analysis was based on benchmark productivity data from 2005 – updated data would reflect more recent advances in applications and technological capabilities which would increase the level of productivity benefit
- our estimate does not capture multiplier or knock-on effects, which would significantly increase the projected overall benefit.

Additional spectrum is needed to address demand and realise economic benefits

Realisation of this potential will require the availability of sufficient spectrum in appropriate bands to deliver both coverage and capacity for the addressable market. A combination of high-frequency (above 2GHz) and low-frequency (below 1GHz) bands is viewed by operators – and supported by the International Telecommunication Union (ITU) – as the optimal solution for mobile network deployment with the low-frequency band providing coverage and the high frequency band providing in-fill capacity. The 700MHz / 2.5GHz combination is expected to have the additional advantage of carrier bandwidths sufficient to deliver maximum data rates over Long Term Evolution (LTE)[1], unlike the current spectrum holdings of most of the Australian mobile operators.

The timetable for the availability of spectrum in both the 2.5GHz and 700MHz bands is still uncertain, which may result in our assumed 2013 deployment for LTE being too optimistic. However, delays in the commercial launch of LTE will place increasing pressure on capacity and increase costs as operators seek to implement strategies for

1 Namely 2×20MHz. Source: 3GPP, at http://www.3gpp.org/lte.

managing expected traffic loads. This may have the effect of reductions in service quality, and higher prices, which may constrain demand and usage, and thus also the anticipated economic benefits.

To assess the impact of such a delay, we have estimated the gross productivity benefit assuming that our penetration assumptions for mobile broadband and LTE services require an additional year to achieve. This has the effect of reducing the productivity benefit for mobile broadband by AUD5.5 billion over the period 2013 to 2020, and for LTE by nearly AUD17 billion.

The future deployment of mobile broadband services

Final report for AMTA

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1 Introduction

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Data for our analysis has been collected from a wide range of sources, including publicly available material, complemented by discussions with key players in the Australian telecoms industry.

Although this study was commissioned by AMTA, the views expressed within this report are entirely those of Network Strategies.

1.1 Background

Australia has a long history as a world leader in mobile technologies, through initiatives such as:

- the launch of GSM in 1993 – the first non-European country to do so, just two years after the world's first GSM network in Finland
- in 2003 the first 3G network in Australia was launched by Hutchison 3G Australia (now part of VHA), 18 months after NTT DoCoMo launched the world's first commercial 3G network in Japan
- in 2006 launching the then world's fastest 3G network – Telstra's Next G™
- in 2010 the world's first HSPA+ Dual Carrier network

- also in 2010, Optus – together with a number of other SingTel subsidiaries – will be participating in a regional trial of LTE, one of the first deployments in the world. Telstra will also be trialling LTE in 2010.

Australians have also been enthusiastic adopters of mobile services, with over 110 subscriptions per 100 persons of which more than half are 3G[2]. Mobile data revenues are growing and with the availability of increasingly affordable smartphones – together with greater data allowances and appealing applications – prospects for the mass market mobile broadband are extremely promising.

In Australia, the 2.5GHz band is currently used for television outside broadcast (TVOB) and electronic news gathering (ENG). The Australian Communications and Media Authority (ACMA) has identified this band as being suitable for wireless access services (WAS), which the ACMA defines as including:

> …IMT[-2000][3], wireless broadband services, 'next generation' – 3G and 4G – mobile telecommunications services and emerging technologies such as WiMAX.[4]

Key reasons noted by the ACMA[5] for the 2.5GHz band's suitability include:

- the global identification of the band for WAS
- global harmonisation resulting in economies of scale and reduced equipment costs
- potential for global interoperable equipment and international roaming
- potential for the band to accommodate a range of licensing frameworks
- suitability of the band for regional and rural areas due to its propagation characteristics.

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2 Australian Communications and Media Authority (2009) *Communications report 2008–09*, November 2009.

3 IMT-2000 is a family of global standards for third generation mobile communications, co-ordinated by the ITU. See http://www.itu.int/imt/.

4 Australian Communications and Media Authority (2010) *Review of the 2.5GHz band and long-term arrangements for ENG*, discussion paper, January 2010.

5 Australian Communications and Media Authority (2006) *Strategies for wireless access services: spectrum access options*, Spectrum Planning Discussion Paper SPP 10/06, December 2006.

In January 2010 the ACMA released a discussion paper on the 2.5GHz band[6] and sought comments from interested parties. The discussion paper outlines four options for the future of the 2.5GHz band, which are not considered to be exhaustive or mutually exclusive:

- **Status quo**: continue using the 2.5GHz band for Television Outside Broadcast Network (TOBN) apparatus licences for ENG applications.
- **Review pricing arrangements**: adjust the apparatus licence fees to reflect more accurately the value of the 2.5GHz band to alternative users. This may encourage incumbents to utilise the spectrum to its highest value; however, licensing parameters would likely need to be amended to allow more flexibility for this to be effective.
- **Make current arrangements more flexible**: this could involve removing regulatory restrictions from existing TOBN apparatus licences, changing the licence category, altering the current channel arrangements, or converting existing apparatus licences into spectrum licences. Licence fees would be reviewed at the same time to encourage use of spectrum to its highest value.
- **Re-allocate and issue new spectrum licences**: allocate the 2.5GHz band for spectrum licences. There would be a metropolitan, regional and remote geographical split defined for licensing, in which case the entire 190MHz available would likely be re-allocated in metropolitan areas where spectrum demand is highest, whereas smaller blocks could be re-allocated in regional and remote areas.

A range of alternative spectrum options for ENG operators are also discussed in the paper. None of the four above options in isolation will facilitate highest value use of the 2.5GHz band, whilst providing suitable long-term spectrum arrangements for ENG. As such, the ACMA's preferred policy outcome would be a combination of the third and fourth options. This would involve converting the ENG apparatus licences to spectrum licences in part of the 2.5GHz band and re-allocating the remainder of the band for WAS. The result would be reduced access to the 2.5GHz band for ENG operators (Exhibit 1.1):

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6 Australian Communications and Media Authority (2010) *Review of the 2.5GHz band and long-term arrangements for ENG*, discussion paper, January 2010.

- ENG access Australia-wide to 2570–2620MHz (the 'mid-band gap') via a converted spectrum licence, reduced by a 5MHz guard band when operating in the same area as adjacent band WAS base station transmitters
- ENG access to additional parts of the 2.5GHz band in regional areas of known high use as well as access on a shared basis with WAS in other areas dependent on demand for WAS.

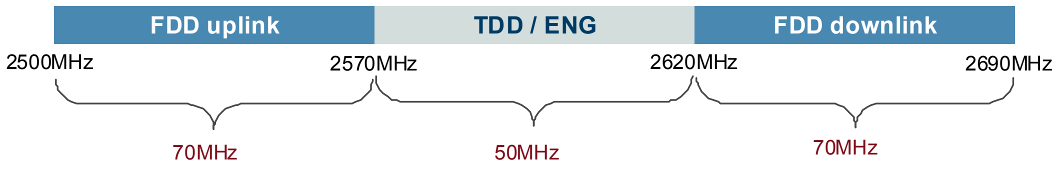

Exhibit 1.1: *ACMA's proposed spectrum arrangements in the 2.5GHz band [Source: ACMA]*

The ACMA also notes[7] that the amount of spectrum currently allocated for WAS (578MHz across all bands, and excluding 2.5GHz) is less than that of other comparable countries (Exhibit 1.2).

[7] *Ibid*.

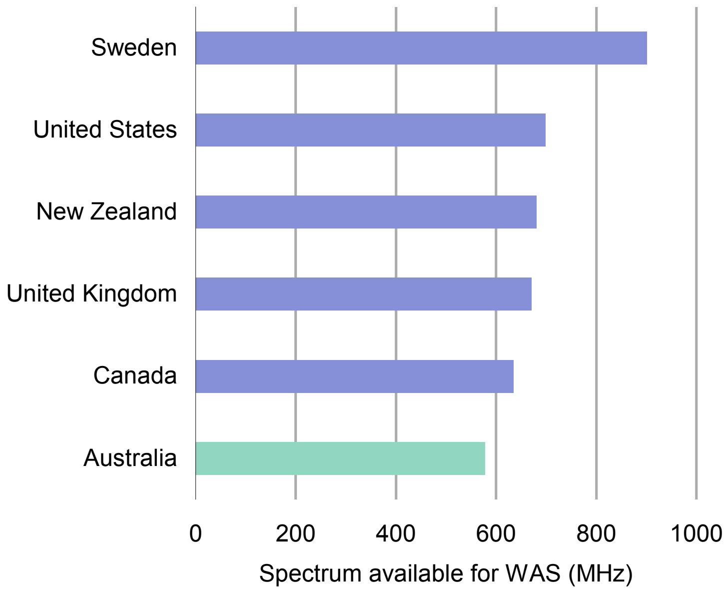

Exhibit 1.2: *Spectrum available for WAS in selected countries [Source: ACMA]*

This constraint on capacity may have implications for industry as demand for wireless services increases.

> Although some of the spectrum allocated for WAS in Australia is unused or under-utilised at present, the international trend suggests that demand in Australia will continue to rise, so that demand may soon exceed available spectrum.[8]

Therefore spectrum in the 2.5GHz band will be needed to ensure that industry is able to satisfy the anticipated future demand.

1.2 Structure of the report

Following the introduction, this report includes the following:

- technological issues associated with the 2.5GHz spectrum band (Section 2)

8 *Ibid*.

- mobile broadband devices and demand characteristics (Section 3)
- 2.5GHz for the Australian market (Section 4)
- concluding remarks (Section 5).

The Annexes contain a list of organisations which provided assistance, a brief background discussion of radiofrequency characteristics and a description of our methodology for estimating the economic effects of mobile broadband services.

2 2.5GHz: spectrum and technologies

In this section, we review the technical aspects of the 2.5GHz band (2500–2690MHz) which make it both complementary to the 700MHz spectrum band, and favourable for providing mobile broadband services.

2.1 The 700MHz and 2.5GHz spectrum bands

There are two important differences between the 700MHz spectrum band and the 2.5GHz spectrum band which means that they are not substitutable:

- the frequency (and the characteristics of that frequency)
- the amount of spectrum available.

The frequency

A fundamental property of radio frequency radiation is that the higher the frequency[9], the shorter the distance it can travel before becoming weak and unusable, and the more susceptible it is to being attenuated (or absorbed or blocked) by objects in its path.

In mobile systems, this means that the higher the frequency the smaller the maximum cell size. Thus if sites are deployed to provide maximum coverage (such as in rural areas) then we have estimated that six times more sites would be required to provide coverage using 2.5GHz sites than using 700MHz sites. This represents a significant increase in the

9 Or equivalently, the shorter the wavelength.

deployment cost, and is twice the increase in the number of sites when comparing 2100MHz sites to 900MHz sites for UMTS[10].

Thus in rural and other areas where the number of sites required is determined by coverage limitations, it will not be cost-effective for any operator with only 2.5GHz spectrum to deploy a full coverage network; the 700MHz frequency is far preferable.

The amount of spectrum available

One of the drivers for the ITU's selection of the 2.5GHz band for mobile services is the amount of spectrum available. As demand for mobile data services increases over time, so has the requirement for more spectrum. This requirement has in general been met by increasingly large allocations of spectrum (Exhibit 2.1).

Band	*Timing*	*Spectrum allocated by ITU*
GSM 900 (standard GSM band) – 2G	1991	2×25MHz
GSM 1800 – 2G	1998	2×75MHz
UMTS 2100 – 3G	2002	2×60MHz
LTE – pre-4G	2010 (projected)	190MHz

Exhibit 2.1: *Spectrum allocated for different mobile bands [Source: ITU, Network Strategies]*

To illustrate the capacity of a mobile system using 2.5GHz, LTE is estimated to be able to support a theoretical peak rate of around 300Mbit/s in a 20MHz carrier in ideal conditions (Exhibit 2.2), although it can operate with a variety of carrier sizes from 1.4MHz to 20MHz. It should be emphasised that actual rates achieved by customers will be less than the theoretical maximum speeds presented here. Actual rates (Exhibit 2.3) depend on many factors, including distance to base station, base station loading and speed of the customer's device[11].

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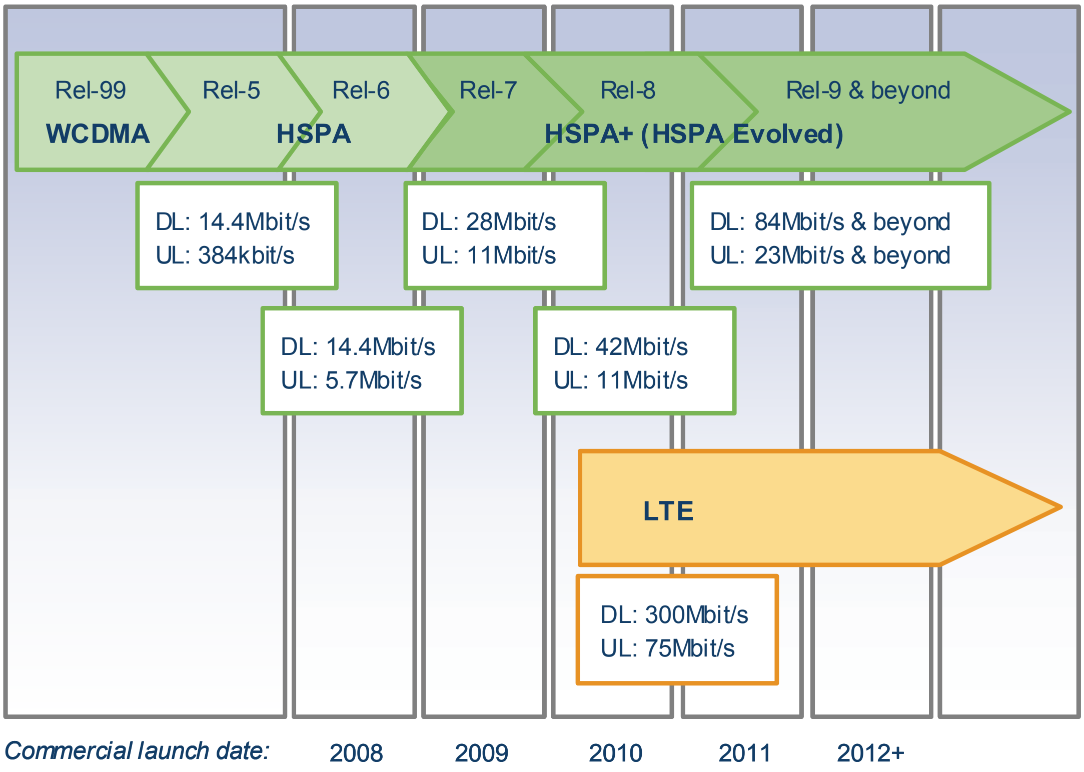
10 Nokia Siemens Networks (2008), *WCDMA Refarming: A Leap Towards Ubiquitous Mobile Broadband Coverage,* available at http://w3.nokiasiemensnetworks.com/NR/rdonlyres/73400A3E-DF4A-42A9-9DC9-00A866582476/0/WCDMA_Frequency_Refarming____White_Paper.pdf

11 Motorola (2009) *Realistic LTE performance: from peak rate to subscriber experience*, white paper.



Note: Speeds presented are theoretical peak speeds – actual speeds achieved by customers will be lower.

Exhibit 2.2: *Evolution of mobile broadband [Source: Qualcomm, UMTS Forum]*

Channel bandwidth	*Antenna technology*	*Realistic average subscriber rate*
20MHz	2 × 2 MIMO	2000 – 12 500kbit/s
10MHz	2 × 2 MIMO	2000 – 7500kbit/s
5MHz	2 × 2 MIMO	500 – 4000kbit/s

Exhibit 2.3: *Realistic subscriber rates for LTE [Source: Motorola]*

Combined with the high spectral efficiency of the technologies designed to use this band – in particular LTE (Exhibit 2.4) – 2.5GHz will have a significantly higher capacity than other spectrum bands, and thus will be desirable in high traffic density areas, such as in a city or regional centre.

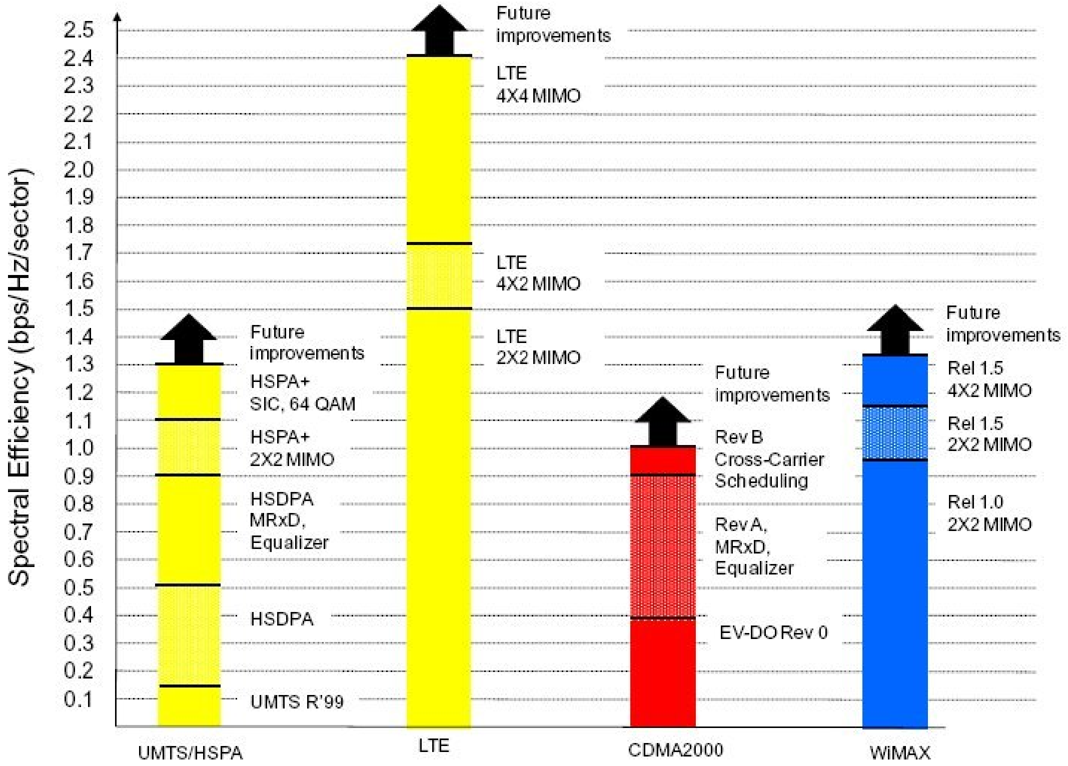


Exhibit 2.4: *Comparison of spectral efficiencies of different mobile technologies [Source: Rysavy Research / 3G Americas]*

An operator with spectrum in only the 700MHz band will need to resort to other measures to support these traffic hot-spots, such as cell splitting and sectorisation. However these solutions may not be satisfactory as the high cost of the additional sites (if cell splitting) and the high cost of additional sectors (if increasing the cell sectorisation[12]) may outweigh the benefit. Furthermore, given the projected demand for mobile data traffic (discussed in Section 3.4), such measures may offer only a temporary solution for high traffic density areas – additional spectrum capacity will eventually be required.

Thus the two spectrum bands, 700MHz and 2.5GHz, are complementary, with the low-frequency band providing coverage and the high frequency band providing in-fill capacity.

12 For example, if an operator deploys six sectors at a site, the capacity gain will not be twice that of a three-sectored site because there will be more overlap between sectors, which increases the interference between sectors, and causes more handsets to be in soft intra-site handoff (or 'softer handoff') which consumes capacity.

Indeed, the ITU also reaches this conclusion[13] (in the context of developing countries, but the principle is the same for any low traffic density area):

> Radio spectrum below 1 GHz is optimum for the needs of developing countries, due to the ability to serve larger rural areas from a single cell site compared to spectrum above 2 GHz. However, it is very challenging to find wide bandwidths below 1 GHz so "broadband" needs must be met primarily through spectrum above 2 GHz.

A combination of low and high frequency bands is the preferred configuration for operators that have suitable spectrum. In Australia Optus and Vodafone both operate UMTS networking that run on both a low frequency (900MHz) and a higher frequency (2.1GHz).

While other mobile spectrum bands, such as 850/900MHz, 1.8GHz and 2.1GHz may also be useful for any operator that does not have both 700MHz and 2.5GHz spectrum, it is also the case in Australia that wide bandwidths below 1GHz are not available: for example in the 900MHz band there is only 2×25MHz in total allocated to Telstra, Optus and Vodafone (Exhibit 2.5). Australian operators hold spectrum in several mobile bands, however the amount of spectrum in each band varies from operator to operator as well as from region to region.

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13 International Telecommunication Union, *Spectrum for IMT*, available at http://www.itu.int/ITU-D/imt-2000/DocumentsIMT2000/Spectrum-IMT.pdf.

	Total size of licensed band	*Optus*	*Telstra*	*VHA*
Capital cities				
850MHz	2×20MHz		✓	✓
900MHz	2×25MHz	✓	✓	✓
1800MHz	2×75MHz	✓	✓	✓
2GHz (unpaired)	20MHz	✓	✓	✓
2GHz (paired)	2×60MHz	✓	✓	✓
Regional areas				
850MHz	2×20MHz		✓	✓
900MHz	2×25MHz	✓	✓	✓
1800MHz	2×15MHz		✓	Canberra, Darwin, Tasmania only
2GHz (unpaired)	–			
2GHz (paired)	2×20MHz	✓	✓	✓

Exhibit 2.5: *Summary of spectrum holdings for Australian operators in selected bands [Source: ACMA]*

Deploying LTE in existing spectrum holdings would produce a less than ideal solution as the optimal carrier sizes for LTE are 2×20MHz, whereas in other bands it is not common for any one operator to have this amount of contiguous spectrum. Optus has a contiguous 20MHz holding of paired 2GHz spectrum that is required for HSPA, but only in the capital cities, and not in any other bands or regions. Neither Telstra nor VHA has contiguous 2×20MHz in any band. To achieve the greatest speeds possible with LTE technology one option could be for operators to negotiate a spectrum trade or swap[14].

Nonetheless deploying LTE in existing spectrum holdings would be a costly and complex procedure. The operator must clear the existing spectrum by either moving subscribers to a new spectrum band while the LTE network is being built and then while subscribers are

14 Note that spectrum trades or swaps are subject to stamp duty, the rate of which varies according to the State jurisdiction. This additional cost may be an additional barrier to the efficient optimisation of spectrum holdings

migrated[15], or by deploying additional sites to relieve the traffic on existing sites. Thus the operators must devise strategies for:

- minimising the cost of the upgrade, in particular minimising the transition costs of either (temporary) migration to a second frequency band and/or additional sites – in addition to the cost of upgrading to LTE itself
- avoiding disruption to existing users caused by migrating them to new services – this may require device replacement for some subscribers.

However, spectrum refarming may not be possible if, for example, the frequency bands are necessary to maintain existing services.

2.2 What is the attraction of the 2.5GHz band?

There are a number of factors that make the 2.5GHz band favourable to operators, including the selected duplex schemes, the size of the band and the global harmonisation of the band. These are discussed below.

Duplex scheme

Unlike some existing mobile spectrum bands, the 2.5GHz band is likely to support both common duplex schemes – FDD (frequency division duplex) and TDD (time division duplex).

FDD is the scheme used by most current (and previous) mobile technologies. It uses separate blocks of spectrum for the uplink (from mobile to base station) and the downlink (from the base station to the mobile). As the blocks are the same size, FDD is suited to symmetric traffic such as voice. FDD transmits continuously in each direction (unlike with TDD) and this requires separate transmitter and receiver equipment at each end of the link,

15 When Vodafone New Zealand deployed its UMTS900 network, it freed its GSM900 spectrum by migrating customers to GSM1800. Up to this point the GSM1800 band had been used only for GPRS, not voice. This migration was relatively transparent to subscribers as enough were using handsets that were GSM1800 capable (that is, dual band). Note that the need for migration was exacerbated by the sale of a portion of Vodafone's GSM900 spectrum to the new operator Two Degrees Mobile.

increasing the cost over having shared transmitter and receiver equipment. The main benefits of FDD are that it provides an upgrade path for existing mobile operators, allows for easier integration with existing mobile (FDD) handsets and most existing spectrum is parcelled to suit FDD technologies.

TDD is a more recent scheme that uses a single block of spectrum. The uplink and the downlink are implemented using separate timeslots on that single block. Since the time slots do not have to be allocated equally between the uplink and downlink, TDD supports asymmetric traffic loads (such as broadband) more efficiently than FDD. It further increases spectrum efficiency by removing the need for a guard band between the uplink and downlink channels[16]. While equipment is more complex[17], as only one transmitter is active at a time some of the transmitter and receiver equipment can be combined which may reduce costs. Disadvantages of TDD are the interference issues between sites and with other frequency bands[18], requiring more complex network planning than FDD systems.

As discussed in Section 2.3, the 2.5GHz band is likely to support both FDD and TDD. This will require a guard band between the FDD and TDD bands to ensure there is no interference between the two systems, which will reduce the amount of usable spectrum.

LTE supports both FDD and TDD modes of operation but future deployments are likely to be primarily FDD. WiMAX uses TDD, and is likely to support either FDD or TDD in the future[19].

Giving operators the ability to choose the duplex scheme that will best support their network and enable the most efficient use of the spectrum increases the value of that spectrum.

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16 Although a guard band is not required, TDD does require a guard period between the transmission and receiving time slots, which will reduce the effective efficiency of the band.

17 Embrace (2002), Time division duplex – flexible and efficient for millimetre broadband access systems, International Workshop on broadband fixed wireless access. Available at http://www.telenor.no/fou/prosjekter/embrace/Workshop/ole2.pdf.

18 Airspan (2007) *Coexistence of TDD and FDD wireless access systems in the 3.5GHz band*, white paper.

19 LTE manufacturers are developing TDD versions of LTE to make use of existing unpaired and thus otherwise unusable spectrum; WiMAX manufacturers are developing FDD versions of WiMAX to to make use of the current mobile spectrum allocations and thus allow it to compete better with LTE.

Size of band

The 2.5GHz band is wide enough at 190MHz – that is, the proposed 2×70MHz paired and 50MHz unpaired split – to support both the large 20MHz LTE carriers, and a number of competing operators.

Most other spectrum bands lower than 2.5GHz do not have as much spectrum available, while bands higher than 2.5GHz face increasing problems in providing wide area and in-building coverage.

Global harmonisation

The 2.5GHz band is likely to be the one of the few mobile/WAS spectrum bands – and in particular 3G – that will be accepted and have frequencies aligned globally[20].

Globalisation has a number of advantages:[21]

- economies of scale for both handsets and network equipment
- better interoperability of terminals and equipment globally (in particular, facilitating subscriber roaming)
- higher chances of technology success and world wide adoption.

Many other mobile spectrum bands have not been globally harmonised, particularly between ITU-R region 1 (Europe, Africa and the Middle East) and region 2 (the Americas). This lack of harmonisation has created incompatible technologies and caused roaming difficulties since the inception of mobile services. Examples of bands not globally harmonised include:

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20 Qualcomm (2010) *Qualcomm Comments On Public Consultation On The Selection And Award Procedure For Licenses In The 2500-2690 Mhz Band*, http://www.nca.org.gh/consultations/qualcomm/Qualcom_Comments_Ghana_BWA_consultation.doc.

21 Arya, V.K. (2007) *Where WiMAX Fits – Mobile WiMAX at Various Bands*, conference paper at the International Conference on WiMAX – Technology for Mobile Broadband & Mobile VoIP Services, 10 January 2007, available at http://www.assocham.org/events/recent/event_136/_v.k.arya.ppt.

- 900MHz for GSM in Europe and 800MHz (850MHz) in North America
- 1800MHz for DCS (later GSM1800) in Europe and 1900MHz for PCS (later GSM1900) in North America
- 2.1GHz for UMTS in Europe
- more recently, the digital dividend spectrum, namely 700MHz (698–806MHz) in North America, and 790–862MHz in Europe.

2.3 The ITU 2.5GHz spectrum band options

The 2.5GHz band was allocated to terrestrial mobile communications services by the World Radiocommunications Conference (WRC) in 2000. For the purposes of international harmonisation of the band, the ITU presented three options for allocating spectrum to support the different duplex schemes (Exhibit 2.6):

- **option 1** – preconfigured allocations of paired (for FDD – frequency division duplex – cellular-type services) and unpaired (for TDD – time division duplex – WiMAX-type services) spectrum
- **option 2** – paired spectrum only, with the uplink portion of some pairs in another undetermined band
- **option 3** – allowing the bidders for spectrum to decide how they want to allocate the spectrum they acquire to paired or unpaired operation.

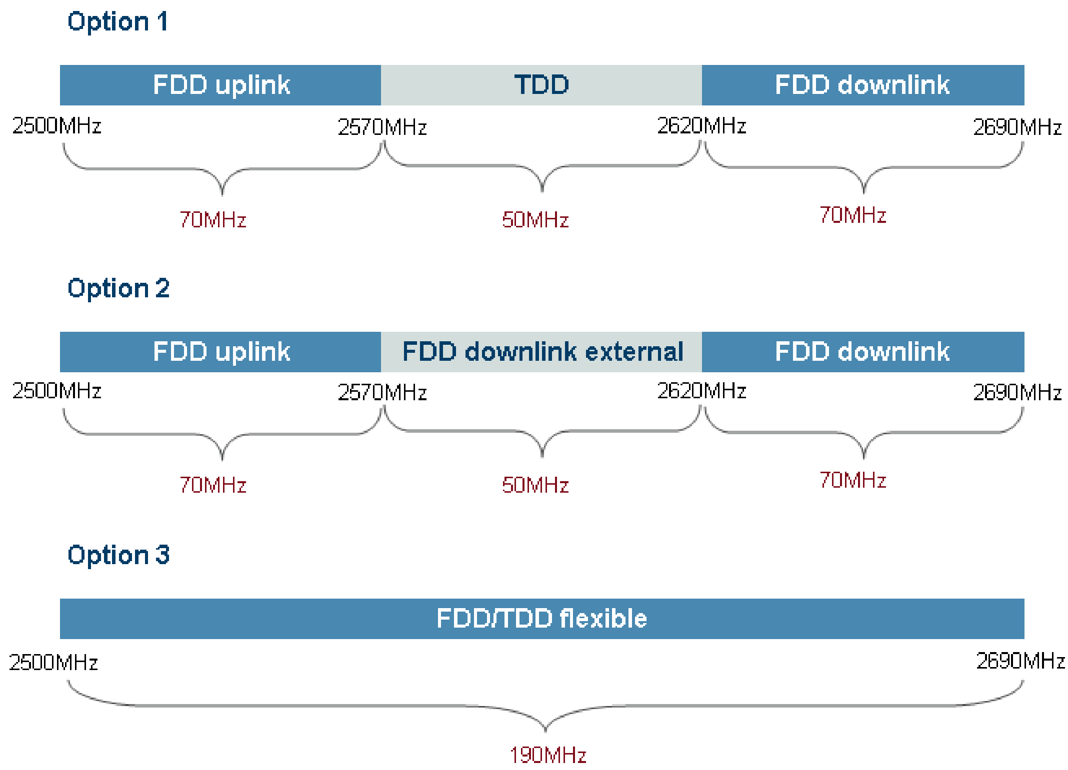

Exhibit 2.6: *Allocation options for 2.5GHz spectrum bands [Source: ITU]*

Option 1 has the advantage of technical neutrality, providing operators with the choice of adopting either FDD or TDD, and encouraging competition between LTE and WiMAX operators. Demand for unpaired spectrum is not addressed with option 2, which thus violates the principle of technical neutrality (often a regulatory objective). Option 3, while the most flexible, could lead to different national band plans – a less than ideal outcome as demand could be constrained by limitations on the availability of suitable equipment, and would also increase the complexity of spectrum management – due to the need to include guard bands at the boundaries of FDD and TDD bands as noted above, which also reduces the amount of usable spectrum – and potentially the costs for spectrum owners.

Note that for option 1, the ITU has recommended that the guard bands at the 2570 and 2620MHz boundaries be taken within the 2570-2620MHz band[22], thus the amount of spectrum available for TDD is affected. In Europe, the size of these guard bands is 5MHz, as specified by the European Commission[23].

Spectrum allocation to date for 2.5GHz has generally been based on these three options. The most recent spectrum allocations tend to favour option 1, with some slight variation due to local circumstances. There are however some exceptions: one key example being the United States (discussed further below).

2.4 International trends in 2.5GHz

The 2.5GHz band has been designated for WAS by the European Commission (discussed below) as well as by many other countries across the Americas, the Asia-Pacific region and Africa. As listed in the ACMA's discussion paper[24], countries that have allocated, or are in the process of allocating, the 2.5GHz band to WAS include:

- **currently using 2.5GHz for WAS:** Canada, Finland, Germany, Hong Kong, Japan, Malaysia, New Zealand, Norway, Poland, Russian Federation, Singapore, Sweden, Taiwan, Turkey, United States
- **in the process of making, or intend to make, 2.5GHz available for WAS:** Austria, Belgium, Brazil, Croatia, Denmark, Estonia, France, India, Italy, Latvia, Netherlands, Portugal, South Africa, Spain, Switzerland, United Kingdom
- **considering using 2.5GHz for WAS, or have identified the band for WAS in the National Frequency Allocations Table:** China, Czech Republic, Malta, Slovak Republic, Thailand, Vietnam.

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22 International Telecommunications Union (2007) *Frequency arrangements for implementation of the terrestrial component of International Mobile Telecommunications-2000 (IMT-2000) in the bands 806–960 MHz, 1710–2025 MHz, 2 110-2 200 MHz and 2 500-2 690 MHz.*

23 European Commission (2008) Commission Decision on the harmonisation of the 2500–2690MHz frequency band for terrestrial systems capable of providing electronic communication services in the Community, Decision 2008/477/EC, 13 June 2008.

24 Australian Communications and Media Authority (2010) *Review of the 2.5GHz band and long-term arrangements for ENG*, discussion paper, January 2010.

Auctions of the 2.5GHz band have already been held in several countries (Exhibit 2.7). In Germany, auctions for the four bands 800MHz, 1.8GHz, 2.0GHz and 2.5GHz were held concurrently over the period April to May 2010. A number of other countries are expecting to schedule auctions over the next two years, for example Austria, Brazil, Colombia and South Africa.

Country	*Date auction concluded*
Norway	November 2007
New Zealand	December 2007
Sweden	May 2008
Hong Kong	January 2009
Finland	November 2009
Netherlands	April 2010
Denmark	May 2010
Germany	May 2010

Exhibit 2.7: *Timetable of spectrum auctions for the 2.5GHz band in selected countries [Source: regulators]*

Harmonisation of the 2.5GHz band in Europe

Under the European Commission Decision 2008/477/EC[25], all European Member States must designate the 2.5GHz band for terrestrial telecoms services, including fixed wireless services. While this Decision supports a flexible allocation plan – ITU's option 3 – many Member States have implemented, or are likely to implement, the more structured option 1 which is better suited to facilitate the objective of enabling users to access compatible services when roaming across national borders.

There have however been delays in some Member States. For example, in France the rights to the band are held by the military until 2015, and in the United Kingdom the intended auction of the 2.5GHz spectrum was delayed – it will now be aligned with the release of 800MHz spectrum and the liberalisation of 900MHz and 1800MHz spectrum (the earliest

25 European Commission (2008) *Commission Decision of 13 June 2008 on the harmonisation of the 2500–2690MHz frequency band for terrestrial systems capable of providing electronic communications services in the Community*, Decision 2008/477/EC.

possible date was expected to be mid 2010, however some commentators believe that it will slip further to 2011).[26]

United States: single player and TDD dominance

In the United States the 2.5GHz band was allocated prior to the international agreements of WRC 2000, and most of the band is currently held by Sprint Nextel and Clearwire (which is 51% owned by Sprint). Sprint and Clearwire use WiMAX TDD technology. The Sprint XOHM (WiMAX) business unit has been merged with Clearwire, with Sprint having an MVNO relationship with Clearwire. As at the end of 2009, Clearwire had 688 000 subscribers (wholesale and retail)[27].

A recent report for the GSMA noted the disadvantages of such market dominance:

- The extent and timing with which the majority of this band will be used to deliver broadband wireless services to customers is subject to the financial strengths and business success of only one operator, which has encountered significant business problems and lost market share in recent years

- The deployment of other technologies such as LTE in the 2.6GHz [2.5GHz] band which would be favored [*sic*] by other operators is for the moment blocked.[28]

This also has implications for international roaming of non-TDD users.

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26 Department for Culture, Media and Sport, and Department for Business, Innovation and Skills (2009) *Digital Britain*, final report, June 2009.

27 Clearwire (2010) *Clearwire reports fourth quarter and full year 2009 results*, media release, 24 February 2010.

28 Global View Partners (2009) *The 2.6GHz spectrum band: unique opportunity to realize global mobile broadband*, report for the GSM Association, December 2009.

3 Mobile broadband devices and demand

Spectrum capacity is under increased pressure from growth in mobile data. Globally, mobile data traffic increased 160% from the end of 2008 to the end of 2009, with mobile video anticipated to be the biggest driver of mobile data traffic growth between 2009 and 2014. Smartphones are significant drivers of mobile data traffic; on average a smartphone user will generate ten times the amount of traffic compared to a non-smartphone user.[29]

3.1 Mobile devices and the 2.5GHz band

Smartphone uptake has been increasing rapidly, with the devices having gone from being primarily the domain of business users to being increasingly used for personal applications. Smartphones accounted for 14% of total worldwide mobile sales in 2009, up from 11% in the previous year. This is predicted to rise to 38% of sales by 2013.[30] In the UK, 16% of mobile handset sales were smartphones during Q1 2009.[31] Almost one quarter of mobile devices purchased in the US over the last year were smartphones.[32] In Australia, Telstra predicts that one in four mobile phones purchased during 2010 will be a smartphone.[33]

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29 Cisco (2010), *Cisco visual networking index: global mobile data traffic forecast update*, 2009-2014, available at http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html.

30 Gartner (2009), *Gartner says worldwide mobile device sales on pace for flat growth in 2009*, 15 December 2009, available at http://www.gartner.com/it/page.jsp?id=1256113.

31 Ofcom (2009), *The communications market report 2009*, August 2009.

32 Adweek (2009), *Smartphone social networking surges*, 24 September 2009, available at http://www.adweek.com/aw/content_display/news/digital/e3i98ea2e9e6ffb5198605dca8a4e94cb86.

33 Fink, R. (2010) *The year ahead in mobiles*, available on Telstra Exchange Viewpoint, available at http://exchange.telstra.com.au/2010/01/06/top-developments-for-mobiles-in-2010/.

In 2009, Italy had the world's highest smartphone penetration (number of smartphones in use as a percentage of total mobile handsets) at 36%, followed by the United States and Canada (Exhibit 3.1).[34]

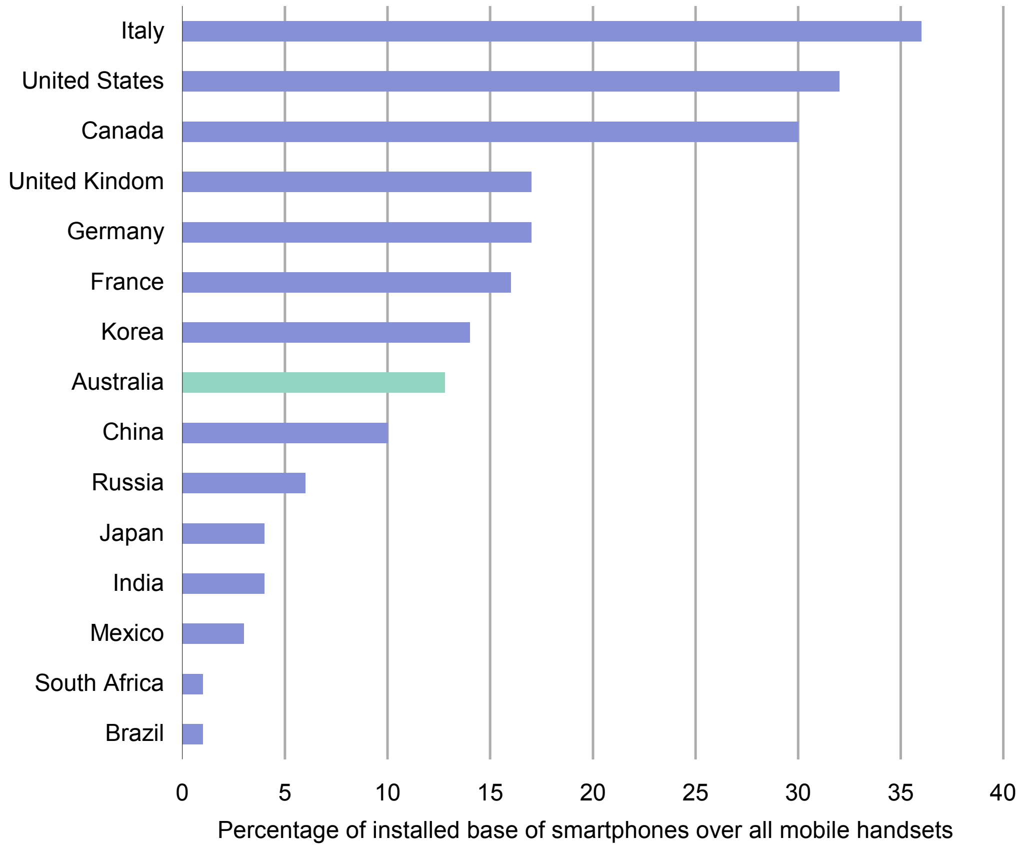

Exhibit 3.1: *Smartphone penetration in various countries, 2009 [Source: Cisco, Network Strategies estimate]*

The key factor that successfully advanced personal use of smartphones was the introduction of the iPhone. A US survey of iPhone owners in April 2009 showed that 73% of respondents spent more than half their time on the device for personal use.[35]

34 Cisco (2010), *Cisco visual networking index: global mobile data traffic forecast update*, 2009-2014, available at http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html.

35 Compete (2009), iPhone users: all play and no work?, 29 April 2009, available at http://blog.compete.com/2009/04/29/iphone-smartphone-personal-business-usage/.

Social networking via smartphones has been one particular area of growth. As of July 2009 in the US alone, there were 18.3 million unique users of social networking on smartphones (187% increase on the 6.4 million users twelve months earlier). Social networking sites account for 32% of all smartphone activity[36], with Facebook, MySpace and Twitter being the most popular sites. Worldwide about 100 million of Facebook's 400 million members are mobile users, as of February 2010, up from 65 million four months previously.[37] As well as the generic social networking sites, mobile-only social networks – such as MocoSpace – are becoming popular.

This interest in visiting popular Internet sites via mobile phones has been recognised by telecommunications operators, with Australian operators offering unlimited access to some specified sites for a monthly fee. These include social networking sites, YouTube, and mobile TV channels.

Social networking is certainly not the only personal application expected to have increased use over the next few years. According to Gartner[38], the top ten consumer mobile applications for 2012 are expected to be:

- mobile money transfer
- location based services
- mobile search
- mobile browsing
- mobile health monitoring
- mobile payment
- near field communication services
- mobile advertising
- mobile instant messaging
- mobile music.

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36 Adweek (2009), *Smartphone social networking surges*, 24 September 2009, available at http://www.adweek.com/aw/content_display/news/digital/e3i98ea2e9e6ffb5198605dca8a4e94cb86.

37 Facebook (2010), *The Facebook blog*, http://blog.facebook.com/.

38 Gartner (2009), *Gartner Identifies the top 10 consumer mobile applications for 2012*, 18 November 2009, available at http://www.gartner.com/it/page.jsp?id=1230413.

Smartphone data service usage is becoming increasingly important for operators, as voice revenues decline. In the US wireless data service revenues increased 31% in first half of 2009, at over USD19.4 billion, comprising more than a quarter of all wireless revenues.[39]

A UK study found that users of smartphones were more than twice as likely as other mobile users to access information using a browser, and nearly four times as likely to access information using a downloaded application. iPhone users were the most likely to use mobile Internet services (Exhibit 3.2).[40]

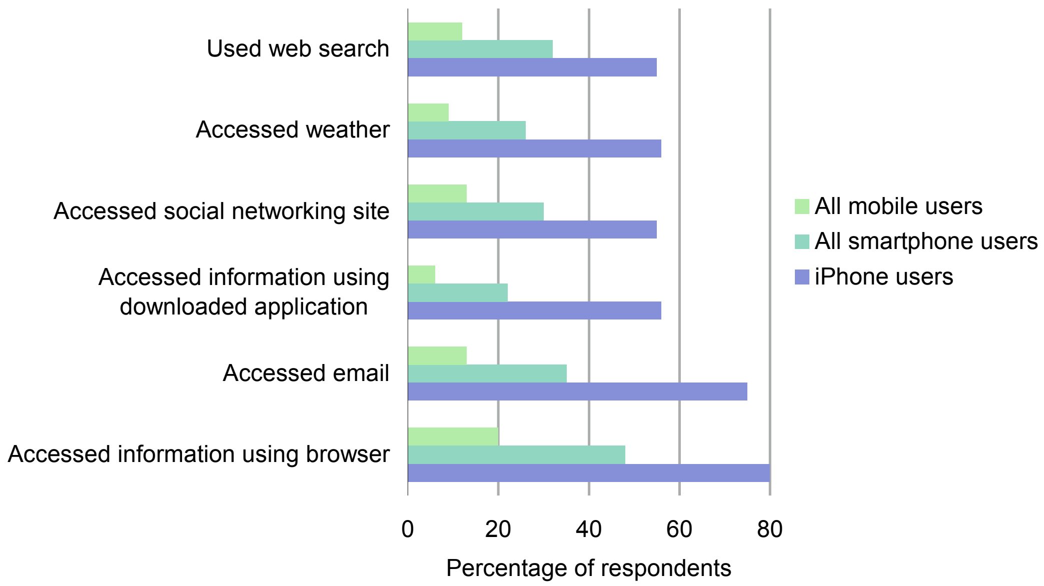


Exhibit 3.2: *Usage of advanced services by UK smartphone users [Source: comScore Mobile, January 2009]*

39 3G Americas (2010), *3GPP mobile broadband innovation path to 4G*, February 2010.

40 Ofcom (2009), *The communications market report 2009*, August 2009.

Similar results were found in the United States, with users of more recently released Android phones shown to have usage characteristics comparable to those of iPhone users (Exhibit 3.3).[41]

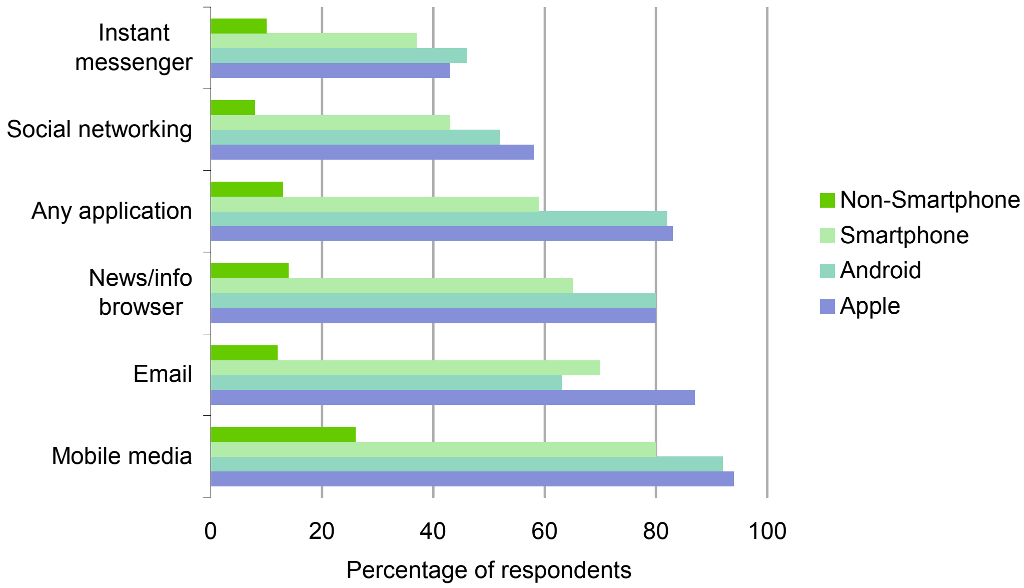


Exhibit 3.3: *Usage of various mobile phone features by phone type [Source: comScore, December 2009]*

There is a rapidly growing market for downloadable smartphone applications, since being popularised by the iPhone Apps Store. By the end of 2009 there were over 100,000 applications available for iPhone and 20,000 for Android, with other operating systems also offering applications to purchase.

Smartphone capabilities are predicted to improve further. Multi-tasking is a key feature expected to become common. Mobile banking and mobile advertising applications are being developed. Augmented reality, utilising GPS technology and mobile cameras to integrate real world images with online data, is a powerful feature currently in development. Power consumption will need to become more efficient for batteries to

41 comScore (2009), *Android: crashing the smartphone party*, 17 December 2009, available at http://www.comscore.com/Press_Events/Press_Releases/2009/12/Android_Crashing_the_Smartphone_Party.

provide long lasting power to increasingly feature-rich phones. Improvements in touch screen technology are also anticipated.[42]

In the future however mobile-enabled devices will encompass more than just smartphones. E-book readers, tablet devices such as the Apple iPad, game consoles, MP3 players, cameras, remote healthcare monitoring devices, and more, will all place even greater pressure on spectrum capacity.

3.2 Demand for advanced mobile services

Analysts predict that the global market for mobile broadband is expected to increase significantly over the next few years. While industry projections do vary, one analyst, Juniper Research, claims that by 2014 annual revenues from the global LTE market will be USD70 million, with over 100 million users[43].

According to the Australian Bureau of Statistics, as at December 2009 over 2.8 million (35%) of non dial-up Australian Internet connections were mobile, demand doubling over the previous twelve months[44]. This represents just under half the number of DSL connections (4.2 million, or 51% of total non dial-up connections).

Great potential for mobile broadband clearly exists in Australia. There is evidence that fixed-mobile substitution is occurring, and the availability of cost-effective high-speed mobile broadband will accelerate that trend, reducing the need to maintain a telephony service for Internet use.

The Australian mobile industry believes that a combination of increased data allowances, and new mobile applications – in particular social applications – will drive demand for the

42 HTCPhones (2010), *8 key points to watch in smartphones of 2010*, 15 January 2010, available at http://www.htcphones.net/8-key-points-to-watch-in-smartphones-of-2010/.

43 Juniper Research (2009) *LTE mobile broadband strategies: consumer & enterprise markets; devices & chipsets 2009–2014*, April 2009.

44 Australian Bureau of Statistics (2009) *Internet activity Australia, December 2009*, catalogue no 8153.0, March 2010.

increased functionality available with smartphones such as the Apple iPhone and Android-based devices, making smartphones a more compelling consumer proposition.

In the United Kingdom, Ofcom notes that mobile broadband can be both a complement to, and a substitute for, fixed broadband, with those in higher socio-economic groups[45] having both mobile and fixed broadband services. In lower socio-economic groups, mobile broadband take-up is much lower, but it is more likely to be the only broadband connection. Ofcom believes this to be related to affordability: the pre-paid options available with mobile broadband allow users to avoid the monthly rental of a fixed broadband service and are better suited to control spend. Users living in rented accommodation were also more likely to have only mobile broadband (Exhibit 3.4).

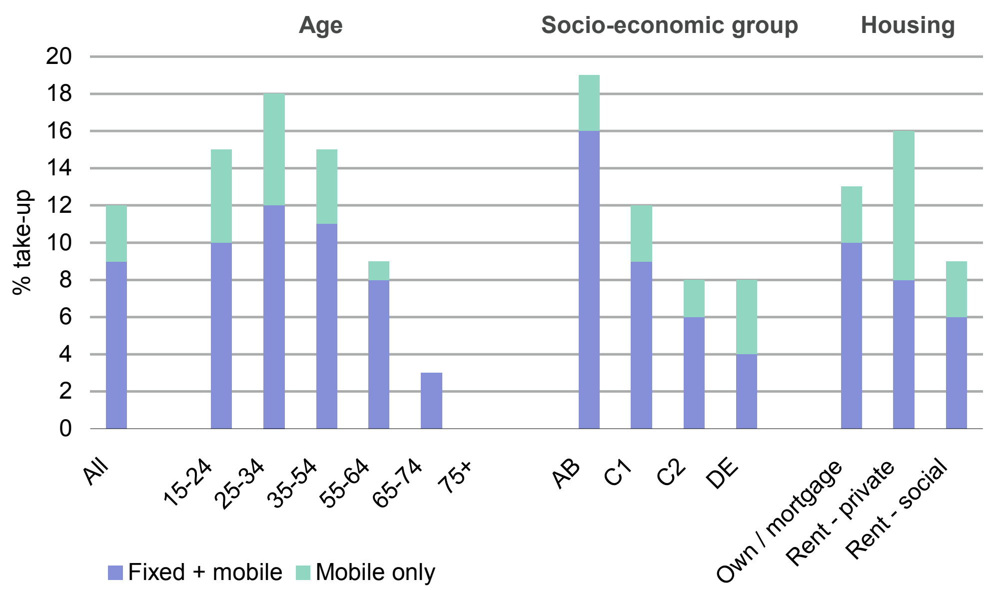


Exhibit 3.4: *Take-up of mobile broadband, United Kingdom, Q1 2009 [Source: Ofcom]*

In Austria – a market with extremely strong evidence of fixed-mobile substitution – a survey conducted by the regulator[46], and supported by statistical analysis, indicated that

45 The population is classified into various socio-economic categories, with A being upper middle class, B middle class, C1 lower middle class, C2 skilled working class, D working class (semi-skilled and unskilled workers) and E those at the lowest level of subsistence.

46 NASE (2009), *Der österreichische Breitbandmarkt aus Sicht der Nachfrager im Jahr 2009*.

business customers use fixed and mobile broadband connections as complements while in the case of residential customers mobile broadband was a clear substitute for fixed. The 2009 survey found that 91% of mobile broadband was over datacards or USB modems, which suggests that the take-up of smartphones is still relatively low.

3.3 Mobile broadband prices

Price will be an issue for the mass (consumer) market. In its survey of mobile broadband tariffs[47] the OECD notes that in most markets mobile broadband is relatively expensive in comparison to fixed broadband. This survey (of packages available from 16 operators in Australia, Czech Republic, Ireland, New Zealand, Norway, Portugal, Spain and Sweden) found that in September 2008 the average price of mobile broadband in Australia was one of the most expensive in the sample, in particular for high usage customers (Exhibit 3.5). Since that time, prices have fallen – both in Australia and in other markets – however mobile broadband is still more expensive than fixed broadband.

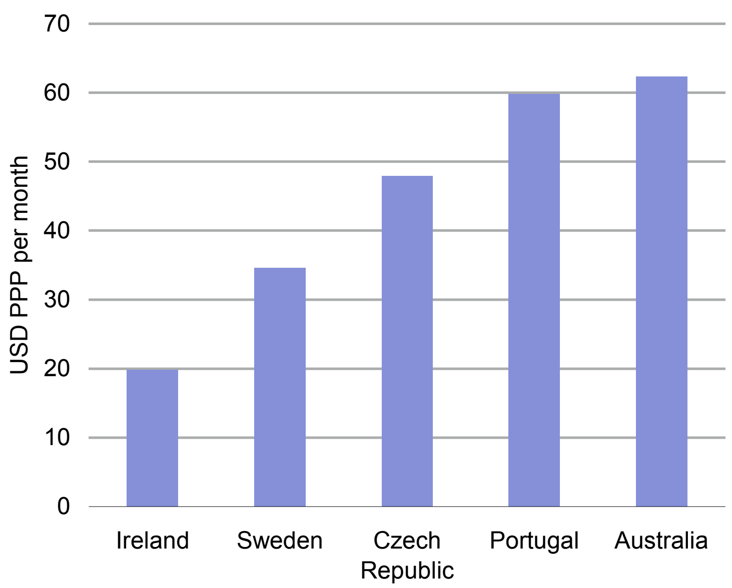


Exhibit 3.5: *Average monthly price for high usage (6–20GB per month) mobile broadband, September 2008 [Source: OECD]*

47 OECD (2009) *Communications Outlook 2009*, August 2009.

Falling prices will make mobile broadband more attractive for the mass market – both in terms of take-up and for increasing usage. The introduction of more spectrally efficient technologies (in particular LTE) will reduce the cost per byte, thus enabling more affordable options for the consumer.

This business model assumes that there will be sufficient capacity for the increased traffic. If however capacity is limited, operators may seek to manage traffic levels during peak periods and in high traffic density areas through pricing. Under this scenario, demand may be constrained through the combination of higher prices and service congestion, in which case the anticipated economic benefits (as described in Section 4.4) may not be realised.

Current Australian prices have fallen significantly from the time of the OECD study. All four Australian networks currently offer mobile data packs with a capped data allowance, which can be added to postpaid plans or bought prepaid. There is also the option of paying by usage amount. The networks offer packs with similar entry price points (Exhibit 3.6), however the data allowance varies significantly.

Network	*Mobile data pack monthly cost (AUD)*	*Data allowance (MB)*	*Cost for excess data (AUD per MB)*
Optus	4.99	75	0.35
Telstra	5.00	30	0.25
Vodafone	4.95	100	0.12
3	5.00	100	0.50

Exhibit 3.6: *Entry level postpaid mobile data packs for Australian operators, assuming 12 month contract, June 2010 [Source: operator websites]*

The networks also all offer mobile broadband plans, with USB modems designed for use with laptops, which offer much higher data allowances (Exhibit 3.7).

Network	*Contract length (months)*	*Monthly cost (AUD)*	*Data allowance (MB)*	*Cost for excess data (AUD per MB)*	*Modem included*
Optus	12	15.00	1000	0.06	no
Telstra	24	29.95	400	Slowed	no
Vodafone	24	10.00	500	0.02	yes
3	12	19.00	1000	0.02	yes

Exhibit 3.7: *Entry level mobile broadband plans for Australian operators, June 2010 [Source: operator websites]*

3.4 Mobile broadband: the traffic explosion

In its latest Visual Networking Index (VNI) Forecast[48], Cisco predicts that global mobile broadband traffic will double each year to 2014. This will be driven largely by video, which is expected to comprise 66% of all traffic in 2014 (Exhibit 3.8). According to Cisco, the average mobile broadband connection currently generates 1.3GB of traffic per month, and is expected to increase to 7GB per month by 2014[49].

48 Cisco (2010) *Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update 2009–2014*, 9 February 2010.

49 WiMAX.com (2010) *Mobile World Congress 2010: Mobile Network Architecture Takes Center Stage*, interview with Andy Capener, Director of Service Provider Marketing for mobility at Cisco, February 2010.

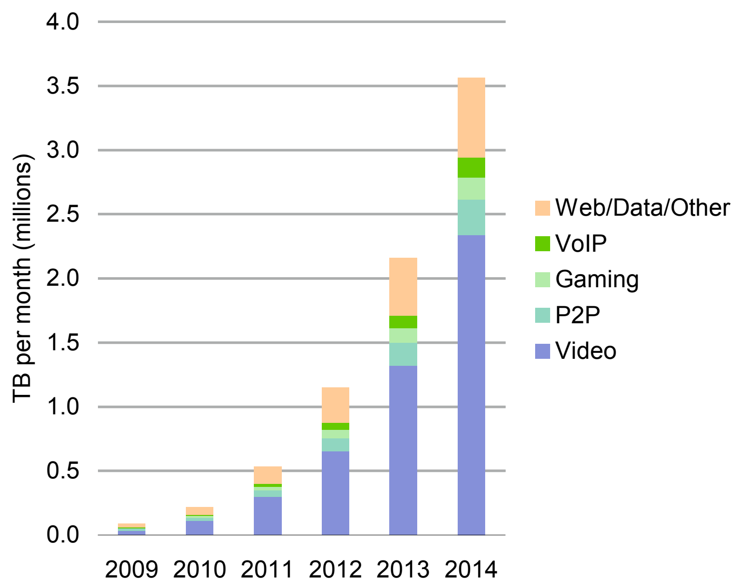


Exhibit 3.8: *Global mobile data traffic per month, by application category, 2009 to 2014 [Source: Cisco]*

Strong growth in mobile data traffic is being observed in many markets, for example:

- in the United States, AT&T announced that mobile data traffic increased by 5000% over the three years to June 2009[50]
- Telefónica O2 UK reported a 20-fold increase in mobile data traffic over the year to September 2009[51]
- in both Denmark[52] and Sweden[53] mobile broadband traffic tripled over the year to June 2009.

In the United States, the chairman of the FCC recently noted that the "spectrum crunch is a serious obstacle threatening the growth of mobile broadband"[54], despite the FCC

50 AT&T (2010) *AT&T calls for constructive, fact-based dialog with FCC on new government push to regulate vibrant U.S. wireless industry*, media release, 7 October 2009.

51 Telefónica O2 2009) *Telefónica Europe announces strong third quarter financial results*, media release, 12 November 2009.

52 National IT and Telecom Agency (2009) *Telestatistics – first half of 2009.*

53 PTS (2009) *The Swedish Telecommunications Market first half year 2009.*

54 Genachowski, J. (2010) *Mobile broadband: a 21st century plan for U.S. competitiveness, innovation and job creation*, speech at the New America Foundation, 24 February 2010.

authorising a three-fold increase in the commercial spectrum available for mobile broadband – including the 700MHz spectrum auctioned in 2008. Even so, the available spectrum is not sufficient to meet the projected increase in demand. To that end, over the next decade the FCC plans to release the 500MHz spectrum band for mobile broadband.

3.5 International roaming

With the global harmonisation of the 2.5GHz band and the international deployment of mobile broadband services, visitors to Australia will be seeking to use their devices for delivering broadband connectivity.

The expectation is that devices will be multi-band, so that if there was no network using the 2.5GHz band, the device will attempt to connect using an alternative band, allowing the user to roam seamlessly, subject to the availability of a network with appropriate functionality that matches the device’s capabilities.

The mix of bands that will be available on commercial devices is still unclear, as few LTE devices are currently available.

The first few commercial launches of LTE – TeliaSonera, Verizon Wireless and NTT DoCoMo – all use different frequency bands, so international roamers may need, at a minimum, devices that support LTE at 700MHz, 2100MHz and 2600MHz. Where LTE is not available, the device may also be required to support HSPA or GPRS at various frequency bands. The combination of mobile technology standards and frequencies within multi-band devices must therefore be suitable for use on the domestic operator’s network and also for roaming.

4 2.5GHz for the Australian market

Despite the challenges of a huge geographic area and dispersed population for deploying infrastructure, Australia is one of the top ten countries in terms of a "Connectivity Scorecard", commissioned by Nokia Siemens Networks[55], ranking seventh behind the Scandinavian countries, the United States and the Netherlands (Exhibit 4.1). This index aims to measure the interaction between a country's telecoms infrastructure, hardware, software and networks with the skills the country's inhabitants and usage of that infrastructure.

	Rank		*Rank*		*Rank*
Sweden	1	Japan	10	Czech Republic	19
United States	2	Singapore	11	Spain	20
Norway	3	Ireland	12	Portugal	21
Denmark	4	Korea	13	Italy	22
Netherlands	5	Hong Kong	14	Hungary	23
Finland	6	Belgium	15	Poland	24
Australia	7	New Zealand	16	Greece	25
United Kingdom	8	Germany	17		
Canada	9	France	18		

Exhibit 4.1: *Connectivity Scorecard for innovation driven economies, 2010 [Source: Connectivity Scorecard]*

55 Waverman, L. and Dasgupta, K. (2010) *Connectivity Scorecard 2010*.

Australia has long been regarded as a leader in mobile technology. National 3G coverage is one of the most extensive in the OECD – delivering services to 99% of the population – with only Japan and Sweden having greater reach[56].

Just over half of all mobile services in Australia are 3G (Exhibit 4.2), however it is estimated[57] that only a third of 3G subscribers use their mobile to access non-voice content and services online. As in other markets, this is likely to change, with the explosion of mobile applications made possible through smartphones, in conjunction with falling prices making mobile data a more affordable proposition.

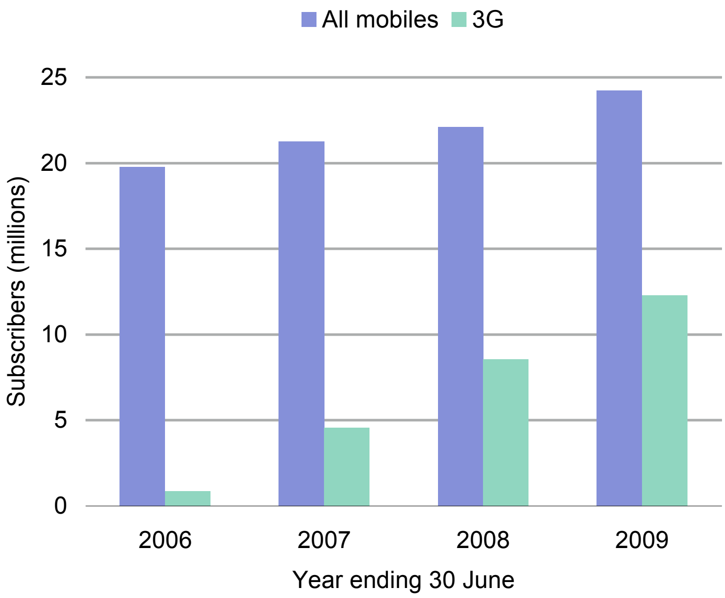


Exhibit 4.2: *Mobile and 3G subscribers, 2006–2009, Australia [Source: ACMA]*

Growth in the mobile data market is already apparent, with financial results from operators in Australia demonstrating that mobile data comprises an increasing portion of total mobile revenues (Exhibit 4.3).

56 Available from the OECD Broadband Portal, at http://www.oecd.org/sti/ict/broadband.

57 ACMA-commissioned consumer survey, April 2009. Reported in *ACMA Communications report 2008–09*, November 2009.

	Telstra	Optus	3[58]	Vodafone
Year ended 30 June 2008				
Total mobile revenue (AUD millions)	5 548	3 775	1 311	n.a.
Mobile data revenue (AUD millions)	806	264	163	n.a.
Mobile data revenue as a percentage of total mobile revenue	14.5%	7.0%	12.4%	n.a.
Year ended 30 June 2009				
Total mobile revenue (AUD millions)	6 101	4 224	1 644	n.a.
Mobile data revenue (AUD millions)	1 134	473	253	n.a.
Mobile data revenue as a percentage of total mobile revenue	18.6%	11.2%	15.4%	n.a.
2008-2009 increase in total mobile revenue	10.0%	11.9%	25.4%	n.a.
2008-2009 increase in mobile data revenue	40.7%	79.0%	55.5%	n.a.

Exhibit 4.3: *Australian operators' revenues from all mobile and mobile data only (excluding SMS) services [Source: company annual reports]*

Below we explore the various issues associated with the introduction of 2.5GHz services in Australia.

4.1 Mobile broadband over 2.5GHz: when can it be delivered?

The ability of providers to deliver services over 2.5GHz is dependent on the availability of spectrum. Given that there is a two-year lead time for the existing spectrum users to vacate the spectrum, the 2.5GHz spectrum band will be available at the earliest by 2012, however several industry commentators viewed 2013 as a more realistic timeframe. Once spectrum is available for mobile operators, there would be a further lead-time for deploying and testing infrastructure, although some commentators noted that infrastructure build may occur in advance of spectrum availability with the result that there may be a relatively brief period after the spectrum is released before commercial services are offered. In particular,

58 During February 2009 Hutchison ("3") and Vodafone signed an agreement to a 50:50 merger to form Vodafone Hutchison Australia. The 2009 financial results for 3 over the relevant period have been adjusted to represent Hutchison's share of the revenues.

the most pressing need for the 2.5GHz spectrum is in "hot spot" areas, for capacity purposes, and as such only a relatively short time may be necessary for deployment.

Industry commentators also noted that the increase in mobile data traffic in recent times is placing pressure on capacity in a number of high density traffic areas – and not only in the capital cities. It was expected that these areas will require additional capacity within the next two to three years, which could be achieved by cell splitting and sectorisation, but as noted in Section 2.1, these solutions are complex, costly and time-consuming and will not provide any more than temporary relief from the capacity problem.

Potential barriers

So, what other constraints are there in Australia that may affect the timing or the ability to deliver 2.5GHz services?

Spectrum band plan	If Australia chose to diverge from the globally harmonised spectrum band plan for 2.5GHz, network infrastructure and devices would be more difficult to procure – and are likely to be more costly, due to lack of economies of scale. This may delay the launch of services, increase the cost to consumers and possibly also create problems for international roaming.
Handset prices	In the short term, the prices of smartphones may limit take-up. While price trends are expected to be decreasing – and in particular more affordable low-end handsets will become available – these will be offset by the costs of increasing functionality and specifications (for example battery life).
Increased demand for backhaul	Take-up of mobile broadband will put additional pressure on backhaul capacity, so operators will need to ensure that sufficient backhaul is deployed to meet the projected traffic.

Competing demands for spectrum fees

Willingness to pay, and thus market prices, for spectrum depend on many factors, not just on a commercial valuation of the business case:

- short- or medium-term economic conditions which may affect the ability (or desire) of players to invest at a particular time
- conditions being placed upon the spectrum licences – as one example, in the United States the FCC imposed conditions for a public-private partnership to create a national public safety broadband network on D Block in the 700MHz spectrum auction, however the block failed to reach the reserve price[59]
- the availability of spectrum in other bands that could be substituted for the spectrum band in question.

Note that over the next three to four years licences in the 850MHz, 900MHz and 1800MHz are due to expire, and both the 2.5GHz and 700MHz bands will become available. This timetable may impose some constraints on the amount operators are willing, or able, to pay for 2.5GHz spectrum.

Timetable for LTE deployment: how will spectrum availability affect the market?

As discussed in Section 2, operators in Australia will most likely be seeking a combination of 700MHz and 2.5GHz to deliver LTE services. The strategies implemented by the operators – in terms of network deployment as well as marketing – will be driven by the timetable for both spectrum bands, as well as the existing spectrum holdings of the individual operators. It should also be noted that there was no consensus amongst operators on the relative timing priorities of the 700MHz and 2.5GHz bands.

For some operators, it may be preferable for the 700MHz band to be available prior to 2.5GHz, due to the former being better suited for coverage, and thus maximising the size of

59 For a discussion of the US 700MHz spectrum auction, see http://www.strategies.nzl.com/wpapers/2008014.htm.

the addressable market. The operator could then focus on a widespread deployment of LTE with 700MHz, using 2.5GHz to provide infill capacity where required.

The situation in Australia, however, is such that 2.5GHz spectrum is likely to become available prior to 700MHz – a scenario that was preferred by at least one operator. Deployment of LTE under 2.5GHz beyond areas with high traffic density is unlikely, as operators would be planning to use the better-suited 700MHz to deliver a nationwide network. There would be little incentive to extend LTE coverage via 2.5GHz when the more cost-effective 700MHz would become available in the short term. Until then, the geographic footprint of LTE would most likely be limited to a relatively small proportion (around 10%) of metropolitan base stations, severely limiting the size of the addressable market. Such coverage would also be non-contiguous. Over time, the 2.5GHz footprint would be expanded and would possibly eventually approach that of 2.1GHz.

An alternative scenario, if the 2.5GHz band was available well in advance of the 700MHz band, would be to reduce economic efficiency. For example, competition for market share may encourage operators to deploy a greater number of sites using the 2.5GHz band than if 700MHz spectrum had been available within a more similar timeframe. Under such a scenario, each operator commits to an early, but costly LTE network deployment in the 2.5GHz band, which could potentially impede timely investment in the 700MHz LTE network deployment. Given the complementary nature of the 2.5GHz and 700MHz bands, economic efficiency is likely to be maximised if the 700MHz is made available for use as close to the availability of the 2.5GHz band as possible.

In Exhibit 4.4 we explore how potential operator strategies could vary based on different timetables for 2.5GHz and 700MHz. It should be noted that strategies and timing will also be influenced by the operator's existing spectrum holdings and traffic distribution.

2.5GHz available	*700MHz available*	*Potential operator strategies*
2013	2014	Commence deployment of LTE over 2.5GHz in 'hot spot' and high profile areas to relieve capacity constraints Initial coverage would comprise about 10% of metropolitan base stations, plus possibly a small number of regional base stations; coverage non-contiguous Commercial services over 2.5GHz available in 2013; limited availability of devices may constrain demand over the first year Commence deployment of LTE over 700MHz during 2013, with services offered soon after spectrum becomes available in 2014 Initial 700MHz LTE coverage to extend over metropolitan areas and key regional areas, extending to national rollout after one to two years; additional 2.5GHz base stations deployed for infill capacity Attractive pricing and service offerings to encourage migration to LTE
2013	2015	Commence deployment of LTE over 2.5GHz in 'hot spot' and high profile areas to relieve capacity constraints Initial LTE coverage would comprise about 10% of metropolitan base stations, plus possibly a small number of regional base stations; coverage non-contiguous Commercial services over 2.5GHz available in 2013; limited availability of devices may constrain LTE demand over the first year Capacity constraints may have an effect on service quality for HSPA; alternatively operators may also use pricing as a mechanism to limit demand and usage for HSPA services Growing 'digital divide' between 'hot spot' users and the rest of the country; consumer pressure for wider LTE coverage and lower mobile broadband prices Development of new hot spots, as growth in data traffic causes additional capacity pressure in other areas; expansion of 2.5GHz coverage to address these new hot spots, which may have been more cost-effectively delivered via 700MHz 2.5GHz unsuited for widespread deployment; with a longer lead time for 700MHz availability, coverage may be extended beyond hot spots, to provide larger areas of contiguous coverage, however this will incur higher costs than via 700MHz, which will then be reflected in pricing Commence deployment of LTE over 700MHz during 2014, with services offered soon after spectrum becomes available in 2015 Initial 700MHz LTE coverage to extend over all metropolitan areas and key regional areas, extending to national rollout after one to two years Attractive pricing and service offerings to encourage migration to LTE

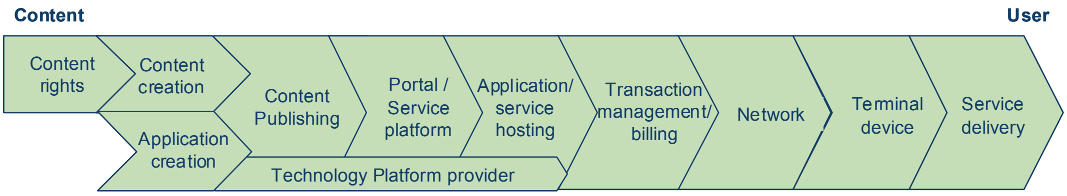
Exhibit 4.4: *Potential operator strategies for various spectrum availability scenarios [Source: Network Strategies]*

2.5GHz available	*700MHz available*	*Potential operator strategies*
2014	2014	Prior to 2014, traffic congestion becomes a significant issue – operators incur higher costs attempting to relieve some pressure on capacity Capacity constraints may have an effect on service quality for HSPA; alternatively operators may also use pricing as a mechanism to limit demand and usage for HSPA services; pricing also reflects higher costs; uptake and usage of mobile broadband constrained; consumer pressure for lower mobile broadband prices Commence nationwide deployment of LTE over both 700MHz and 2.5GHz in 2013 Initial LTE coverage to extend over all metropolitan areas and key regional areas, extending to national rollout after one to two years Commercial services available in 2014 as deployment progresses Attractive pricing and service offerings to encourage rapid migration to LTE
2014	2015	Prior to 2014, traffic congestion becomes a significant issue – operators incur higher costs attempting to relieve some pressure on capacity Capacity constraints may have an effect on service quality for HSPA; alternatively operators may also use pricing as a mechanism to limit demand and usage for HSPA services; pricing also reflects higher costs; uptake and usage of mobile broadband constrained; consumer pressure for lower mobile broadband prices Commence deployment of LTE over 2.5GHz in 2013 for ‘hot spot’ and high profile areas to relieve capacity constraints Initial coverage would comprise about 10% of metropolitan base stations, plus possibly a small number of regional base stations Commercial services over 2.5GHz available in 2014 Attractive pricing and service offerings to encourage migration to LTE Commence deployment of LTE over 700MHz during 2014, with services offered soon after spectrum becomes available in 2015 Initial 700MHz LTE coverage to extend over all metropolitan areas and key regional areas, extending to national rollout after one to two years

Exhibit 4.4 (cont): *Potential operator strategies for various spectrum availability scenarios [Source: Network Strategies]*

4.2 The value chain for mobile broadband in Australia

The value chain for mobile broadband represents the relationships between the major entities, summarised in Exhibit 4.5 below, and including a small selection of Australian and international companies in the value chain. It should be noted that many entities engage in several roles within the value chain.



ABC	B33hive	Android	Operators	Jumbuck	Operators	3	Apple	Operators
BBC	Blue Rocket	Apple	Android	Logica	eServGlobal	Optus	HTC	MVNOs
BMG	iFone	Aspiro	Apple	Mnet Group	Mastercard	Telstra	Nokia	High street retailers
Fox Sport	Jumbuck	Be.Interactive	Mnet Group		PayPal	Vodafone	RIM	Online retailers
Network Ten	Kukan Studio	Codetoys	ninemsn		Visa		Sony Ericsson	
Nine Network	Mnet Group	Jumbuck	RIM					
SBS		Mnet Group	Triple J					
Seven Network		Zed	Zed					
Sony								
Time Warner								
Universal								

Note: Australian companies are shown in red text.

Exhibit 4.5: *Mobile broadband value chain [Source: Network Strategies]*

4.3 Projections for the Australian market

We have developed demand projections for mobile broadband services in Australia. Our focus is on the two categories: handset devices and mobile datacards.

We have not scoped the machine-to-machine segment which will also be an important growth area (discussed further below); nonetheless it will be an additional revenue stream for mobile operators.

Handsets

Our projections for mobile broadband services over handset devices are based on a number of key assumptions:

- the mobile penetration rate continues to increase over time, reaching 125 services per 100 persons by 2013 – this is comparable to take-up seen in several leading markets worldwide
- virtually all subscribers will have a device capable of accessing mobile broadband by 2013.

We have developed two scenarios with different projections for the take-up of mobile broadband: moderate growth and accelerated growth (Exhibit 4.6).

Scenario	*2009*	*2013*	*2020*
Assumed take-up as percentage of mobile handset subscriptions			
Moderate growth	17%	45%	56%
Accelerated growth	17%	54%	73%

Exhibit 4.6: *Mobile broadband take-up [Source: Network Strategies]*

We estimate that under the moderate growth scenario, there will be almost 20 million mobile broadband subscriptions on handsets by 2020, and under the accelerated growth scenario this will become 25 million subscriptions by 2020 (Exhibit 4.7).

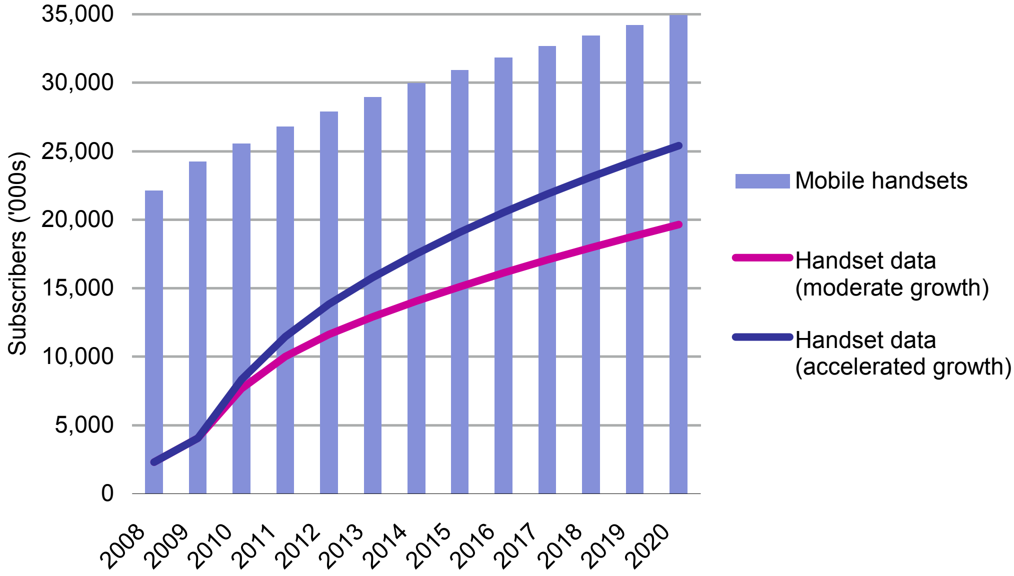


Exhibit 4.7: *Projections for data subscriptions on mobile handsets [Source: Network Strategies]*

Mobile datacards

We view the market for mobile datacards as having two sub-segments:

- substitution for fixed broadband – subscribers have only a mobile broadband service, either in preference to a fixed service or because a fixed broadband service is not a viable option
- complement for fixed broadband – subscribers have both a fixed and a mobile broadband service, with the former being used when in a specific base location (for example, the home or the office) and the mobile service being used when away from base.

Note that the first sub-segment may be affected by the launch of the NBN, although we note that even with the added option for technology choice many consumers may prefer the increased flexibility of a mobile solution.

We have developed projections for two datacard scenarios (Exhibit 4.8):

- moderate growth – increase in datacards (as a proportion of broadband services) to slow from the rates experienced for the past two years
- accelerated growth – a greater rate of increase than the moderate growth scenario, with datacards reaching just under 50% of broadband services by 2020. Growth rates are also lower than over the past two years. Note that under this scenario the total number of broadband services is higher, as there will be a greater number of people with both fixed and mobile broadband.

Scenario	*2009*	*2013*	*2020*
Assumed take-up as percentage of broadband services			
Moderate growth	27%	36%	39%
Accelerated growth	27%	40%	48%

Exhibit 4.8: *Datacard take-up [Source: Network Strategies]*

Under the moderate growth scenario, we estimate that by 2020 there will be 6.3 million datacard subscriptions, or 8.9 million subscriptions with the accelerated growth scenario (Exhibit 4.9).

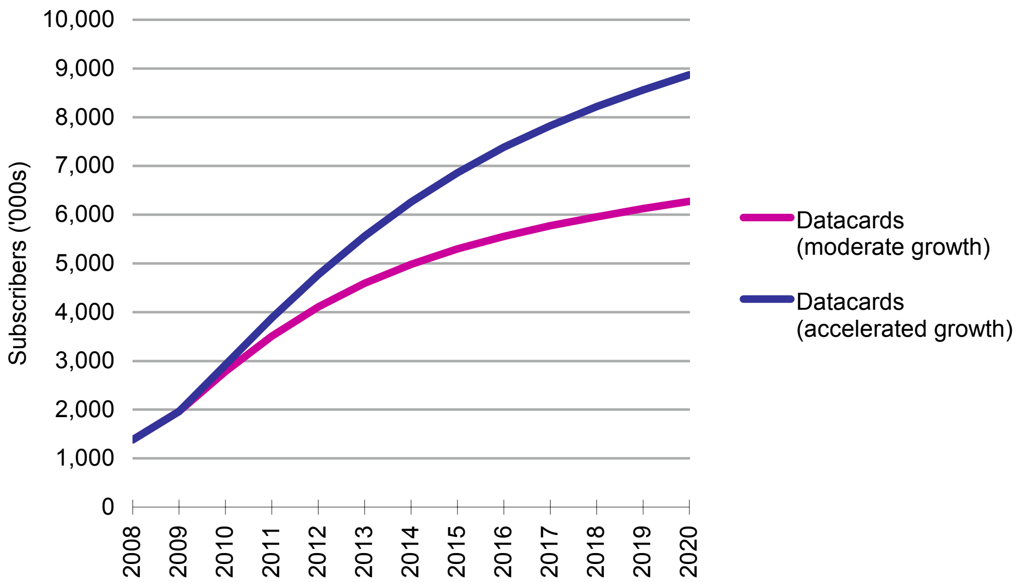


Exhibit 4.9: *Projections for mobile datacards [Source: Network Strategies]*

If prices of fixed and mobile broadband were comparable, we would expect usage for the first segment to be similar to that of a fixed broadband user. At the current time, prices for mobile broadband are higher than those for fixed broadband, so affordability could constrain the level of usage. Over time, we would expect the gap between prices to reduce, and thus mobile broadband usage would approach that of a fixed broadband user.

Usage for the second sub-segment, for whom mobile broadband is a complement to fixed broadband, is likely to be lower than for a user with only a single broadband connection. These users will split their usage across the two services, depending upon where they are when they need to access data services. They may also reserve more data-intensive applications for fixed broadband, either due to affordability issues or relative bandwidth performance.

Machine-to-machine

The machine-to-machine (M2M) segment is a potential opportunity for operators seeking new revenue streams as (human) mobile markets approach saturation. Juniper Research predicts that mobile connected M2M and embedded devices will increase to 412 million globally by 2014[60], with a small number of key industries dominating the segment:

- connected buildings – site and building management monitoring and security
- mobile connected smart meters
- consumer telematics – mobile connected vehicles
- commercial telematics – mobile connected vehicles
- healthcare – monitored individuals.

Many M2M applications have relatively modest data traffic and thus may not require the bandwidths of 3G or other mobile broadband technologies. Furthermore the usage (per subscriber) is likely to be low relative to that of handsets and datacards, which translates into low ARPUs. Mobile broadband will however be required for a variety of applications – for example remote video monitoring – and the need for higher bandwidth is expected to increase as new M2M applications are developed.

60 Juniper Research (2010) *M2M – Rise of the Machines*, white paper, January 2010.

We have not attempted to scope this segment, but it may be viewed as potential additional benefit for operators.

Traffic projections

If we assume that traffic for Australian users will be comparable to Cisco's global usage projections (described in Section 3.5), then based on our demand forecasts the annual traffic for mobile broadband in Australia will reach 1360–1680PB[61] by 2014 (Exhibit 4.10). This represents a compound annual growth rate over the period 2010 to 2014 of 87–95%, however the rate of increase is slowing over this time.

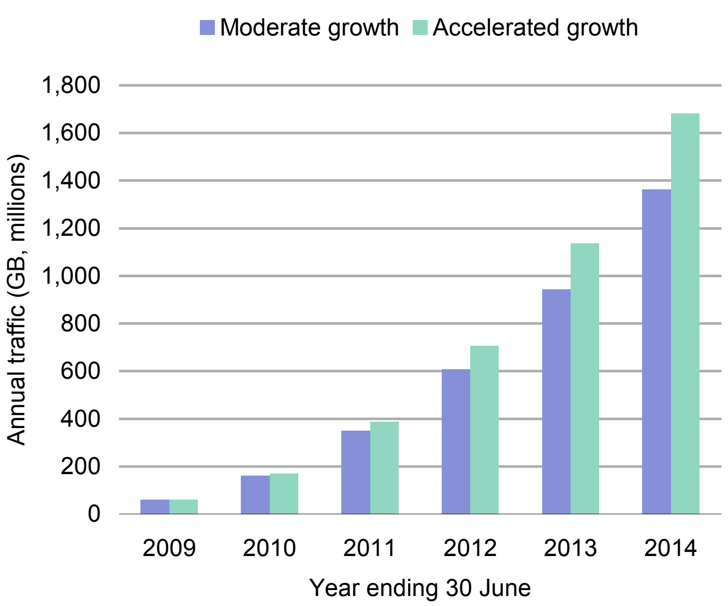


Exhibit 4.10: *Mobile broadband annual traffic projections, Australia, 2009 to 2014 [Source: Network Strategies]*

61 One petabyte (PB) is equivalent to one million gigabytes.

4.4 The economic impact of mobile broadband in Australia

There is a growing body of empirical evidence that both mobile and broadband have a significant impact on economic growth and development. In 2009 the World Bank published a study that analysed the impact of penetration of ICT technologies on the average GDP growth rate in 120 countries from 1980 to 2006. The study found that a 10% increase in broadband penetration in developed countries yielded a 1.2% increase in economic growth. The impact of mobile and Internet penetration[62] were also significant, yielding (respectively) 0.6% and almost 0.8% increases in economic growth (Exhibit 4.11).[63]

62 Note that the study examines separately broadband penetration (broadband subscribers per 100 persons) and Internet penetration (Internet users per 100 persons).

63 The World Bank (2009), *Information and communications for development 2009: extending reach and increasing impact*.

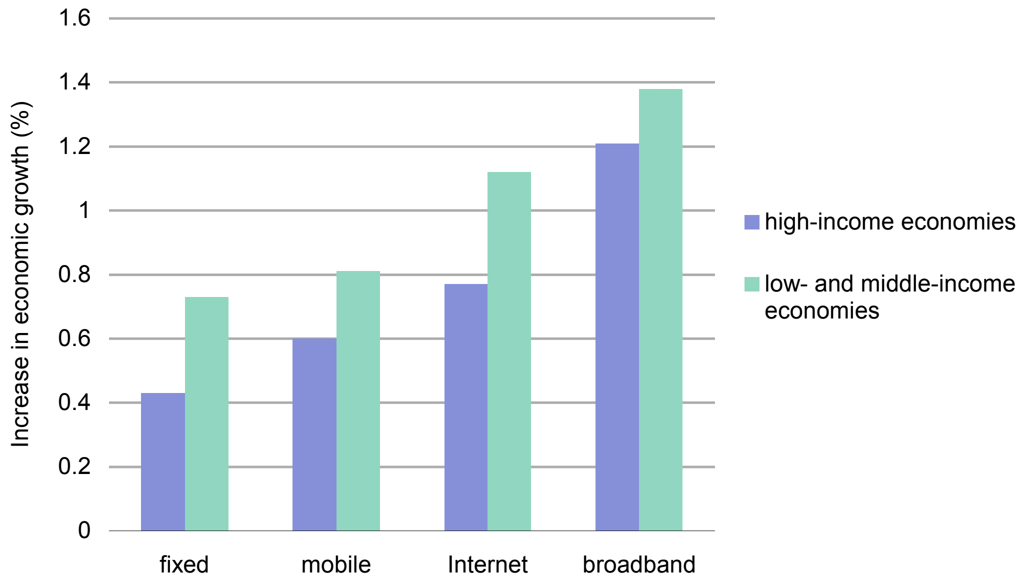


Exhibit 4.11: *Percentage increase in economic growth due to a ten percent increase in penetration of various communications technologies*[64] *[Source: World Bank]*

Recent OECD research[65] emphasises the significance of social benefits from broadband investment that are not captured in commercial business cases (that is, network externalities). This study was referenced by the UN's Denis Gilhooly in his recent speech[66] announcing the formation of a Broadband Commission for Digital Development at the Mobile World Congress in Barcelona. Recognising the importance of mobile as an enabling technology Gilhooly indicated that spectrum allocation priorities should be re-examined and in particular 3G licensing conditions may be unnecessarily restricting operators at the expense of potential wider social and economic benefits.

64 The y axis represents the percentage-point increase in economic growth per 10-percentage-point increase in telecommunications penetration. All results are statistically significant at the 1% level except for that of broadband in developing countries, which is at the 10% level.

65 OECD (2009), *Network developments in support of innovation and user needs*, Working party on Communication Infrastructures and Services Policy, 9 December 2009.

66 See http://www.commsday.com/node/790.

4.4.1 Quantitative impact

Benchmark data

Exhibit 4.12 provides estimates of the economic (direct and indirect) and employment effects in the European Union (EU) of the use of spectrum by the mobile and broadcasting sectors[67]. The analysis shows that the economic gains from mobile use of spectrum outweigh those of use by the broadcasting sector, and this is caused primarily by the impact on productivity of mobile applications which feeds through into higher GDP growth.

		Mobile	*TV*
Direct	Operators – service provision	EUR208 billion (2007)	EUR43 billion (2005)
	Suppliers/distributors – hardware (handsets), software, networks, content,	EUR87 billion (2007)	EUR30 billion (2006)
	Economic output per MHz at 900 MHz	EUR168 million (2006)	EUR28 million (2005)
Indirect	Economic stimulus of mobile working, cumulative driving effect of mobile productivity to 2020	0.6% GDP growth	Negligible
	Indirect stimulus to the economy by spend of direct impact revenues in other sectors: • user surplus, social and economic value, i.e. difference between what paid and prepared to pay • producer surplus, i.e. difference between margins to stay in business and margins actually achieved	EUR165 billion(2007)	EUR95 billion
Jobs	Employment in sector	0.5 million	0.4 million
	Employment stimulated by spend from sector	2.3 million	1.8 million

Exhibit 4.12: *Mobile as an economic driver – comparison of direct and indirect economic impacts on the EU economy [Source: Forge et al]*

67 Forge, S., Blackman, C. and Bohlin, E. (2008) "Economic Impacts of Alternative Uses of the Digital Dividend", in *Intereconomics* 43:3, May/June 2008.

In the United States research on the economic impact of mobile broadband services indicated that even in 2004 and 2005 when such services were in their infancy substantial productivity benefits (USD8 billion in 2004 and USD33.1 billion in 2005) were accruing with improving efficiency and reduced costs across many industry sectors[68]. This represents a productivity benefit in 2005 of USD1924 per user or AUD2671 (using purchasing power parity exchange rates). Note that this estimate represents gross benefits.

Six key areas were identified where mobile broadband was delivering tangible benefits:

- resource and inventory management
- health care efficiency
- field service automation
- inventory loss reduction
- sales force automation
- replacement of desk phones with mobile handsets.

Based on efficiency gains in these areas across 360 job categories (representing approximately 82 million employees) an estimated saving of USD528 billion from 2005 to 2016 could be achieved through mobile broadband. Note that these estimates are based on an assumption of 50% penetration of mobile broadband amongst business users in 2010 and 83% penetration by 2016.

Two recent Australian studies provide productivity estimates for mobile broadband, using both primary and secondary research. The study that uses the largest sample size[69] assesses the productivity benefits of Telstra's Next G™ network. Quantitative estimates are obtained utilising the TERM general equilibrium model of Australia with productivity input data from the US study referenced above in combination with Australian data. The key estimates indicate that annual real household consumption will be 1.4% greater with mobile broadband than without, while real GDP increases by 0.9% over what it would have been in the absence of mobile broadband. Average real wages are estimated to increase by

68 Ovum (2008), *The increasingly important impact of wireless broadband technology and services on the US economy*, A Study for CTIA – the Wireless Association, 2008, and Ovum (2005), *The impact of the US wireless telecom industry on the US economy*, A report for CTIA – the Wireless Association, September 2005.

69 Concept Economics (2009) *Next G Productivity Impacts Study*, 13 February 2009.

over 1.0%. In total an annual gain of AUD7.4 billion is estimated of which the authors attribute AUD5.4 billion to the Telstra Next G™ network. We believe that these results are an underestimate, as the US productivity figure that forms the basis of the calculations has been incorrectly converted to Australian dollars[70].

The second study also considered the productivity gains of using the Telstra Next G™ network[71]. A survey approach is used which covers a wide range of industries but only 26 companies in all. All respondents reported positive benefits with a 9.3% average productivity gain, but it should be noted that the reported range for the gain was large (1.1% to 27.3%).

It should be noted that quantitative research on the economic impact of specific spectrum bands is very scarce. In a previous study for AMTA[72], Value Partners estimated that over a 20-year timeframe there would be a net benefit to the Australian economy of between AUD7 billion and AUD10 billion from the reassignment of 700MHz spectrum due to the switch-off of analogue television. This analysis, while focussing on the 700MHz spectrum band, also assumed that operators had access to the 2.5GHz band for meeting capacity requirements beyond 2012 after the 2.1GHz band was fully utilised.

Network Strategies estimates for Australia

We have also estimated productivity benefits from mobile broadband, using the US productivity figure applied in the Concept Economics study: that is, gross benefits of USD1924 which is equivalent to AUD2671 using PPP exchange rates. An outline of our methodology is provided in Annex C. We estimated productivity benefits for mobile broadband in the region of AUD143 billion for the period 2013 to 2020 (Exhibit 4.13).

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70 *Ibid*, Appendix B. The US productivity figure of USD1924 has been converted to AUD1386 with an incorrect application of the PPP exchange rate. The AUD figure was obtained by dividing the USD figure by the PPP rate of 1.388, whereas multiplication should have been used.

71 Econtech (2007), *Productivity gains of Next G: results on the customer survey*, 4 December 2007.

72 Value Partners (2009) *Getting the most out of the digital dividend in Australia*, report for AMTA, April 2009.

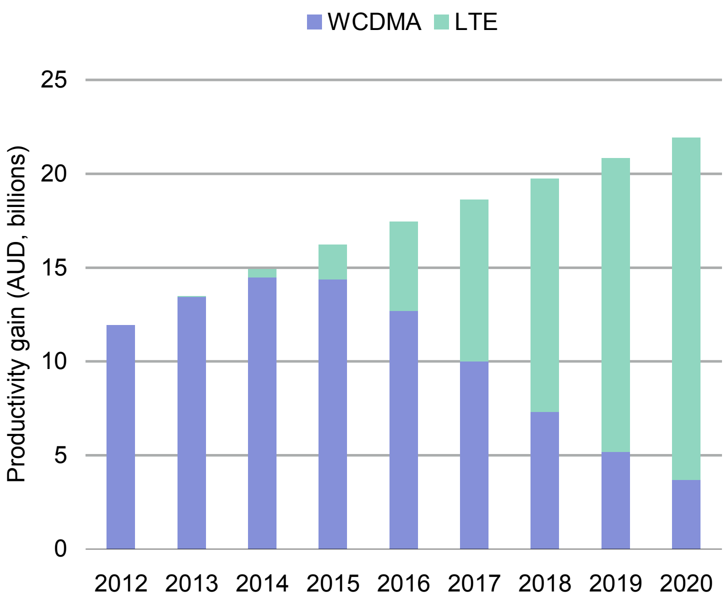

Exhibit 4.13: *Estimated productivity benefit from mobile broadband Australia [Source: Network Strategies]*

Allocating the productivity benefit between WCDMA and LTE (the latter delivered over a 700MHz / 2.5GHz combination) becomes more uncertain. We estimate that the cumulative productivity benefit for LTE will be AUD62 billion over the period 2013 to 2020, assuming that commercial launch of LTE over 2.5GHz will occur in 2013, with 700MHz one year later.

Note that the benchmark data limits our analysis to the benefits of only mobile broadband, rather than being able to distinguish between the higher bandwidths available via LTE. If it can be assumed that faster broadband delivers greater productivity benefits, then our projected productivity benefit via LTE would be an underestimate.

Clearly, the productivity benefit will be affected by the timetable for spectrum. As we have seen in Section 4.1, delays in the commercial launch of LTE will place increasing pressure on capacity and increase costs as operators seek to implement strategies for managing expected traffic loads. This may have the effect of reductions in service quality, and higher prices, which may constrain demand and usage.

To assess the impact of such a delay, we have estimated the productivity benefit assuming that targets for uptake of mobile broadband and LTE services require an additional year to achieve. This has the effect of reducing the productivity benefit for mobile broadband by AUD5.5 billion over the period 2013 to 2020, and for LTE by nearly AUD17 billion.

It should be noted that our productivity estimates of the gross benefit are conservative as we would expect an updated US productivity figure would be significantly higher than the USD1924 from 2005 taken as the basis for our calculations. Since that time, the mobile broadband market has undergone considerable development, with new and innovative applications, reductions in pricing and more appealing service propositions, all of which would have a positive effect on productivity. Furthermore a more sophisticated model would capture multiplier or knock-on effects in the economy. Such effects have not been accounted for in our estimation, and again would significantly increase the projected overall benefit.

So what value will be derived by consumers from mobile broadband? Consumer surplus is a traditional economic measure that captures the difference between what a consumer would be willing to pay and the price actually paid. Europe Economics calculated the consumer surplus for mobile broadband, using WiFi data, in a study for Ofcom during 2006 to measure the economic impact of use of the use of radio spectrum in the UK.[73] Using a similar approach we considered three types of mobile broadband in Australia:

- WiFi hotspots use
- mobile broadband use through datacards and USB wireless modems
- mobile data use via 3G handsets.

The consumer surplus for these three mobile broadband products was calculated for both 2008 and 2009 where possible, with the results shown below in Exhibit 4.14. It is notable that the 2009 estimate of consumer surplus for mobile data using 3G handsets increased substantially from AUD911 million in 2008 to over AUD1.5 billion in 2009. Further details are provided in Annex C.

73 Europe Economics (2006), *Economic impact of the use of radio spectrum in the UK*, 16 November 2006.

	2008 (AUD millions)	2009 (AUD millions)
WiFi hotspots – mid range willingness to pay	–	41
WiFi hotspots – high range willingness to pay	–	114
Mobile broadband using datacards and USB modems	414	411
Mobile data via 3G handsets	911	1 512

Exhibit 4.14: *Consumer surplus for wireless broadband products for the years of 2008 and 2009 [Source: Network Strategies]*

4.4.2 Qualitative impact

Isolating the economic benefits to consumers of the 2.5GHz band specifically is problematic. Mobile broadband and the associated services and applications that can be realised through such wireless connections can be delivered over various spectrum bands. Note also that Australian industry representatives viewed the combination of 700MHz and 2.5GHz as the "best" option for addressing coverage and capacity requirements.

Despite the paucity of quantitative evidence, qualitative indicators point to both direct and indirect benefits accruing to producers and consumers with the use of the 2.5GHz radiofrequency spectrum band in the future deployment of mobile telecommunications services.

For example, significant benefits to consumers were identified by Ofcom in respect of the release of the 2.0GHz, 2.3GHz and 2.5GHz spectrum bands in the form of:

- innovations in relation to new or improved services and applications that operators may be able to offer
- opportunities for new entry into the relevant downstream markets, offering services in competition with the existing operators which could result in price reductions and more consumer choice for services

- cost savings for the existing operators which are likely to be passed on to consumers in the form of price reductions, given the relatively competitive nature of these markets.[74]

With respect to producers (or operators), this report has already identified a number of benefits including:

- global economies of scale for network equipment and devices
- better interoperability of terminals and equipment globally, facilitating roaming
- cost savings via the ability to support more traffic in dense areas.

In these circumstances it is reasonable to expect that producer surplus will be generated – that is, operators can expect to obtain benefits beyond the net direct economic benefits.

74 Ofcom (2007) *Award of available spectrum: 2500-2690Mhz, 2010-2025MHz and 2290-2300MHz*, 11 December 2006.

5 Concluding remarks

Our analysis has indicated that there will be significant economic benefits from mobile broadband, however our ability to realise those benefits will depend upon the ability of the mobile operators to deliver mobile broadband services both cost-effectively and in a timely manner to meet the anticipated future demand.

We estimated gross productivity benefits for mobile broadband over the period 2013 to 2020 to be around AUD143 billion. Furthermore the cumulative productivity benefit for LTE is estimated to be AUD62 billion over this same period, assuming that commercial launch of LTE over 2.5GHz will occur in 2013, with LTE over 700MHz available one year later.

There has been extraordinary growth in mobile data traffic in recent times, and this trend is expected to continue, driven by a combination of increased data allowances, and new mobile applications. Mobile data will be delivered over smartphones, datacards and USB modems, as well as other mobile-enabled devices such as e-book readers, tablet devices such as the Apple iPad, game consoles, MP3 players, cameras, remote healthcare monitoring devices and machine-to-machine interfaces, all of which will be increasing pressure on spectrum capacity.

Without sufficient spectrum in appropriate bands to deliver both coverage and capacity for the addressable market, Australians will not reap the economic benefits of mobile broadband. A combination of high-frequency (above 2GHz) and low-frequency (below 1GHz) bands is viewed as the optimal solution for mobile network deployment with the low-frequency band providing coverage and the high frequency band providing in-fill capacity. The additional advantage of the 700MHz / 2.5GHz combination is expected to be the 2×20MHz bandwidths required to deliver maximum data rates over LTE, unlike the current spectrum holdings of most of the Australian mobile operators.

Annex A: Acknowledgements

Network Strategies thanks the following organisations who provided assistance to us during this project.

Alcatel-Lucent
Ericsson
Nokia Siemens Networks
Optus
Qualcomm
Telstra
Vodafone Hutchison Australia (VHA)

Annex B: Radiofrequency characteristics

A fundamental property of radio frequency radiation is that the higher the frequency, the shorter the distance it can travel before becoming weak and unusable, and the more susceptible it is to being attenuated (absorbed or blocked) by objects in its path.

This is shown by the examples provided in the table below:

	Frequency	*Use in telecommunications*
Extremely low and super low frequencies	3–30Hz, 30–300Hz	Used for communication with submarines because of their abilities to propagate through water
Low frequency	3kHz–30kHz	Used for longwave broadcasting and navigation; transmissions can propagate thousands of kilometres through the atmosphere around the world
Ultra high frequency	300MHz–3000MHz	Most mobile networks operate in this range; signals can propagate through some barriers but are greatly attenuated (for example, mobile phones will usually work inside, but often not in the centre of a large building or in a lift).
Extremely high frequency	30GHz–300GHz	Point to point microwave links are a common use of frequencies in this range. Signals will be blocked by any obstacle in the signal path and so links must be line-of-sight. Rain and even haze will attenuate the signal, and are taken into account when designing such systems.

Exhibit B.1: *Examples of frequency bands used in telecommunications and propagation ranges [Source: Network Strategies]*

Annex C: Economic methodology

C.1 Estimating the productivity benefit

Our estimation of the productivity benefit uses industry-specific assumptions from Concept Economics[75]. In particular, we used assumptions relating to the proportion of employees that would benefit from mobile broadband by industry, however we added three industry categories that were omitted – with no explanation – from the Concept Economics analysis. These were:

- Professional, Scientific and Technical Services
- Administrative and Support Services
- Public Administration and Safety.

Given that these industry categories are likely to be users of mobile broadband services, this would have understated the gross productivity benefit from industry, and omitted roughly 30% of the labour force from estimation of those gains. The assumptions we applied to these additional categories were similar to those for the industry category Communication Services, which ranked below (in terms of the proportion that would benefit from mobile broadband) the categories Finance and Business Services, and Education (Exhibit C.1).

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75 Concept Economics (2009) *Next G Productivity Impacts Study*, 13 February 2009.

Industry category	*Proportion that would benefit from mobile broadband*
Finance & Insurance	0.88
Education	0.77
Communication Services	0.75
Property & Business Services	0.72
Mining	0.71
Wholesale Trade	0.69
Agriculture, Forestry & Fishing	0.68
Electricity, Gas & Water Supply	0.68
Transport & Storage	0.62
Health & Community Services	0.57
Construction	0.46
Cultural & Recreational Services	0.46
Manufacturing	0.45
Personal & Other Services	0.43
Retail Trade	0.33
Accommodation, Cafes & Restaurants	0.31

Exhibit C.1: *Assumed proportion of employed persons that would benefit from mobile broadband by industry categoy [Source: Concept Economics]*

We then applied these assumptions to employment data by industry from the Australian Bureau of Statistics to obtain a ceiling for the number of business users ('addressable market'). In addition, we assumed that business users would have a growth rate similar to that for total employment.

Concept Economics assumed that the addressable market for mobile broadband across all industries would have a take-up of 80%. Rather than using a constant take-up, we have modelled take-up using a logistic curve, with the following more conservative assumptions, take-up being expressed as a percentage of the addressable market:

- target take-up in 2014 – 70%
- target take-up in 2018 – 80%
- maximum take-up – 95%

The addressable market was then multiplied by the modelled take-up curve to obtain the number of mobile broadband subscribers.

For each year, the average number of mobile broadband subscribers was then multiplied by the (correct) US productivity benefit per user applied by Concept Economics (USD1924, converted to AUD2671 by applying the PPP rate and adjusted for inflation by the Consumer Price Index). Note that this figure represents the gross benefits.

This productivity benefit was then apportioned across WCDMA/HSPA and LTE (the latter assumed to be the technology deployed on the 700MHz / 2.5GHz combination), based on assumed take-up for LTE expressed as a proportion of mobile broadband services. This was modelled using a second logistic curve, with the following parameters:

- commercial launch in 2013
- target take-up in 2014 – 5%
- target take-up in 2019 – 80%
- maximum take-up – 100%

These assumptions represent one potential scenario for the diffusion of LTE services in the mobile broadband market, with a relatively conservative level of migration from WCDMA in the early stages, and with LTE share increasing to 80% of the mobile broadband market six years after commercial launch.

The number of mobile broadband subscribers was then multiplied by this take-up curve to obtain the number of business LTE subscribers. This was multiplied by the productivity benefit per user, as described above, to obtain the productivity benefit for LTE. Productivity benefit for WCDMA was obtained by subtraction.

For our alternative scenario exploring the effect of delaying the commercial launch of LTE, we used the assumptions for take-up of mobile broadband and LTE as detailed above, but lagged one year to reflect the various constraints that may have a downward effect on the market:

- mobile broadband, as a percentage of the addressable market
  - target take-up in 2015 – 70%
  - target take-up in 2019 – 80%
  - maximum take-up – 95%
- LTE, as a percentage of mobile broadband subscribers

- commercial launch in 2014
- target take-up in 2015 – 5%
- target take-up in 2020 – 80%
- maximum take-up – 100%.

The original methodology used by Concept Economics examined only a productivity benefit per mobile broadband user, where a user is an employed person. Thus the methodology does not consider alternative uses of the 2.5GHz spectrum, which may also have an effect on the productivity benefit. Furthermore the methodology assumes that demand is not constrained by spectrum capacity issues or the use of guard bands.

C.2 Estimating the consumer surplus

Consumer surplus was calculated as:

Consumer surplus = Number of users × individual consumer benefit

The report by Europe Economics focused on WiFi hotspots, being the most commonly used example of wireless broadband. Consumer surplus was calculated for WiFi hotspot usage at airports, based on data for average cost of hotspots in Western European airports and number of passengers, as well as connections per passenger. In the absence of data from willingness to pay surveys, the highest price charged was assumed to equal the willingness to pay.

Using a similar approach to the Europe Economics report to calculate consumer surplus of wireless broadband in Australia we have considered three types of wireless broadband:

- WiFi hotspots use
- mobile broadband use through data cards and USB wireless modems
- mobile data use via 3G handsets.

For WiFi hotspot use we estimated number of users per month based on the number of WiFi sessions per month at McDonalds hotspots, which was then adjusted to account for the proportion of McDonalds hotspots compared to the total number of hotspots in

Australia. The actual price paid was estimated based on the assumption that a WiFi user at a café offering 'free' WiFi would be expected to purchase at least a beverage. This estimated price matched the low range price for an hour's usage at paid hotspots. Willingness to pay was based on the higher prices that we found at paid hotspots; we used two values: a mid range price, and the highest price we found, based on one hour's usage.

McDonalds hotspots were chosen as a proxy for our analysis as Australian data was readily available.

For mobile broadband using datacards and USB modems we used Australian Bureau of Statistics (ABS) data on the number of users. The actual price paid was calculated based on the average price per month for 1GB data allowance across the four networks – Telstra, Optus, Vodafone and 3. The willingness to pay was based on the highest monthly tariff for 1GB data allowance.

For mobile data use via 3G handset ACMA data was used for the number of users. The actual price paid was based on an average ARPU for mobile data excluding SMS reported by the following operators: Telstra, Optus and 3/VHA. Willingness to pay was based on the most expensive monthly mobile data pack offered by these operators.

The consumer surplus for these three wireless broadband products was calculated for both 2008 and 2009 where possible, using the above formula. The individual consumer benefit was calculated as the difference between the willingness to pay and the actual price paid.