Harmonised spectrum for mobile services in ASEAN and South Asia: an international comparison

Report for
Axiata Group Berhad

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About Axiata

Axiata Group Berhad (Axiata) is one of Asia's largest communications companies. Axiata has controlling interests in mobile operators in: Malaysia, Indonesia, Sri Lanka, Bangladesh and Cambodia with significant strategic stakes in mobile operators in India and Singapore. The Group's mobile subsidiaries and associates operate under the *'Celcom'* brand in Malaysia, *'XL'* in Indonesia, *'Dialog'* in Sri Lanka, *'Robi'* in Bangladesh, *'Smart'* in Cambodia, *'Idea'* in India and *'M1'* in Singapore. Axiata also has interests in "*I-Mobile"* in Thailand.

Including subsidiaries and associates, Axiata has over 215 million mobile customers in Asia. Group revenue for 2012 was USD5.7 billion and the Group now employs over 20,000 people across Asia.

Axiata's vision is to be a regional champion by 2015 by piecing together the best throughout the region in connectivity, technology and talent, uniting them towards a single goal: ***Advancing Asia.***

This Plum Consulting report has been commissioned to contribute to this goal. The views in this report are the responsibility of Plum based on terms of reference defined by Axiata.

About Plum

Plum Consulting is a specialised consulting firm offering strategy, policy and regulatory advice on telecoms, online and spectrum issues. We draw on economics, our knowledge of the sector and our clients' perspective to deliver soundly based solutions to problems. We are an international leader in advising on spectrum policy and regulation. We work in many countries in Asia, Africa, the Americas and Europe on issues affecting all uses of spectrum. Our clients include telecoms operators, regulators, equipment vendors, broadcasters and online service providers. Many of our reports are published and can be seen at http://plumconsulting.co.uk/publications.

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Executive summary

Governments around the world are seeking ways of developing their broadband infrastructure to enhance productivity in all sectors, stimulate job creation and promote social inclusion. As the rapid take-up of smartphones and other devices drive up data traffic on wireless broadband networks, there is now a greater policy emphasis on spectrum assignment as an engine of wider economic development. This is reflected in plans to make available more spectrum for mobile services in many countries particularly in Europe and North America.

This study by Plum Consulting for Axiata Group Berhad investigates the availability of harmonised spectrum for mobile services in ASEAN and South Asia. It addresses the following questions:

- How much harmonised spectrum is currently assigned to mobile operators in ASEAN and South Asia compared to operators in competitor regions elsewhere in the world? Is there a significant spectrum *"divide"* and, if so, of what form?
- Is it likely that current differences in spectrum assigned to mobile operators will reduce or increase over time, based on published national policies for future spectrum release?
- What are the potential implications of current and future differences in spectrum assigned to mobile operators for aggregate national broadband capacity and cost?
- What are the measures that can be taken by ASEAN and South Asian policy makers to address any identified spectrum *"divide"*?

The study was carried out between March and June 2013. All spectrum comparisons are based on publicly available information on current allocations and future availability as of June 2013. Where national administrations have developed, or are developing, plans for future availability which are not yet published these, inevitably, are not included.

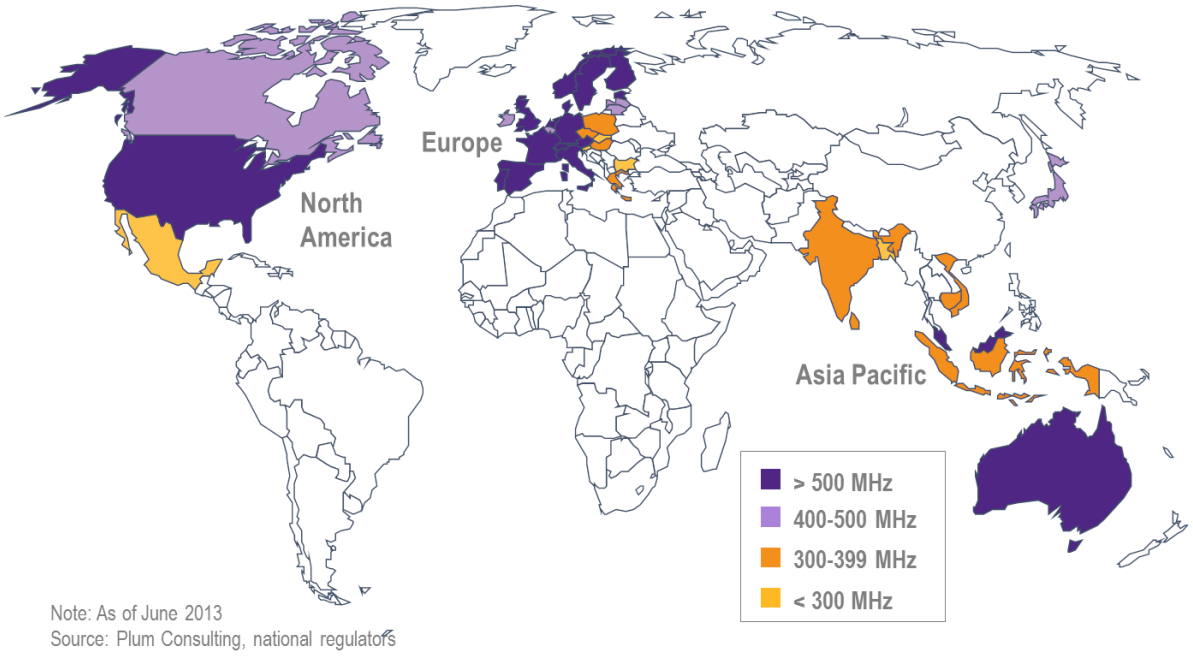
There is potentially more harmonised spectrum available to countries in the Asia Pacific region than elsewhere because of the availability of specific regional bands in addition to bands harmonised in other regions for mobile services. However, this potential regional competitive advantage is dissipated in a significant number of ASEAN and South Asian countries as the amounts of spectrum actually assigned to operators do not reflect higher potential spectrum availability.

Our findings from published information indicate that in the high income countries of Europe, North America, and the Asia Pacific region some 500-600 MHz of spectrum is currently assigned to mobile services. However, in most middle and low income countries in ASEAN and South Asia only some 300-400 MHz of spectrum is assigned to mobile services. Hence there is a spectrum "*divide"* of around 200 MHz between these groups of countries.

In addition to a *"divide"* in spectrum assigned for mobile services, unlicensed spectrum for wireless LANs / Wi-Fi is also more limited in many ASEAN and South Asian countries compared to countries in Europe and North America.

Within each of the three global regions it appears there is a core group of countries which is taking the lead in spectrum assignments (see Figure 1).

Figure 1: Amount of spectrum assigned to mobile services in the countries in North America, Europe and Asia Pacific regions

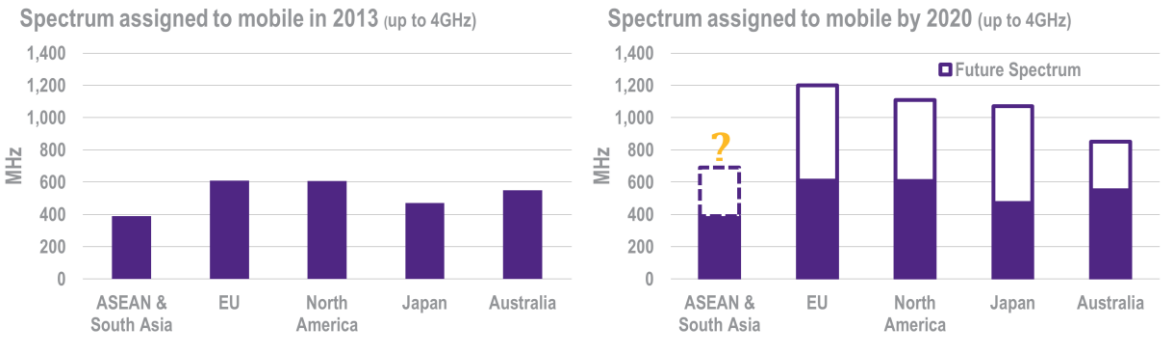


Note: As of June 2013
Source: Plum Consulting, national regulators

In North America and Europe countries forming the regional economic core have assigned more spectrum compared to the region as a whole. In South and South East Asia this phenomenon is reversed underlining the inter-regional *"divide"*. A detailed examination of the underlying reasons for these *"divides"* is beyond the scope of this study. However, it appears an opportunity is being missed by middle and low income ASEAN and South Asian countries to catch up with wealthier regions and countries by assigning further spectrum nationally to support mobile broadband services. This may be seen as particularly concerning given the low availability of fixed broadband services in many middle and low income ASEAN and South Asian nations.

Our review of published future spectrum plans suggests that this spectrum *"divide"* is likely to increase substantially over the next seven years, possibly amounting to around 500 MHz by 2020 as shown in Figure 2.

Figure 2: A widening global and regional spectrum *"divide"* in assigned mobile spectrum



Source: Plum Consulting

In addition, new regulatory approaches are being developed in Europe and the US to enable more efficient use of assigned spectrum such as implementation of technology neutral licences, spectrum trading, and exploration of increasing spectrum utilisation through sharing either between operators or with other services. In the US and Europe there are also initiatives to increase the amount of spectrum allocated for Wi-Fi to support high bandwidth services including offload from mobile networks.

The assignment of less spectrum to mobile services will either reduce the capacity of networks with negative impacts on service quality and coverage, or increase the costs of providing the capacity required to meet demand. If the spectrum *"divide"* is not closed, the negative outcomes identified by Plum may include:

- The long term cost per gigabyte of providing mobile broadband in urban areas of ASEAN and South Asia could be double that in cities in the US and EU. This could impede the development of high tech service development in the megacities of ASEAN and South Asia.
- The costs of rural networks in ASEAN and South East Asia may be 50% higher than could otherwise be the case. This will inevitably limit rural coverage.

By assigning more spectrum for broadband, middle and low income ASEAN and South Asian countries have an opportunity to catch up with high income regions and countries in terms of the aggregate national capabilities of broadband service capacity and cost, and thereby enhance their economic growth and social development. They can close, at least in part, the current broadband digital divides, and prevent these from growing further in terms of relative capacity and costs of supply in densely populated urban areas and rural, remote areas.

We suggest the following policy actions are required to mitigate these risks:

- Ensure a spectrum release and assignment policy is included in all national broadband plans. National broadband plans should prioritise spectrum already harmonised on an Asia Pacific basis, but not yet assigned, for assignment through an appropriate mechanism in the short term.
- Assess national requirements for additional spectrum for broadband services (how much and which type of bands) and identify further candidate bands for release in consultation with industry.
- Remove regulatory restrictions that inhibit flexible deployment of technologies and use of spectrum so that operators can re-farm their spectrum holdings from old to new technology where this is beneficial.
- Allow operators to share spectrum to support wider bandwidth services where this does not have significant negative impacts on competition. More generally spectrum trading and leasing should be permitted so as to give licensees incentives to share their spectrum and to move spectrum from low to high values uses and users.
- Adopt a transparent, fair and timely approach to national spectrum assignment to ensure the release of spectrum packages suitable for broadband so as to promote broadband development.
- Build further regulatory capacity to undertake these activities on a regional basis in the Asia Pacific e.g. co-operation on managing interference issues and the timing of reallocating spectrum from existing uses to mobile services.

1 Introduction

There is now general recognition of the huge potential of the broadband Internet to stimulate economic and social development[1]. Governments around the world are therefore seeking ways of developing their broadband infrastructure to enhance productivity in all sectors, stimulate job creation and increase social inclusion. This study is motivated by a concern that countries in the ASEAN and South Asia regions may be losing ground compared to other regions, in particular North America and Europe, in identifying and allocating spectrum to develop broadband infrastructure using mobile networks. This is a critical concern as these networks provide the main means of access to communications services by many citizens in ASEAN and South Asian countries where the reach of fixed broadband is limited.

Until relatively recently, demand for communications services was driven by demand for voice calling, text messaging (on mobile networks) and, to a lesser extent, low speed internet access. However, the advent of higher speed, broadband internet access is changing this picture. For example, mobile data traffic in the Asia Pacific region overall is forecast to grow nine-fold between 2013 and 2017[2].

This study for Axiata Group Berhad addresses the following issues:

- How much harmonised spectrum is currently assigned to mobile operators in ASEAN and South Asia compared to operators in competitor regions elsewhere in the world? Is there a significant spectrum *"divide"* and, if so, of what form?
- Is it likely that current differences in spectrum assigned to mobile operators will reduce or increase over time, based on published national policies for future spectrum release?
- What are the potential implications of current and future differences in spectrum assigned to mobile operators for aggregate national broadband capacity and cost?
- What are the measures that can be taken by ASEAN and South Asian policy makers to address any identified spectrum *"divide"*?

The structure of the report is as follows:

- Section 2 describes the current assignment of spectrum to mobile operators in Europe, North America and the Asia Pacific region. The main bands allocated to mobile services are given in Appendix A.
- Section 3 describes published plans in countries in Europe, North America and the Asia Pacific region for future assignment of spectrum to mobile operators over the next 5-10 years. Details of the plans are given in Appendix B.
- Section 4 evaluates the findings from Sections 2 and 3.
- Section 5 discusses the consequences of the spectrum *"divide"* identified in previous sections.
- Section 6 identifies policy options based on leading international practice for reducing or removing this spectrum *"divide".*

[1] http://www.broadbandcommission.org/Documents/Broadband_Challenge.pdf, 25 October 2011

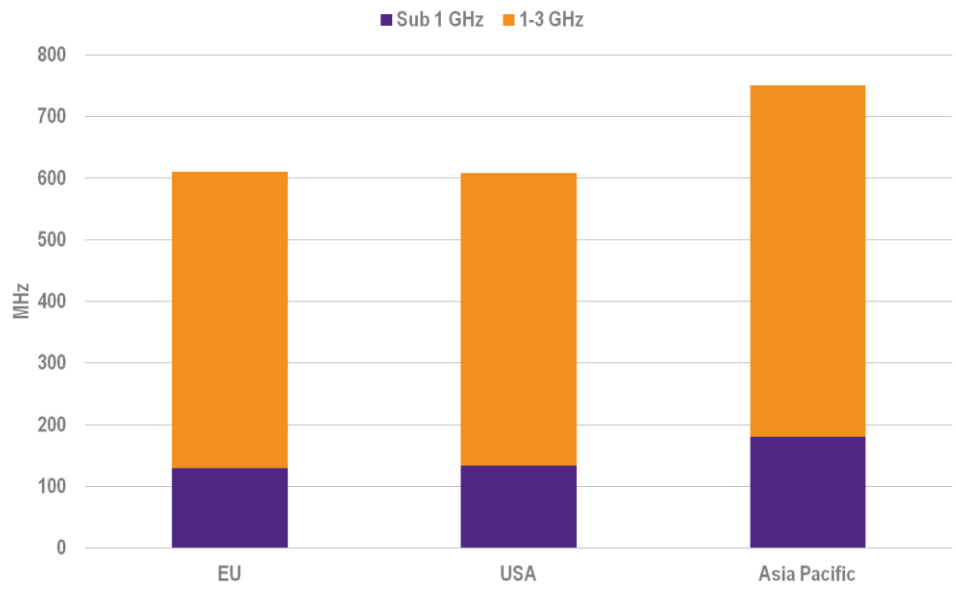
[2] Cisco Virtual Networking Index 2013

2 Spectrum currently assigned to mobile services in Europe, North America and Asia Pacific countries

2.1 Introduction

Mobile services require access to frequency spectrum to operate. The frequency bands need to be harmonised at a regional and ideally a global level to maximize the availability of low cost handsets, support international roaming and limit the extent of cross border interference between services. The main frequency bands that have been harmonised for mobile service use are listed in Appendix A together with an indication of the main countries/regions of the world where their use is permitted. Figure 2-1 shows the amounts of spectrum allocated to mobile services by region. As can be seen there is potentially more spectrum available to countries in the Asia Pacific region than in Europe or North America.

Figure 2-1: Harmonised spectrum allocated to mobile services by region



Source: Plum Consulting, ECO, FCC, APT

Importantly all frequencies in harmonised bands must be released to mobile operators before theoretical service capabilities can be translated into actual ones. Below we report the total amounts of spectrum actually assigned to operators for mobile services use in the three regions under investigation: Europe, North America and Asia Pacific with a focus on ASEAN and South Asia[3]. We find that in some countries not all harmonised bands have been assigned and in others harmonised bands have only been partially assigned. Figure 2-2 explains the difference between allocation and assignment.

[3] Within this region we focus on Axiata's key markets – Malaysia, Indonesia, Sri Lanka, Bangladesh, Cambodia, India and Singapore.

Figure 2-2: Definition of allocation and assignment

Allocation (of a frequency band): Entry in the Table of Frequency Allocations of a given frequency band for the purpose of its use by one or more terrestrial or space radiocommunication services under specified conditions. This process involves updating of a country's national frequency allocation table (NFAT).

Assignment (of a radio frequency or radio frequency channel): Authorisation given by an administration for a radio station to use a radio frequency or radio frequency channel under specified conditions. This process involves issuing of licences to operators to provide services.

Source: ITU

In our analysis we also make a distinction between spectrum assignments below and above 1 GHz because frequencies below 1 GHz are particularly useful to operators for low cost in-building and rural coverage, whereas frequencies above 1 GHz are primarily used as capacity bands in densely populated urban areas.

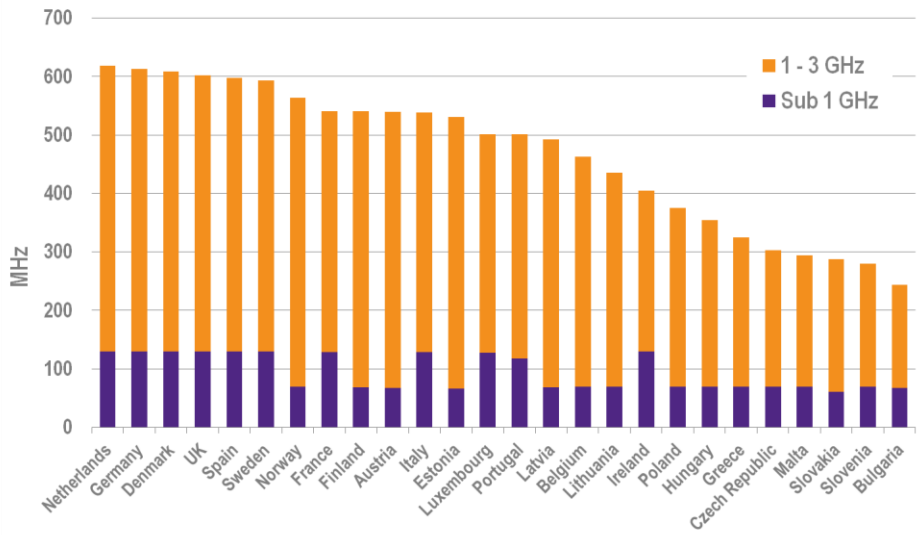
2.2 Total assignments

Figure 2-3, Figure 2-4 and Figure 2-5 illustrate the amount of spectrum currently assigned to mobile operators in selected countries in Europe, North America and in a range of Asia-Pacific countries including those where Axiata is active.

The frequencies compared by Plum are between 400 MHz and 3 GHz which contains all currently harmonised mobile spectrum except the 3.4 – 3.6 GHz band which is not uniformly harmonised for mobile services across the three global regions[4]. Also the 3.4 – 3.6 GHz band often contains assignments for fixed wireless access. This means that, although the band (and possibly also the 3.6 – 3.8 GHz band) is likely to be used in future for technologies such as LTE-Advanced, it will require recovery and re-assignment and/or existing licences must be re-purposed before the band is available on a harmonized basis for mobile service use.

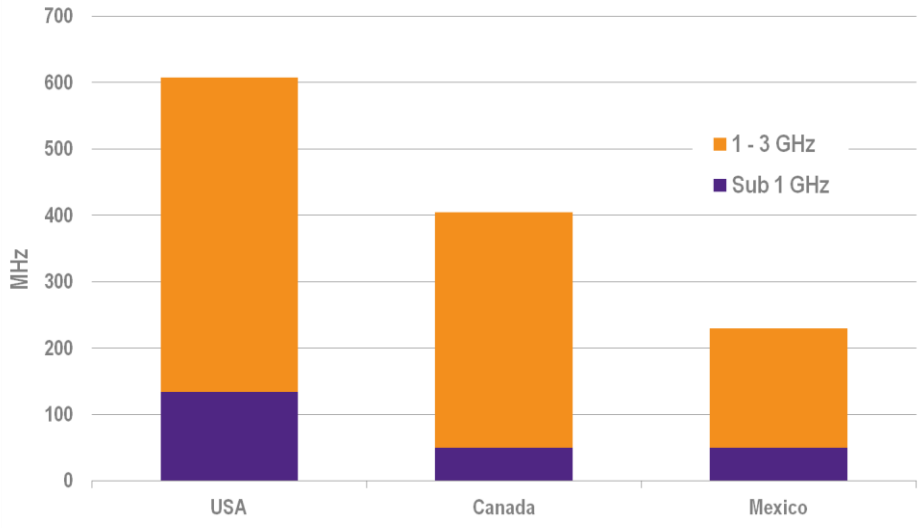
[4] The status of allocations is described at paragraph 29 of the FCC's Notice of Proposed Rule Making on the 3.5 GHz band http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-12-148A1.pdf

Figure 2-3: Spectrum assigned for cellular mobile use in Europe (June 2013)



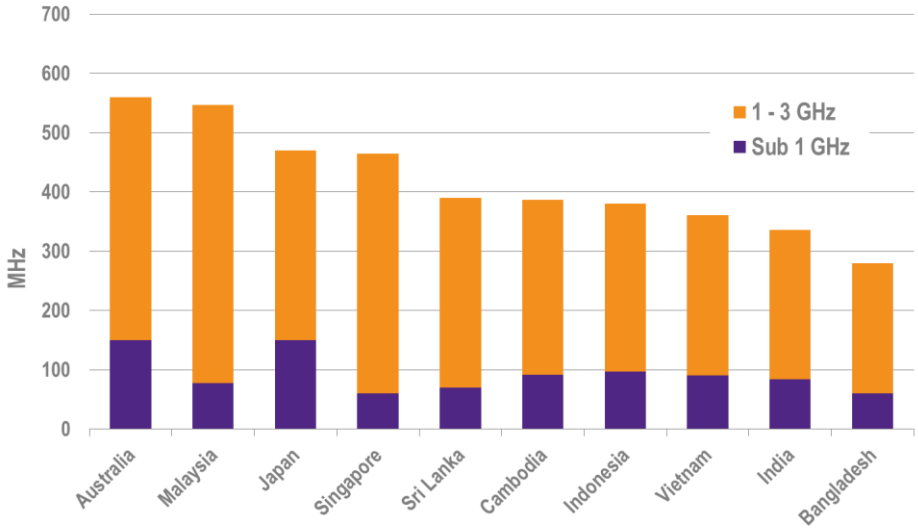
Source: Plum Consulting, ECO

Figure 2-4: Spectrum assigned for cellular mobile use in North America (June 2013)



Source: Plum Consulting, National regulators, Operators

Figure 2-5: Spectrum assigned for cellular mobile use in selected APAC countries (June 2013)



Source: Plum Consulting, National regulators, Operators

Figure 2-3 shows that most major EU countries have assigned over 500 MHz of spectrum and are heading towards totals in excess of 600 MHz as the 800 MHz and 2.6 GHz bands are auctioned.

Figure 2-4 shows that the total bandwidth already released in the US is more than 600 MHz. The same is not true in Canada, although there are auctions planned for 68 MHz in the 700 MHz band in January 2014 and 60-125 MHz (depending on region) in the 2600 MHz band in 2014. Mexico is the only country that has yet to publish plans for auctioning the 700 MHz band. There is, nevertheless, the possibility that 40 MHz of the 2.6 GHz band may become available in the near future[5] though the timing of the assignment process is still uncertain. Mexico also has a total of 60 MHz vacant bandwidth in the AWS band, which could be released in future, but we are not aware of any published plans for this release[6].

Figure 2-5 shows that high income countries in the Asia-Pacific region tend to have more spectrum assigned for mobile services than others. The majority of lower income countries in ASEAN and South Asia have only a total of between 300 MHz and 400 MHz assigned to mobile operators.

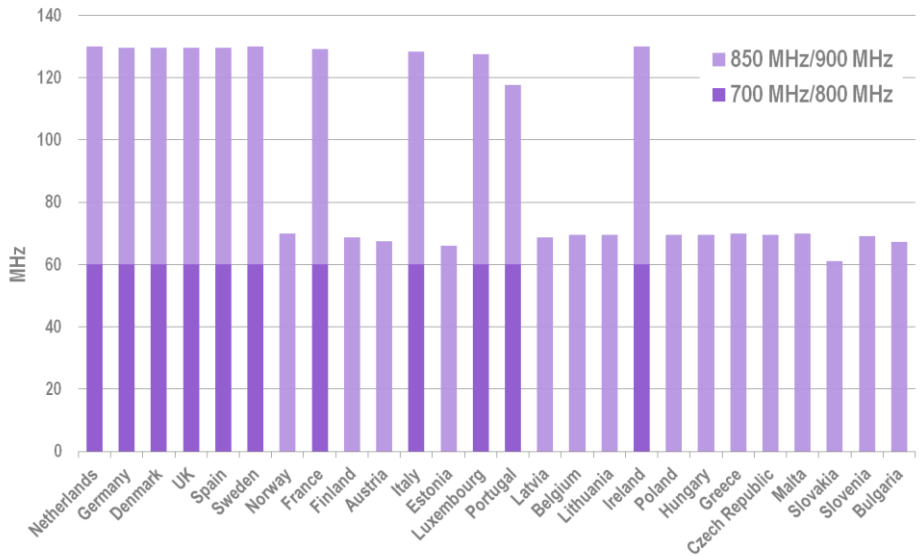
2.3 Spectrum below 1 GHz

Figure 2-6, Figure 2-7 and Figure 2-8 show the spectrum assigned to mobile operators for bands below 1 GHz in selected countries in Europe, North America and the Asia Pacific region.

[5] http://www.reuters.com/article/2012/08/14/mexico-telecoms-idUSL2E8JE4SO20120814

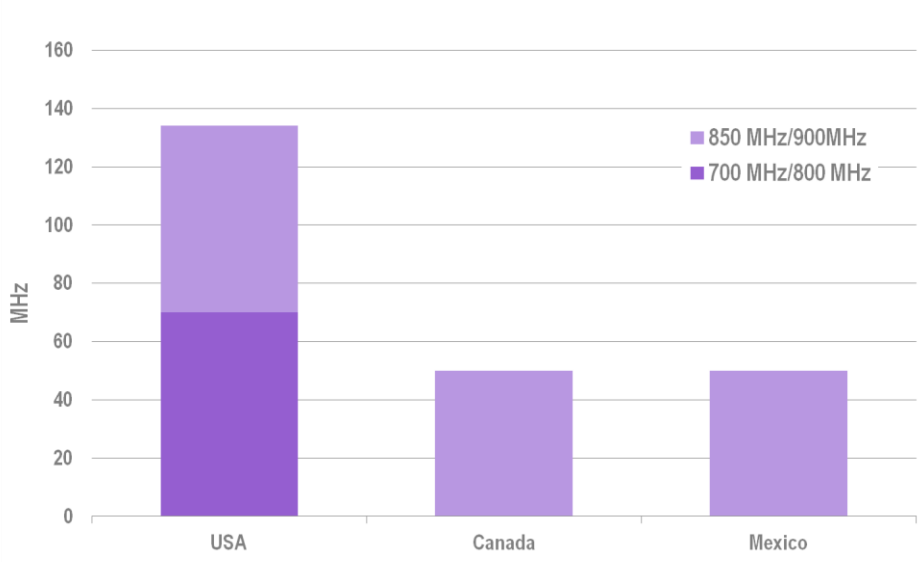
[6] Only 60 MHz of the total 120 MHz was assigned in the AWS band auction that took place in August 2010.

Figure 2-6: Sub-1 GHz spectrum assigned for mobile service use in Europe (June 2013)



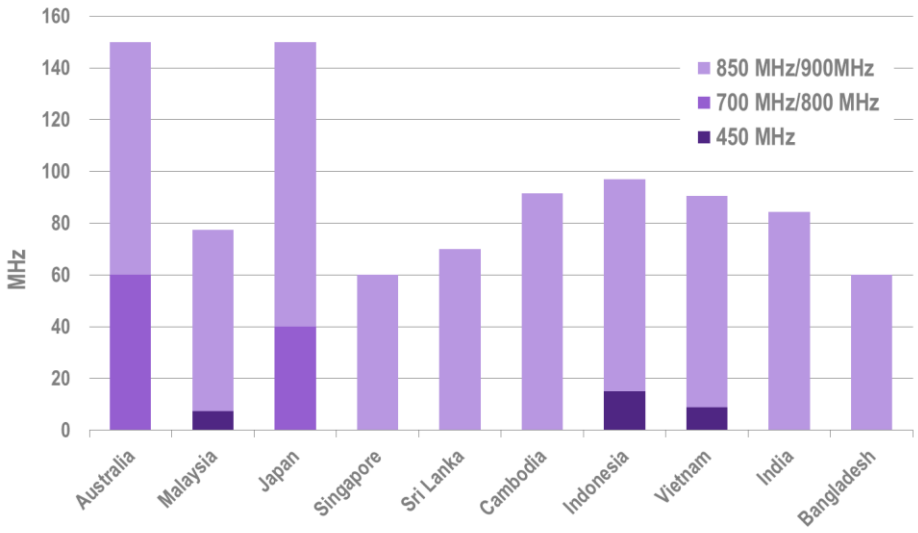
Source: Plum Consulting, ECO

Figure 2-7: Sub-1 GHz spectrum assigned for mobile service use in North America (June 2013)



Source: Plum Consulting, National regulators, Operators

Figure 2-8: Sub-1 GHz spectrum assigned for mobile service use in selected APAC countries (June 2013)



Source: Plum Consulting, National regulators, Operators

The disparity between the regions arises principally from differences in the bands that are harmonised in each of the three regions. Specifically, there is potentially more spectrum available in the Asia Pacific countries than elsewhere due to advantages in regional harmonization approaches:

- The Asia Pacific 700 MHz band (2x45 MHz) has 30 MHz (2x15 MHz) more than the European 800 MHz band and 20MHz more than the US 700 MHz band
- The present configuration of the 850 MHz band in North America only provides a total of 64 MHz of spectrum, whereas the 850 MHz and 900 MHz bands combined have a maximum bandwidth of 90 MHz in Asia Pacific
- Europe is unable to use the 850 MHz band, so its sub-1 GHz allocation is less than other regions in cases where the 800 MHz band has not been assigned. The 900 MHz band alone provides at most 70 MHz of bandwidth.

The above factors account for the greater amount of sub-1 GHz spectrum assigned to mobile operators in Australia, Japan and the US compared to countries in Europe. However, they do not explain why operators in a number of ASEAN and South Asia countries have much less assigned spectrum (less than 100 MHz) than operators in high income countries in the same region and elsewhere (130 MHz or more).

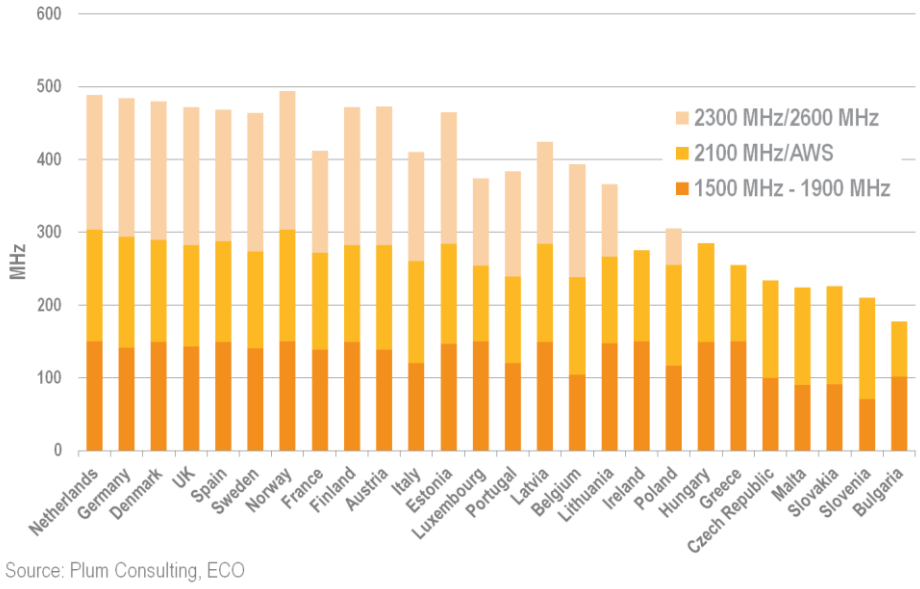
2.4 Spectrum above 1 GHz

Figure 2-9, Figure 2-10 and Figure 2-11 show the spectrum assigned to mobile operators for bands from 1 GHz to 3 GHz in selected countries in Europe, North America and the Asia Pacific region.

For frequencies above 1 GHz the main differences in spectrum assigned to mobile operators in each country investigated depend on how much of the 1.8 GHz and 2.1 GHz bands have been assigned and whether the 2.6 GHz band has been assigned.

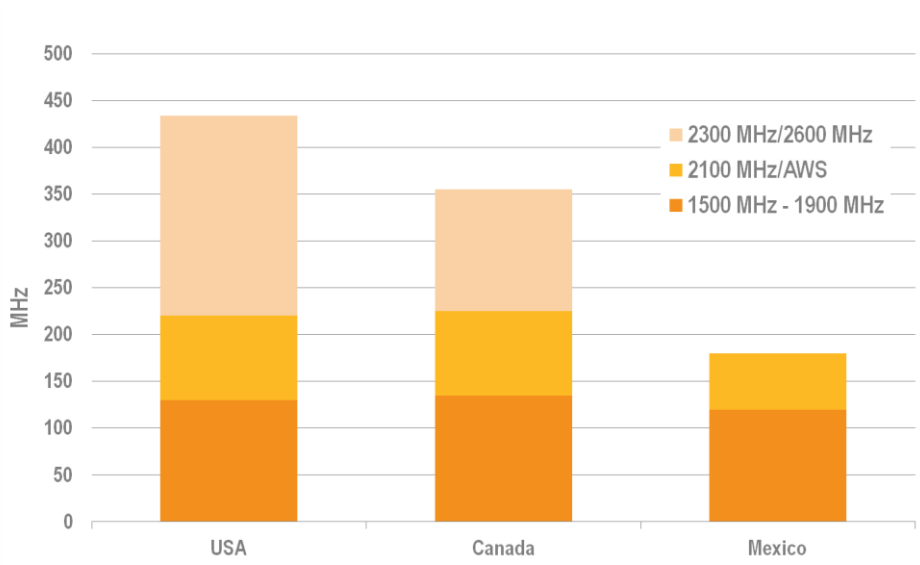
Some differences arise from differences in the amounts of harmonised spectrum in each region, with the European 1800 MHz and 2.1 GHz bands together offering 2x10 MHz more spectrum than their US counterparts i.e. 1900 MHz PCS and the AWS band. As the Asia Pacific region has tended to follow European band plans for these frequencies more spectrum is similarly available to countries in the Asia Pacific.

Figure 2-9: 1-3 GHz spectrum assigned for mobile service use in Europe (June 2013)



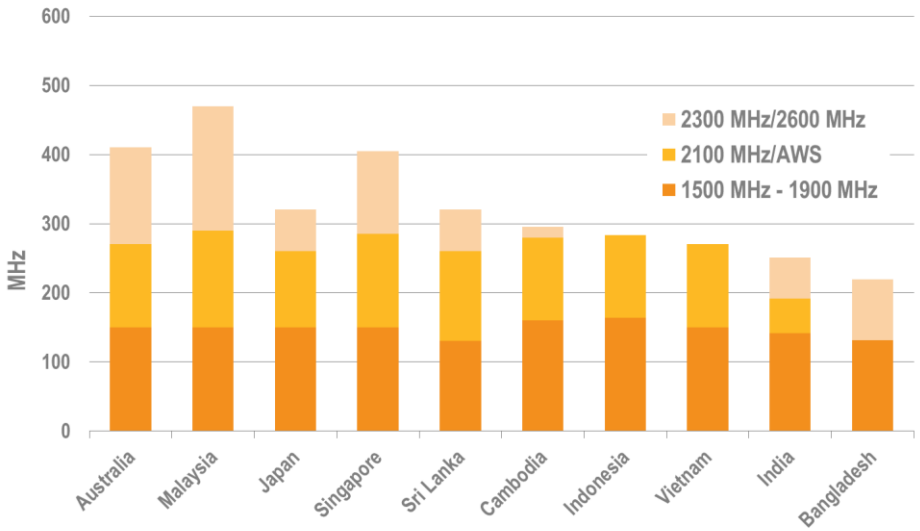
Source: Plum Consulting, ECO

Figure 2-10: 1-3 GHz spectrum assigned for mobile service use in North America (June 2013)



Source: Plum Consulting, National regulators, Operators

Figure 2-11: 1-3 GHz spectrum assigned for mobile service use in selected APAC countries (June 2013)



Source: Plum Consulting, National regulators, Operators

2.5 Spectrum access for wireless LANs / Wi-Fi

There are two internationally harmonised frequency ranges for wireless LANs / Wi-Fi, namely the 2.4 GHz band and parts of the 5 GHz band. In both cases there are national regulatory restrictions on the power and other aspects of transmissions to avoid interference to other services in the bands. The

2.4 GHz band is the most widely used Wi-Fi band and its use is supported by most wireless routers and mobile devices. There is now extensive use of Wi-Fi by mobile devices which can help reduce capacity required on the mobile network[7].

In Europe and North America and in some, but not all, countries in the Asia Pacific region, access to the 2.4 GHz and 5 GHz bands is permitted for consumers and businesses on an unlicensed basis.

In some ASEAN and South Asian countries, including Sri Lanka, Bangladesh and Cambodia the use of the bands for commercial purposes is subject to control through licensing. While licensing does not inevitably translate into a restriction on access to spectrum this may illustrate a less flexible approach.

2.6 Summary

In summary we find that:

- There is potentially more harmonised spectrum for mobile services available to countries in the Asia Pacific region than elsewhere because of the availability of regionally harmonised bands.
- However, this potential regional competitive advantage is dissipated in a significant number of ASEAN and South Asian countries as the amounts of spectrum actually assigned to operators do not reflect higher potential spectrum availability. Our findings are that:
  - In the high income countries of Europe, North America, and the Asia Pacific region some 500-600 MHz of spectrum is currently assigned to mobile services.
  - However, in most middle and low income countries in ASEAN and South Asia[8] only some 300-400 MHz of spectrum is assigned to mobile services i.e. around 200 MHz less than the high income countries in Europe, North America and the Asia Pacific.
- About 30% of this 200 MHz *"divide"* is accounted for by differences in assignments below 1 GHz and the remainder arises from differences in assignments of spectrum above 1 GHz.
- In addition to a divide in spectrum assigned for mobile services, unlicensed access to spectrum for wireless LANs / Wi-Fi is also more limited in many ASEAN and South Asian countries compared to countries in Europe and North America.

[7] According to Cisco VNI 2013, the percentage of data consumed by mobile devices globally that is offloaded to a fixed network via Wi-Fi or femtocell will rise from 33% in 2012 to 46% in 2017.

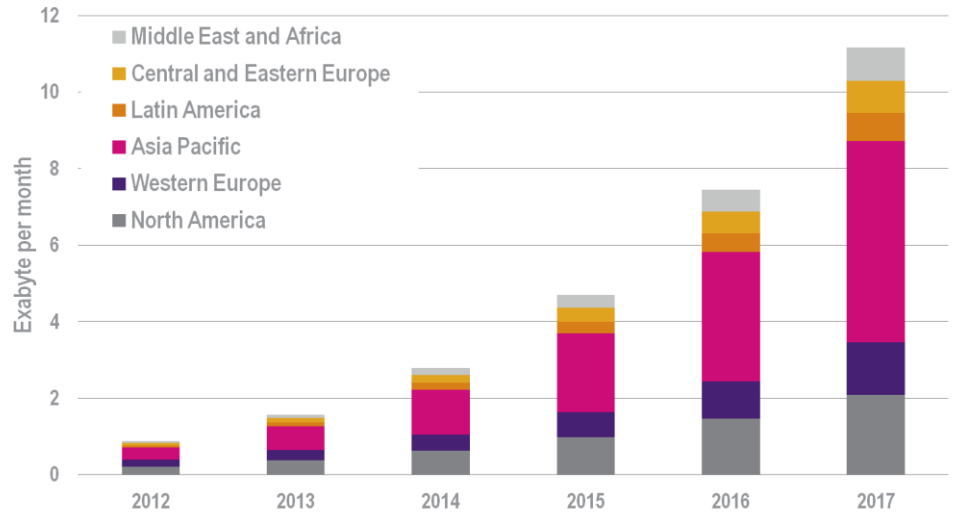
[8] Apart from Singapore, the ASEAN and South Asian countries covered in this study are classified as middle and low income by the World Bank. GDP per capita (PPP) as reported by the World Bank in Mexico and Malaysia is about 30-50% that in high income countries of Australia, Canada, Japan, Singapore, the US and the EU. GDP per capita (PPP) in Bangladesh, Cambodia, India, Indonesia, Sri Lanka and Vietnam ranges from 5-25% of the level in the high income countries.

3 Public plans to assign additional spectrum for mobile

3.1 Introduction

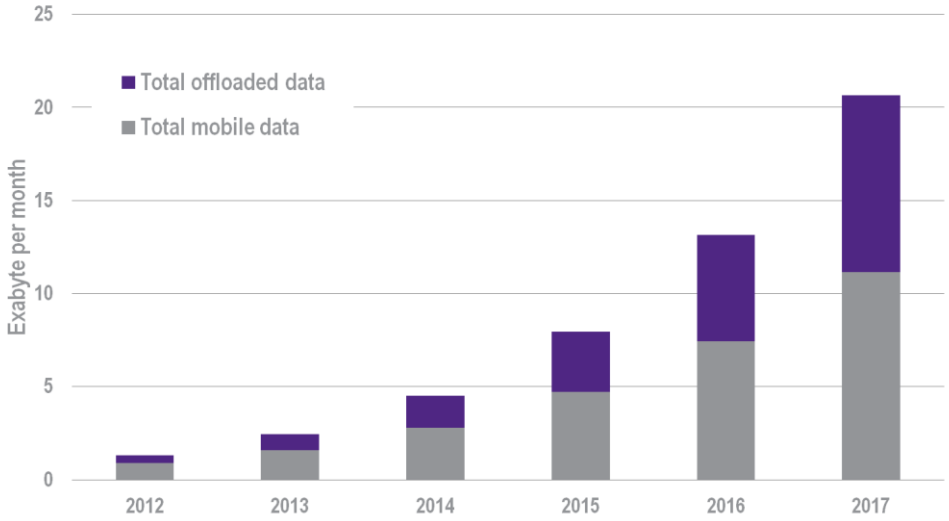
Exponential growth in mobile traffic is forecast for all regions of the world (see Figure 3-1). This is driven by rising take-up and use of laptop PCs, smartphones and tablets coupled with adoption of higher-speed applications, notably video. While broadband consumption is increasingly from mobile devices there will also be growth in the offload of traffic via Wi-Fi to fixed networks, where these exist. By 2017 offloaded data is forecast to account for around half of all traffic from mobile devices (see Figure 3-2).

Figure 3-1: Forecast mobile data traffic by region



Note: 1 exabyte = 10^{18} bytes
Source: Cisco VNI 2013

Figure 3-2: Forecast mobile data traffic and offloaded data traffic- global



Note: 1 exabyte = 10^{18} bytes
Source: Cisco VNI 2013

Plum believes three factors will, in combination, increase capacity to meet expected growth in traffic:

- More spectrum allocated to mobile services by regulators at global and regional levels will be made available to mobile operators nationally;
- There will be further operator investment in broadband network infrastructure which will be increasingly shared between operators; and
- Operators will adopt new more efficient radio technologies and this process will be more rapid than to date, shortening network investment cycles.

Regions and countries where the mobile industry is able to combine these factors to produce greatly increased aggregate national broadband capacity at high quality and low cost, will be best placed to exploit the economic and social benefits of broadband.

The economic importance of broadband has led international organizations and governments to review the potential opportunities for providing access to additional spectrum for broadband services. Spectrum that could, in principle, be used to provide broadband services lies broadly in the frequency range 300 MHz to 6 GHz. Finding additional spectrum is often difficult because the frequencies are typically assigned to other users – who are understandably reluctant to relinquish their assignments (based on historic technology) without compensation. Hence the processes used for finding additional spectrum can be complex and time consuming. The work required typically includes:

- Demand studies to determine the amount of additional spectrum that might be required;
- A spectrum release target that is publicly announced;
- An inventory of existing spectrum use in order to identify candidate bands to achieve the target and;
- Analysis of the costs and benefits of sharing or releasing bands from their existing use to mobile services.

From a review of internationally available public information we have found that the countries who are aggressively taking initiatives to allocate additional spectrum for broadband include: Australia, the European Union as a whole (and within that Denmark, France, Sweden and the UK are assuming leadership positions), Japan and the United States.

In addition, there are now spectrum release targets and plans for a spectrum audit in India. ITU sponsored Wireless Broadband Masterplans for certain ASEAN and South Asian countries have been published which contain spectrum release targets, though the level of national support from governments[9] for these initiatives remains unclear. The current status of these activities to identify and release more spectrum for mobile services is reported below and in Appendix B.

3.2 Spectrum release targets

Spectrum release targets for broadband have been published in numerous countries, sometimes based on demand analyses and often in advance of detailed work being conducted on the potential availability of bands. A target can be helpful in itself as a means of providing political commitment to, and a stimulus for, the detailed work to identify and assign candidate bands which may take a number of years. Where this commitment is endorsed at a very senior level in government, for example by the President, the Prime Minister, the Minister of Communications or the Minister of Finance, spectrum release is typically associated with a political view that it has the potential to act as a catalyst for economic development.

The countries that have published long term spectrum release targets for broadband are shown in Table 3-1. The target amounts of spectrum to be assigned (300 MHz-1.2 GHz) are generally large compared with the amounts of spectrum currently assigned to mobile services of around 600 MHz or less and tend to be based on demand forecasts such as those from Cisco shown in Figure 3-1.

As can be seen from Table 3-1 most of the initiatives identified started in the last two years and as a consequence most countries listed have yet to release significant amounts of spectrum. It usually takes at least 2-3 years to identify and consult on possibilities for release or sharing of new bands and potentially much longer to assign the identified spectrum before the mobile industry can put it into use.

Developments in the US are arguably the most advanced among all the countries examined in this study. For example the National Telecommunications and Information Administration (NTIA) has identified 210 MHz (1695-1710 MHz, 1755-1850 MHz, 3550-3650 MHz) to be made available for mobile services on a shared basis although actual mechanisms and technical rules are still being developed by the FCC. In addition, the FCC has recently revised rules for the 2.3 GHz band to accommodate 30 MHz for mobile broadband, and for the 2 GHz band to free up 40 MHz of underutilised mobile satellite service spectrum (2000-2020/2180-2020 MHz) for mobile use. The FCC is also in the process of implementing incentive auctions as a way to reallocate broadcast TV spectrum for broadband.

[9] See, for example, Wireless Broadband Masterplan until 2020 for the Socialist Republic of Vietnam, ITU, October 2012.

Table 3-1: Spectrum targets and plans

	Spectrum required to meet demand for mobile broadband	Plans for candidate bands	Demand analysis	Year process started publicly
Australia	300 MHz by 2020, with 50% of this by 2015	Candidate bands published	Yes to 2016 and 2020	2011
India	300 MHz by 2017, a further 200 MHz by 2020	Not yet developed	This has just started	2012
Japan	300 MHz by 2015; up to a further 1.2 GHz by 2020	Action plan published identifying a number of bands to be considered	Yes for 2015 and 2020	2010
Canada	300-415 MHz by 2017	Candidate bands published	Yes	2013
US	300 MHz by 2015; a further 500 MHz released by 2020	Some immediate releases identified and 11 priority bands are under investigation	Yes to 2020	2010
European Union	1200 MHz in total to be identified by 2015. This implies 200 MHz additional to bands already harmonised and 600MHz additional to bands already assigned.	Not yet but some candidate bands proposed	Yes being undertaken	2010
Denmark	300 MHz by 2020; a further 300 MHz by 2025	Yes – priority bands for investigation identified	Yes to 2020	2011
France	500-700 MHz by 2020	Work undertaken but not published	Yes to 2020	2011
UK	500 MHz of public sector spectrum by 2020	Candidate bands published	Yes for commercial applications.	2010

Source: Government and regulator announcements. See Appendix B for details.

In Japan there are ambitious plans to release a considerable amount of spectrum, most of it in higher frequency ranges (3 – 5 GHz) to provide the small cell capacity for very high traffic levels. In Australia the regulator has also published a target of an additional 300MHz for mobile services and is undertaking work on the possible bands that might be used to reach this target. However, the relatively small size of the Australian market means that it must either persuade other countries in the Asia Pacific region to follow its lead or adopt bands harmonised in for Europe or North America.

In Europe, a harmonised European allocation and band plan is required before individual countries can assign new bands to mobile services – no one market is big enough to support unilateral action and cross border interference issues can also be a major consideration. The European Union (EU) as a whole has a target of having 1200 MHz identified for mobile services by 2015. Around 600 MHz is already identified and assigned in many countries. A further 400MHz has been identified in the 3.4-3.8 GHz frequency range and the band plan and other technical conditions of use are expected to be

agreed in CEPT[10] this year. National plans to release large amounts of spectrum – 300-500 MHz - in countries such as Denmark, France, Sweden and the UK are contingent on timely completion of harmonisation activities for these and other frequency bands e.g. the 700 MHz, 1.4 GHz and 2.3 GHz bands.

3.3 National activities to support achievement of the targets

Table 3-2 lists countries in which a spectrum inventory is being or has been undertaken to identify bands that could be repurposed for broadband and the frequency and scope of the activity. About half of the countries that have conducted a spectrum inventory have done so on a one-off basis, while others have committed to a rolling programme that updates spectrum usage information either annually or on a three year cycle. This information provides a base-line for identifying unused and under-used spectrum and for determining the cost and feasibility of repurposing or sharing the spectrum with broadband services.

Table 3-2: Nature and scope of spectrum inventory

Country	Inventory?	Frequency and scope?
Australia	Yes	Updated each year in the five year spectrum outlook
India	Planned	Periodic, a roadmap for spectrum will be published every 5 years
Japan	Yes	Each year a third of the frequencies is assessed: bands below 770MHz; 770MHz–3.4GHz; above 3.4GHz
Canada	Yes	One off
US	Yes	One-off. Main focus is on bands used by federal agencies in frequency range 225-4400MHz
European Union	Planned	Prototype undertaken for 300MHz-6GHz; expected to be conducted on a rolling basis
Denmark	No	Not applicable
France	Yes	Annual. Bands are divided into three groups: under 223MHz, 223MHz-5GHz and above 5GHz.
Sweden	Yes – in progress	One-off
UK	Yes	One-off. Government and non-government use addressed by separate processes

[10] The European Conference of Postal and Telecommunications Administrations which develops technical harmonisation measures for Europe.

3.4 Candidate bands for release

The World Radio Conference in 2012 acknowledged the need for more spectrum to be allocated for mobile services in order to accommodate the exponential growth in broadband. This resulted in agreement to identify suitable candidate bands, subject to technical examination.

The bands that are being investigated as possibilities for future mobile use in the countries reviewed are shown in Table 3-3. The main focus is on:

- Bands that are already harmonised for mobile services though are not assigned nationally for this purpose such as bands in the 470-790 MHz range, and the 2.3 GHz and 3.5 GHz bands.
- New bands that potentially offer significant amounts of additional spectrum, such as those around 1.4 GHz, 2.7-2.9 GHz, 3.6-4.2 GHz, 4.4-5 GHz. These bands will also need to be harmonised at a regional or global level (in ITU Radio Regulations and 3GPP) before equipment will be manufactured on a mass-market basis to use the bands.
- Additional spectrum between 5150 MHz and 6000 MHz for Wi-Fi to support high bandwidth services utilising spectrum channels of up to 160 MHz in bandwidth and supporting much greater offload of traffic from mobile networks in indoor and urban contexts.

Activities initiated regionally by the Asia Pacific Telecommunity (APT) include surveys on current usage of the 806-960 MHz and 3.4-3.6 GHz bands, with a view to consider greater harmonisation among APT member countries. These have not yet resulted in public plans for spectrum assignment at a regional or national level to match the successful and globally influential model of the APT 700 MHz band-plan.

However, this work is likely to feed into the identification of APT's preliminary candidate bands for the World Radio Conference in 2015 (WRC-15). Relevant international activity in Europe includes the potential implementation of a second *"digital dividend"* in the 700 MHz band proposed for Europe and Africa (ITU Region 1) at the last World Radio Conference (WRC-12). Assuming this spectrum is made available by leading European markets relatively quickly it will further increase the lead of these markets in total harmonised spectrum in use by mobile operators.

Table 3-3: Main candidate bands for meeting future spectrum demand from mobile devices

Frequency range	Country and specific frequency range	Maximum bandwidth that might be released for mobile services
470-790 MHz	European Union	60 MHz
	Denmark	320 MHz
	Canada, US (VHF and UHF TV bands)	120 MHz
800-960 MHz	Australia (803-960 MHz)	30 MHz
1300-1390 MHz	US	90 MHz on a shared basis
1.4/1.5 GHz	Australia (1427-1511 MHz)	83 MHz
	EU – 1375-1400 MHz, 1427-1452 MHz, 1452-1492 MHz and various member states e.g. France, UK	90 MHz

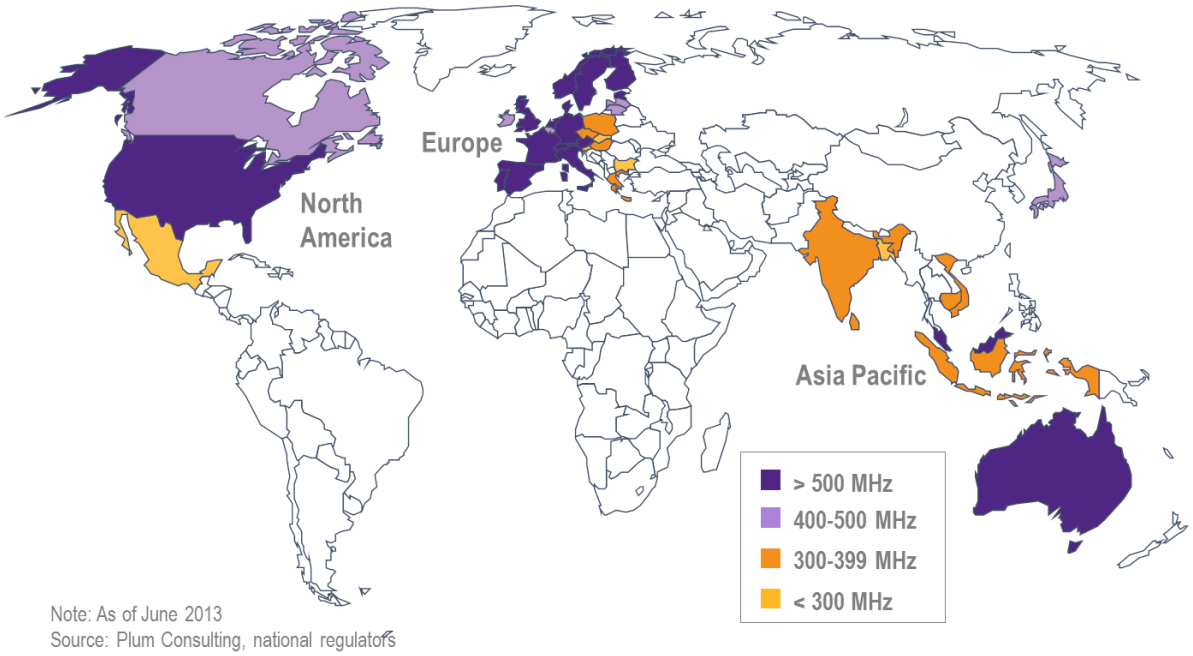
Frequency range	Country and specific frequency range	Maximum bandwidth that might be released for mobile services
	Denmark (1427-1518 MHz)	101 MHz
	Japan (1427-1525 MHz)	20 MHz
1695-1710 MHz	Canada, US	15 MHz
1755-1850 MHz	Canada, US	95 MHz
2000-2020/2180-2200 MHz	Canada, US	40 MHz
2.3 GHz	EU and numerous member states	Up to 100 MHz, some countries on a shared basis
	Canada, US	20 MHz
2.7-2.9 GHz	UK, Sweden	200 MHz
	US	Sharing potential to be examined
2.9-3.4 GHz	US	Sharing potential to be examined
3.4-3.6 GHz	Australia	200 MHz
	Japan	200 MHz
	Various EU member states (e.g. UK)	160-200 MHz
	Canada, US	100 MHz plus on a shared basis
3.6-4.2 GHz	Denmark (3.8-4.2 GHz)	400 MHz
	Japan (3.6-4.2 GHz)	600 MHz on a shared basis
	Sweden (3.8-4.2 GHz)	400 MHz
	US	200 MHz
4.4-5 GHz	Japan	500 MHz
	UK	50 MHz
5 GHz	EU, Canada, US	An additional 200 MHz shared for Wi-Fi

4 Findings from the international comparisons

In Section 2 we identified a 200 MHz *"divide*" in the current spectrum assigned to mobile operators in lower income ASEAN and South Asian countries versus Europe and North America (particularly the US). This is despite the fact that there is potentially more regionally harmonised spectrum available to countries in the Asia Pacific region than elsewhere because of the availability of specific harmonised regional bands in addition to bands harmonised in Europe and North America.

Within the Asia Pacific region, there is also an intra-regional spectrum *"divide"* between high income countries, such as Australia, Singapore, Japan and Malaysia, and remaining middle and low income countries including those in ASEAN and South Asia (see Figure 4-1).

Figure 4-1: Amount of spectrum assigned to mobile services in the countries in North America, Europe and Asia Pacific regions

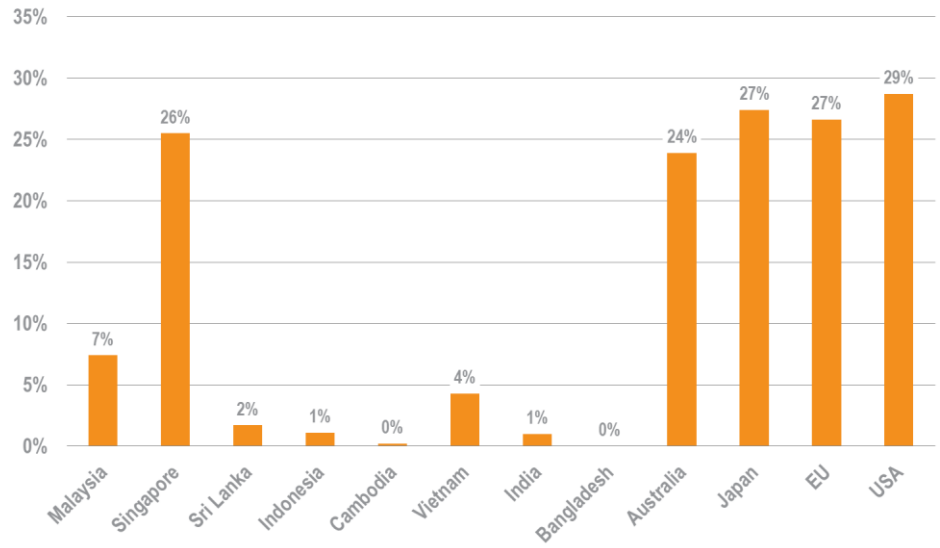


Note: As of June 2013
Source: Plum Consulting, national regulators

More broadly it appears there is a group of countries in each of the three global regions examined which is taking the lead in spectrum assignments. While the ASEAN and South Asia regions are not unique in their current intra-regional spectrum *"divide",* in North America and Europe countries forming the major regional economic core, compared to the region as a whole. In South and South East Asia this phenomenon is reversed underlining the inter-regional *"divide".* A detailed examination of the underlying reasons for these *"divides"* is beyond the scope of this study. These may, for example, reflect higher demands for mobile and broadband services in the core group countries. Alternatively, certain countries may, for reasons of scale or geography, find it easier to take unilateral action to achieve the national assignment of regionally harmonised spectrum. This is not the case for many of the countries in ASEAN and South Asia or in Europe where co-ordinated action is required to avoid cross-border interference problems particularly at lower frequencies.

Whatever the underlying reasons, it appears an opportunity is being missed by middle and low income ASEAN and South Asian countries to catch up with wealthier regions and countries by allocating further spectrum nationally to support mobile broadband services. This may be seen as particularly concerning given the low availability of fixed broadband services in many middle and low income ASEAN and South Asian nations (Figure 4-2).

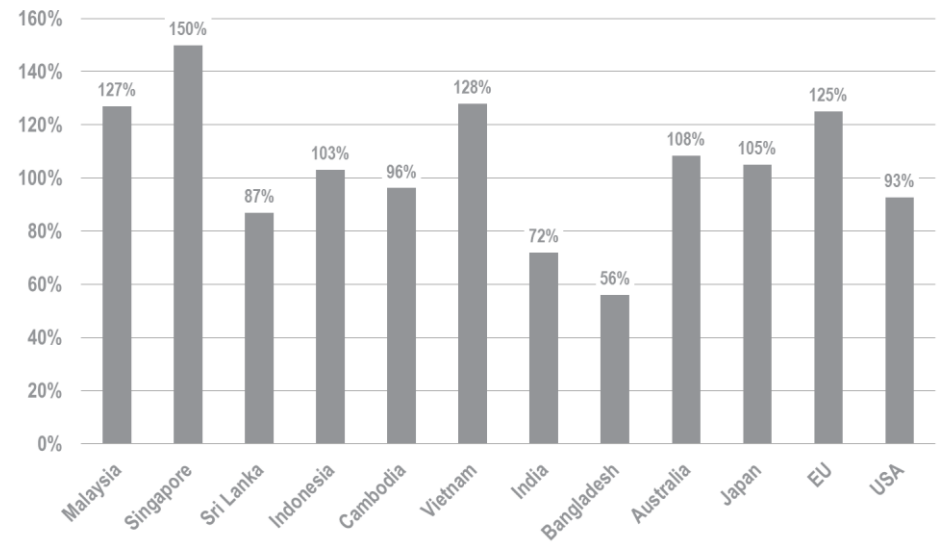
Figure 4-2: Fixed broadband penetration in selected APAC countries, the EU and the US (2011)



Source: ITU, EC, National Regulators

While consumers in high income countries may typically purchase both fixed-line and mobile service, those in middle and low income countries may have no, or only limited, access to fixed networks, so mobile services which have lower cost of provision serve as substitutes for fixed services (see Figure 4-3). This pattern of mobile adoption and use means benefits from increasing the level of assigned mobile spectrum in ASEAN and South Asia should be greater than in Europe and North America because mobile provides the primary broadband service for the majority of consumers.

Figure 4-3: Mobile take-up in selected APAC countries, the EU and the US (2011)

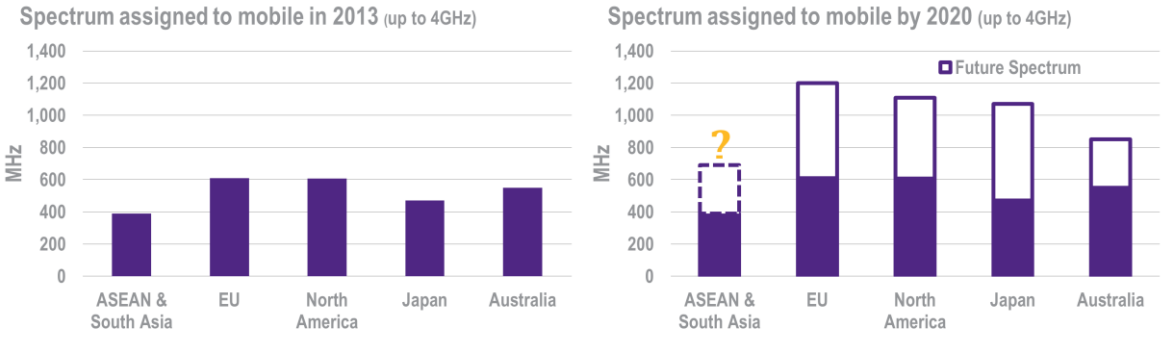


Source: ITU, EC, National Regulators

Looking forward, our review of published future spectrum plans suggests that most middle and low income ASEAN and South Asian countries are unlikely to narrow the existing spectrum *"divide"* with wealthier regions and nations within the next few years.

Instead, we believe differences in spectrum allocation are likely to widen over the next seven years to 2020. In our comparison we have included frequencies in the range up to 4GHz[11] to provide a view of the potential "*divide*" by the end of the decade (see Figure 4-4). This amounts to differences of around 500MHz. This appears consistent with current underlying differences in policy impetus at both regional and national levels to increase spectrum availability to promote economic growth.

Figure 4-4: A widening global and regional spectrum *"divide"* in assigned mobile spectrum



Source: Plum Consulting

[11] Spectrum above 4GHz is not counted because we do not expect IMT technology to be used in these frequency ranges.

The same regions and countries currently planning to make large increases in spectrum assigned to mobile services are also considering increased allocations for wireless LANs / Wi-Fi at 5 GHz to support anticipated growth in traffic offloaded from mobile devices onto available fixed broadband networks[12][13].

So, while globally broadband infrastructure capacity is likely to increase to cater for the expected growth in data traffic, it appears that ASEAN and South Asian nations are not positioning themselves ideally to bridge the current broadband digital *"divide"*.

Instead countries such as Australia, Japan, core countries of the EU and the US will continue to enjoy advantages over middle and low income ASEAN and South Asian nations due to:

- Greater availability of fixed broadband reflecting historic investment by operators;
- Plans to release greater amounts of harmonised mobile spectrum for broadband services; and
- Increases in wireless LAN / Wi-Fi spectrum which leverages these advantages for mobile broadband users.

There is a significant risk that the middle and low income ASEAN and South Asian countries, which have low amounts of spectrum assigned by international standards and have yet to publish plans to address and improve the situation over the next 5-10 years, may suffer from strategic disadvantage as a consequence of lagging spectrum release policies.

Without a shift in spectrum assignment policy, these countries are also likely to miss a potentially significant opportunity to catch up with higher income regions and countries in terms of their long term economic and social development.

[12] http://transition.fcc.gov/Daily_Releases/Daily_Business/2013/db0220/FCC-13-22A1.pdf

[13] https://circabc.europa.eu/d/d/workspace/SpacesStore/9367e691-df81-408c-a17e-ef895449bd7f/RSPG13-511_Rev1_Draft%20Opinion%20Wireless%20Broadband.pdf

5 Consequences of a growing spectrum *"divide"*

5.1 Economic importance of spectrum for broadband services

It is widely recognised that broadband communications networks are required to support economic growth and competitiveness, particularly with the current growth of information-based economies[14]. For example:

- The EU's Digital Agenda[15] (adopted in 2010) is a strategy to help digital technologies, including the internet, to deliver sustainable economic growth. One element of the Digital Agenda is the radio spectrum policy programme.[16]
- In 2010 the US government published a National Broadband Plan[17] (that includes a spectrum release plan) which is intended "*to stimulate economic growth, spur job creation, and boost our capabilities in education, healthcare, homeland security and more*".
- At the ASEAN level, member states adopted an ICT Masterplan (AIM 2015)[18] in 2011 which includes a key initiative - ASEAN Broadband Corridor - to promote greater broadband rollout, penetration, affordability and universal access.

Similar objectives are echoed in many of the national broadband or ICT plans published by governments internationally.[19] Increased spectrum assignments for broadband and other services will have a crucial role to play in delivering desired broadband outcomes.

The availability of broadband can enhance and expand the opportunities and capabilities for businesses as a result of being able to access the Internet and exchange large amounts of data. This then gives rise to a wide range of economic benefits including[20]:

- Improved firm productivity – broadband facilitates more efficient business processes; better supply chain management; lower costs of accessing suppliers/wholesale markets as a result of improved interaction and coordination among market agents
- Extended geographic reach of markets – broadband facilitates e-commerce; enables access to wider customer base and new ways of delivering products and services.
- Lower barriers to entry – there are reduced financial and reputational barriers to trade online (especially for Small and Medium Enterprises), as access to web tools and applications makes it easier for businesses to develop a web presence

[14] ITU-UNESCO (2011). "Broadband: a platform for progress. A report by the Broadband Commission for Digital Development"; "The State of Broadband in 2012: Achieving Digital Inclusion for All", A Report by the Broadband Commission, September 2012; "Broadband Strategies Handbook", T Kelly and C Rossotto (eds), The World Bank, 2012.

[15] http://ec.europa.eu/digital-agenda/

[16] http://rspg.groups.eu.int/

[17] http://www.broadband.gov/

[18] http://www.aseansec.org/documents/ASEAN%20ICT%20Masterplan%202015.pdf

[19] For example, India's National Telecom Policy, Malaysia's National Broadband Initiative, Singapore's Intelligence Nation 2015, the National Broadband Policy (draft) Cambodia, January 2013.

[20] For example, see OECD Work Party on the Information Economy (2011). The economic impact of internet technologies; ITU-UNESCO (2011). Broadband: a platform for progress. A report by the Broadband Commission for Digital Development.

- Innovation – new business models perhaps based on e-commerce may develop; eliminating need for intermediaries in some cases.
- Greater employment opportunities – online job websites allow lower cost job search and better matching in labour market; job creation in IT-related sectors is stimulated and many workers have greater flexibility as result of teleworking.

Numerous studies have shown that there is a positive relationship between broadband penetration and GDP growth in both high and low income countries. Estimates of the impact of a 10 percentage point increase in broadband penetration on GDP growth rates range from an increase of 0.1-1.5 percentage points[21], with higher impacts found in lower income countries[22].

Some specific findings for ASEAN and South Asian countries are as follows:

- A study for the GSMA[23] which estimates that the socio-economic benefits of allocating the 700 MHz band to mobile in the Asia-Pacific region could be worth up to US$1 trillion in GDP by 2020 and could create many new businesses and jobs.
- Katz (2012) found that since 2005 a 10 percentage point increase in mobile broadband take up resulted in an annual 0.6 percentage point increase in the GDP growth rate in the Philippines[24].
- In Malaysia, the Malaysian Communications and Multimedia Commission estimated a 50% broadband penetration rate would create 329,000 new jobs by 2022[25].

5.2 Impacts of the spectrum *"divide"* on service provision

5.2.1 Impact in urban areas

The size of an operator's spectrum portfolio has significant implications for service delivery. For example, the peak-data rates for LTE roughly double as the channel bandwidth used doubles[26].We have shown in section 2 that a typical country in ASEAN and South Asia currently has roughly two-thirds the spectrum available in the US. With a lower amount of spectrum, the data throughput achievable will be correspondingly lower – either fewer subscribers are supported or service quality is reduced.

[21] See reviews of the literature in "The State of Broadband in 2012: Achieving Digital Inclusion for All", Broadband Commission, September 2012; "Broadband Strategies Handbook", T Kelly and C Rossotto (eds), The World Bank, 2012.

[22] The duration of these impacts is often not clear from these studies. However while there is no consensus on the duration of impacts and estimates at the upper end of the range have been questioned (Waverman L, Mobile Broadband: Economic Growth and Productivity Enhancement? A paper for WIK 30th anniversary, September 2012), the effects are all positive and have been found for a wide range of countries (Katz, R, The Impact of Broadband on the Economy, ITU Broadband Series, April 2012)

[23] The Economic benefits of Early Harmonisation of the Digital dividend Spectrum and the Cost of Fragmentation in Asia-Pacific, BCG for the GSMA, May 2012. The Asia-Pacific countries covered by this study are: High income group – Australia, Brunei, Japan, Korea, New Zealand, Singapore; Middle income group – China, Fiji, Indonesia, Iran, Malaysia, Philippines, Samoa, Sri Lanka, Tonga, Vanuatu and Vietnam; Low income group – Afghanistan, Bangladesh, Cambodia, India, Laos, Myanmar, Nepal, Pakistan, Papua New Guinea and Solomon Islands.

[24] The Economic Impact of Broadband in the Philippines, Broadband series No 1, May 2012, Broadband Commission, ITU.

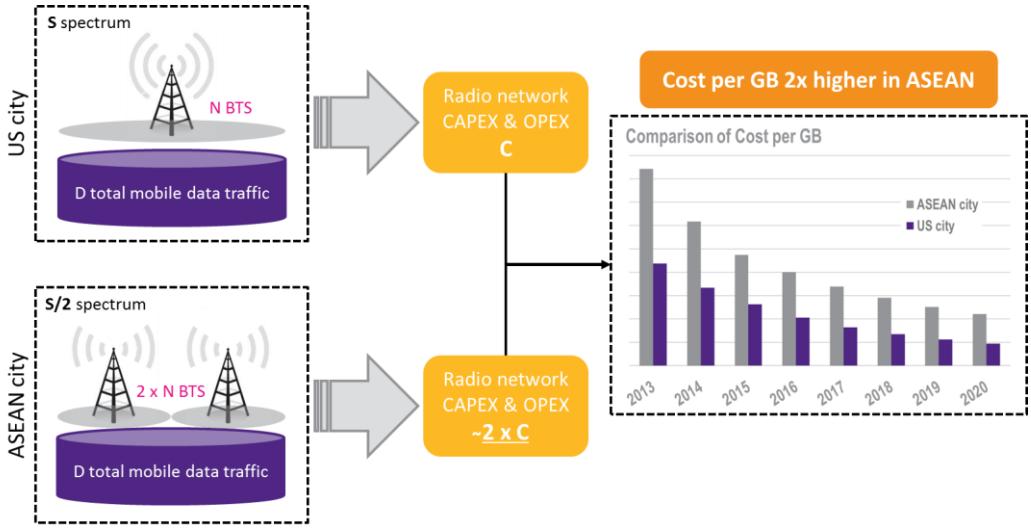
[25] Referenced in "Broadband Strategies Handbook", T Kelly and C Rossotto (eds), The World Bank, 2012

[26]http://www.motorolasolutions.com/web/Business/_Documents/static%20files/Realistic_LTE_Experience_White_Paper_FINAL.pdf

Operators in ASEAN and South Asia that are not in the position to expand their networks quickly enough to meet the ballooning demand of their subscriber base in urban areas, particularly in cities and megacities, may find that they need to artificially restrict demand. This could lead to higher prices or more limited usage policies than otherwise and so affect consumers. Future growth in traffic could be impeded if mobile services are viewed as a costly or ineffective means of mass-market broadband communications.

Alternatively, if mobile operators in ASEAN and South Asia try to accommodate all demand, then they will have to invest in more network infrastructure (i.e. base stations) than their US counterparts, which leads to higher total costs assuming that other factors such as degree of infrastructure sharing are comparable. Our illustration of the impact of low mobile spectrum availability on cost of service in cities and megacities[27] is shown graphically in Figure 5-1.

Figure 5-1: Implication of spectrum availability differential on cost of mobile data



Source: Plum Consulting

To quantify the magnitude of the cost differences we estimated annual network costs to support traffic levels in two example cities – one in ASEAN (population of 10 million) and one in the US (population of 8 million) and have estimated traffic in each of them using national forecasts from Cisco.

We also assume:

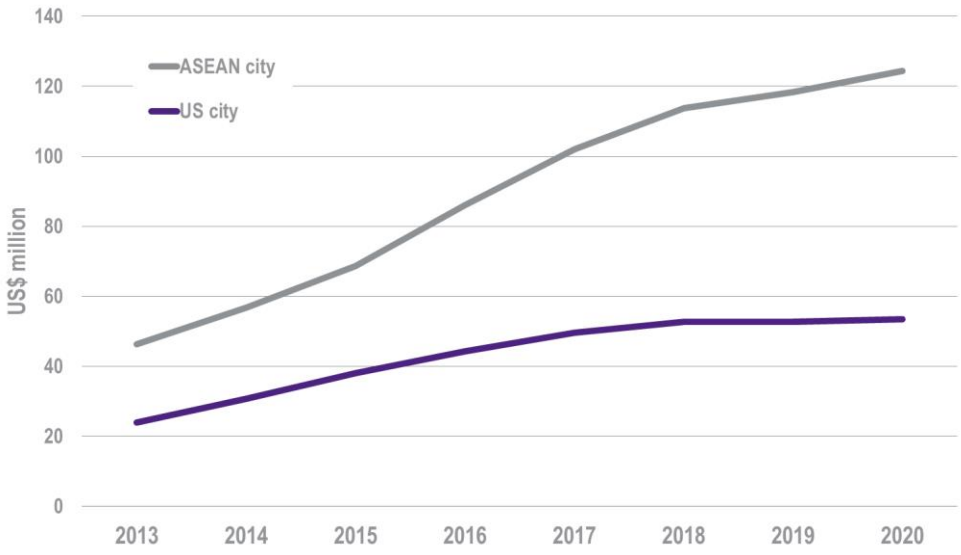
- The ASEAN city accounts for 30% of total national traffic (Cisco, 2012) and this percentage declines to 18% by 2020 as the rest of the country becomes more urbanised.
- Mobile traffic in the US city as a proportion of total US traffic equals to the ratio of its population to the US population.

These assumptions result in both cities having roughly the same traffic volume. The modelling methodology and assumptions are given in Appendix B. The resulting estimates of annual mobile

[27] Cities with a population of more than 10 million.

network costs for the two cities are shown in Figure 5-2. The main driver of cost differences is the amount of spectrum available to operators[28].

Figure 5-2: Total annual network costs for mobile broadband networks in a large ASEAN city and a large US city



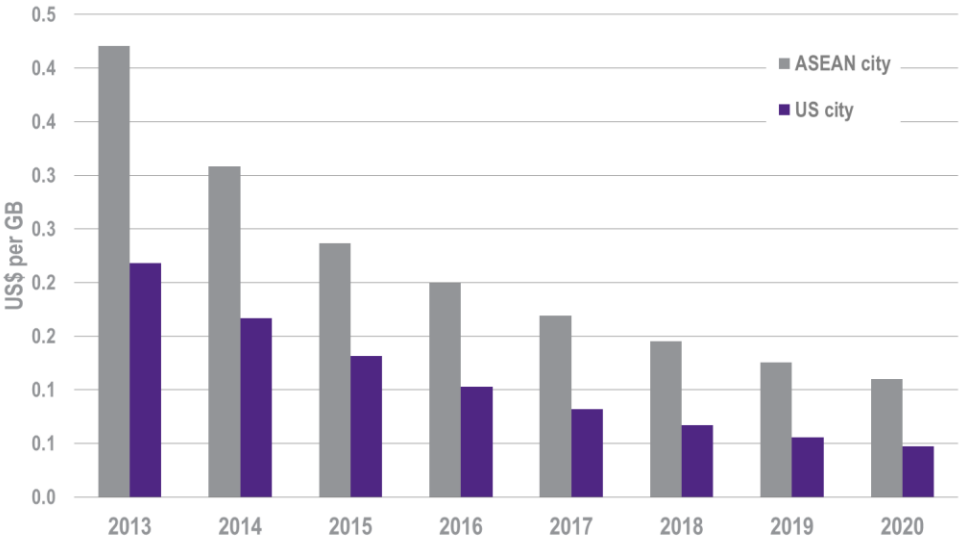
Source: Plum Consulting

We estimate that the cost to serve the equivalent volume of mobile data traffic is much higher (about double) in the ASEAN city than in the US city (Figure 5-2). This is a direct result of our assumption that in the absence of a spectrum release plan, only 140 MHz of 2.6 GHz spectrum will be made available between 2013 and 2020 in the ASEAN city while in the US city we assume that an additional 500 MHz of spectrum for mobile services is made available by 2020, thereby giving operators a significant capacity increase without the need to install new urban base stations. Figure 5-3 translates the total cost into cost per Gigabyte of mobile data.

In line with the total cost, the cost per unit mobile data in urban ASEAN and South Asia will be roughly twice as high as in urban US through to 2020. This will raise significant affordability issues and could limit the scope for expansion of services which depend on broadband technology.

[28] We assume infrastructure costs, including accommodation, equipment, support services etc. are the same in each city and that other factors such as degree of infrastructure sharing are comparable – see Appendix C.

Figure 5-3: Forecast estimates of cost per GB in a large ASEAN city and a large US city



Source: Plum Consulting

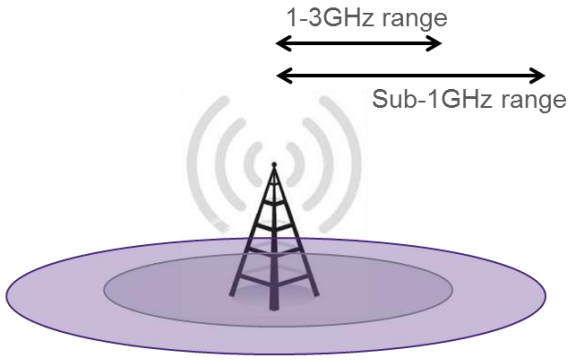
Therefore, the trade-off between capacity and cost is much more acute for operators in ASEAN and South Asia. If they are to keep their cost of service provision in check, their network capacity may fall short of demand in densely populated areas such as in cities and megacities and service quality will be impaired (e.g. call/data session failure, stalling / interruption of video and longer download times). On the other hand, by expanding their network to support the rapidly growing broadband traffic, operators' costs will rise and this could result in higher consumer prices or more limited usage policies than otherwise.

5.2.2 Impact in remote, rural areas

Mobile traffic in remote, rural areas is expected to be relatively low in ASEAN and South Asian countries due to low population density and low incomes. The crucial task for policy makers and operators is, therefore, to provide sufficient coverage to ensure that broadband services are available. This presents a different problem to that in urban areas. Operators are not likely to have to overlay individual base station with multiple bands, and one frequency band that offers 2x10MHz of spectrum is likely to be adequate to support broadband connectivity in remote, rural areas.

The 850 MHz and 900 MHz bands are currently widely used to provide 2G voice service in most countries' rural areas due to the fact that they experience lower attenuation and radio waves travel a longer distance. This advantage in radio wave propagation characteristics is illustrated in Figure 5-4. All else constant, fewer base stations are required to cover an area using sub-1 GHz bands compared to 1-3 GHz bands.

Figure 5-4: Stylised coverage advantage of sub-1 GHz frequencies



Source: Plum Consulting

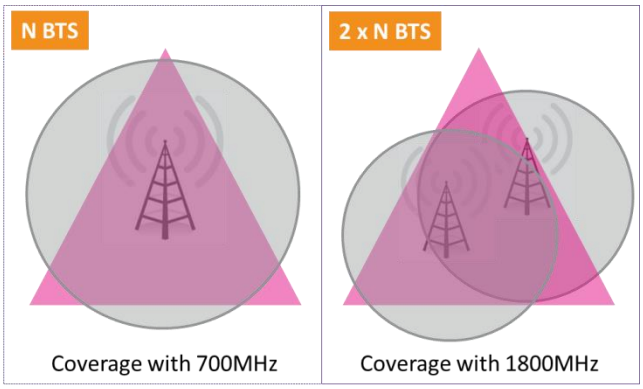
Internationally it is likely that operators will progressively seek to re-farm existing assignments in the 850 MHz and 900 MHz bands for LTE or 3G mobile services, assuming this is not blocked by regulatory controls. While re-farming has occurred in many high-income countries as consumers migrate from 2G to 3G and 4G technology, the situation is different in ASEAN and South Asian countries with large rural populations as 2G devices will be used by the majority of low-income rural users for voice and SMS services and this is likely to continue for some time.

Short term repurposing of bandwidth in the 850 MHz and 900 MHz bands (a total of less than 2x60 MHz compared to 2x60 MHz in the 2100MHz band alone) on a large scale could, therefore, have an adverse impact on basic services for significant proportions of the population. Equally, offering rural broadband services over the 1.8 GHz or 2.1 GHz bands is unlikely to be economically attractive for operators. While in principal operators might reduce the impact of re-farming on 2G users by sharing some of their spectrum below 1 GHz to jointly provide broadband services this is likely to be difficult to achieve both in regulatory and business terms, and a simpler approach could be for regulators to increase the availability of additional harmonised sub-1GHz spectrum.

An example is the 700MHz band which has been or is being assigned in 2013 in a number of Asia-Pacific countries including Japan, Taiwan, New Zealand and Australia[29]. The 700 MHz band has a considerable coverage advantage which translates into lower base station density in remote rural areas, as shown in Figure 5-5. The band is likely to be deployed on the same sites as are used for 900MHz. Table 5-1 shows the relative cost advantage of the 700 MHz band over the 1800 MHz band (both 4G bands) for a 2000-square-kilometer rural area.

[29] The regulators from Brunei Darussalam, Indonesia, Malaysia and Singapore have announced their public commitment to the APT 700MHz plan. The spectrum could be freed up for mobile services in 2020. http://www.straitstimes.com/breaking-news/singapore/story/four-asean-countries-agreed-using-tv-spectrum-4g-services-20130618

Figure 5-5: Network implications of the 700 MHz spectrum coverage advantage



Source: Plum Consulting

Note: The pink triangle represents the geographic area over which mobile service is required and the grey circle represents the coverage of each base station.)

Table 5-1: Annualised radio access network cost comparison between 700 MHz and 1800 MHz

Frequency band	Maximum coverage area[30]	Minimum number of sites	Estimated total cost (annualised)
700 MHz	305 km^2	6.5	US$254k
1800 MHz	139 km^2	14	US$546k

Sources: van Hooft, L, Building next generation broadband networks in emerging markets. In "Making Broadband Accessible for All", Vodafone Policy Paper Series, May 2011; Markendahl, J; Makitalo,O; Molleryd, B; and Werding,J., "Mobile broadband expansion calls for more spectrum or base stations: analysis of the value of spectrum and the role of spectrum aggregation", Conference paper, 21st European Regional ITS Conference, Copenhagen, September 2010.

This suggests that the cost to cover the same land area will more than double if the 1800 MHz band rather than the 700 MHz band is used to provide broadband. This differential could be even higher in practice since we assume that the maximum coverage range can be achieved based on the maximum coverage area per base station. In reality, terrain obstacles such as hills, buildings and trees are likely to increase attenuation of the 1800 MHz band relative to the 700 MHz band.

5.3 Impact of a spectrum *"divide"* on overall economic activity

A spectrum *"divide"* will have significant consequences for ASEAN and South Asia. As discussed above, the amount of spectrum is a key factor in broadband costs and/or service quality in both urban and remote, rural areas and this will have knock-on effects on a multitude of indicators such as broadband penetration, Internet use, quality of service, affordability and service availability.

Governments in ASEAN and South Asia have an opportunity to prioritise the release and assignment of spectrum for broadband, as their counterparts in higher income regions and countries are now

[30] This is assumed to be the same as for UMTS 900 and as UMTS 2100. The parameters are sourced from Ovum, Market study for UMTS900: A Report to the GSMA, February 2007.

doing. If this opportunity is missed then middle and low income countries will be exposed to a number of long-term competitive and social disadvantages:

- The long term cost of providing equivalent aggregate mobile broadband capacity in cities and megacities[31] of ASEAN and South Asia could ultimately be double that in cities in the US and EU. Seven of the world's 10 most populous cities are in Asia (Tokyo, Delhi, Mumbai, Shanghai, Kolkata, Dhaka and Karachi), and over the next decade to 2020, Asia is expected to account for two-thirds of the demographic expansion in the world's cities.[32] The aspirations of many governments and policymakers are to transform their major cities not just into centres of economic and political activities, but also knowledge and innovation hubs where national educational and research institutions, businesses as well as creative and cultural centres are concentrated. This vision is often aligned with the urban design concept of a "smart city" – where investment in communication infrastructure and human and social capital fuel sustainable economic growth and a high quality of life.[33] Robust, high quality communications infrastructure will be a fundamental element of megacities of the future.
- The costs of equivalently extensive rural broadband networks in rural ASEAN and South Asia could also be twice as high as would otherwise be the case with more aggressive national spectrum allocation plans. This will either limit the extent of rural coverage or increase the relative cost to the state and/or industry of providing it.
- Significant economic and social development benefits will be delayed or forgone because higher costs will, in full or in part, feed through into higher prices and result in reduced access to high speed communications and reduced levels of internet use. This will affect economic growth, trade and employment across all sectors of the economy as well as the delivery of government and social services.
- Local Internet ecosystems aimed at developing high value added services supplied over broadband networks are unlikely to develop as quickly in ASEAN and South Asia and current competitive advantages enjoyed by certain wealthier regions and countries in the *"Internet age"* are likely to become entrenched.

In the next section we discuss the policy and regulatory actions to address the spectrum *"divide"* and contribute towards building and improving broadband networks and communications infrastructure in ASEAN and South Asian countries.

[31] Cities with a population of more than 10 million

[32] UN-Habitat. The State of Asian Cities 2010/11.

[33] Caragliu, A et al (2009). Smart cities in Europe. http://dare.ubvu.vu.nl/bitstream/handle/1871/15296/20090048.pdf?sequence=2

6 Policy actions to address the spectrum *"divide"*

By assigning more spectrum for broadband, middle and low income ASEAN and South Asian countries have an opportunity to catch up with high income regions and countries in terms of the aggregate national capabilities of broadband service capacity and cost, and thereby enhance economic growth and social development.

In this section we discuss the policy actions required to make this a reality over the next 5-10 years. Our proposals involve enhancing existing policies and, in parallel, building national competence and regional co-operation so that the successful focus which exists in spectrum harmonisation in the Asia-Pacific region gains further traction at national level.

In summary we propose the following actions:

- Ensure a spectrum release and assignment policy is included in all national broadband plans. National broadband plans should prioritize spectrum already harmonised on an Asia Pacific basis, but not yet assigned, for assignment through an appropriate mechanism in the short term.
- Assess national requirements for additional spectrum for broadband services (how much and which type of bands) and identify further candidate bands for release with industry consultation
- Remove regulatory restrictions that inhibit flexible deployment of technologies and use of spectrum so that operators can re-farm their spectrum holdings from old to new technology where this is beneficial.
- Allow operators to share spectrum to support wider bandwidth services where this does not have significant negative impacts on competition. More generally spectrum trading and leasing should be permitted so as to allow licensees to share their spectrum and to move spectrum from low to high values uses and users.
- Adopt a transparent, fair and timely approach to national spectrum assignment to ensure the release of spectrum packages suitable for broadband so as to promote broadband development.
- Build further regulatory capacity to undertake these activities on a regional basis in Asia-Pacific e.g. co-operation on managing interference issues and the timing of reallocating spectrum from existing uses to mobile services.

6.1 A spectrum release and assignment policy included in all national broadband plans

The importance of broadband for economic development is widely recognised and many countries in ASEAN and South Asia have plans to foster its development. These plans often seek to extend the coverage of mobile services, to provide low cost broadband in rural areas and to accelerate broadband take-up elsewhere.

However the direct linkage with spectrum policy is sometimes understated or ignored. This should be corrected by including a firm spectrum release plan in all national broadband plans. Spectrum release plans are an integral part of the European Digital Agenda and the US National Broadband Plan, and should be an essential component of the national broadband strategy for ASEAN and South Asian countries.

A first step in policy development is to raise awareness of the linkage between, broadband and spectrum policy so that every national broadband initiative contains a programme of work aimed at providing access to the spectrum required to deliver the aims of the national broadband policy. This programme of work will need to involve both the Ministry responsible for delivering the broadband plan and the national body responsible for spectrum management for the communications sector. It should in particular, assess the possibilities for releasing spectrum in frequency bands already harmonised on an Asia Pacific basis, but are not yet assigned nationally. The release of frequencies in these bands should be prioritised and accelerated where possible.

6.2 Assess national requirement for additional spectrum for broadband services

Spectrum requirements for broadband services may be expressed as a national spectrum target which develops over time. While targets from elsewhere may serve as an indicator, these targets vary greatly between countries as shown in Section 3 which suggests that country-specific analysis is required. This analysis is likely to include:

- Assessment of the traffic that will need to be supported in future on all networks to fulfil broadband goals, and then:
  - Translate this traffic into a spectrum capacity requirement
  - Translate the coverage objective into the supply of spectrum in low frequency bands.
- Assessment of the possibilities for releasing spectrum in frequency bands which may be internationally harmonised for mobile services. This will involve quantifying the extent of current use by other services/equipment and developing options for sharing the spectrum, migrating existing users (e.g. through migration to another band and/or technology) or terminating the licences of existing users.
- Prioritising bands for release in conjunction with industry according to the ease, cost and possible timing of release and band characteristics which are of interest to operators. Those bands that are presently lightly used or unused should be priorities for future release. However, work on bands that offer large benefits but are potentially more difficult and costly to release also needs to be undertaken because of the potentially long timescales involved in migrating existing spectrum users.

The outputs from these activities could comprise:

- A published spectrum release target that is approved by senior politicians including the Minister of Finance, the Minister of Communications and ultimately the President or Prime Minister. The target should also be backed by all other Ministries that deal with large spectrum users (e.g. broadcasting, transport, defence)
- A published spectrum release plan with indicative timings for spectrum release and detailed plans for accommodating the needs of incumbent users.

Spectrum licences could be issued or tendered in advance of the clearance and money raised from licence tenders used to compensate existing spectrum users required to migrate to other bands. This can facilitate much faster release of spectrum than would otherwise be possible.

It is now standard international practice to assign spectrum by competitive tender. Whatever the tender process used (auction, beauty contest or some hybrid) it should be transparent and fair with the primary objective of maximising spectrum release to promote broadband development. Future variation in spectrum in use for mobile services in different regions and countries may be driven by the approach taken by governments to valuation. Governments that adopt policies which act to prevent operators bringing into use available, harmonised spectrum are likely to see lower national aggregate broadband capacities and higher costs as a consequence.

6.3 Build further capacity to undertake these activities on a regional basis

It is necessary for regulators, ministries, and government generally to have the capacity to implement spectrum policies effectively. The setting and implementation of spectrum policy involves decision makers across all levels of government, from the President or Prime Minister through to the Ministries of Finance and Communications and national regulators.

There is a requirement for governments to have institutional arrangements and regulatory processes to manage the competing demands placed on spectrum, particularly between the current users and future opportunities for economic development.

It is common to find that spectrum suitable for mobile broadband services is already in use for other purposes, such as broadcast television, satellite communications, or by the military. These existing users may be reluctant to make spectrum available for broadband service growth and they may incur costs if they relinquish their spectrum holdings, such as investing in new assets to maintain services.

From the perspective of setting policy and the preparation of spectrum plans, as described in Section 6.2 above, international experience (in particular that of the EU and the US) shows that stakeholders' actions need to be coordinated to fully utilise new spectrum. In particular, operators need to be confident in the spectrum availability signalled in government plans so that they can invest in assets that will utilise the spectrum and deliver the benefits of broadband services.

Furthermore ASEAN and South Asian countries may be unable to make unilateral changes in the use of spectrum because of the risk of interference to/from neighbouring countries. Hence regional co-operation, ideally with Ministerial involvement, will facilitate future regional harmonisation.

The competing interests of stakeholders mean that governments and regulators need to be actively engaged in the consultation, development and implementation of a spectrum release plan. Figure 6-1 is an illustration of the general institutional arrangements between various departments within government. The President or Prime Minister's Office and the Ministry of Finance often play a leading role by setting policy goals and controlling funds received and paid out.

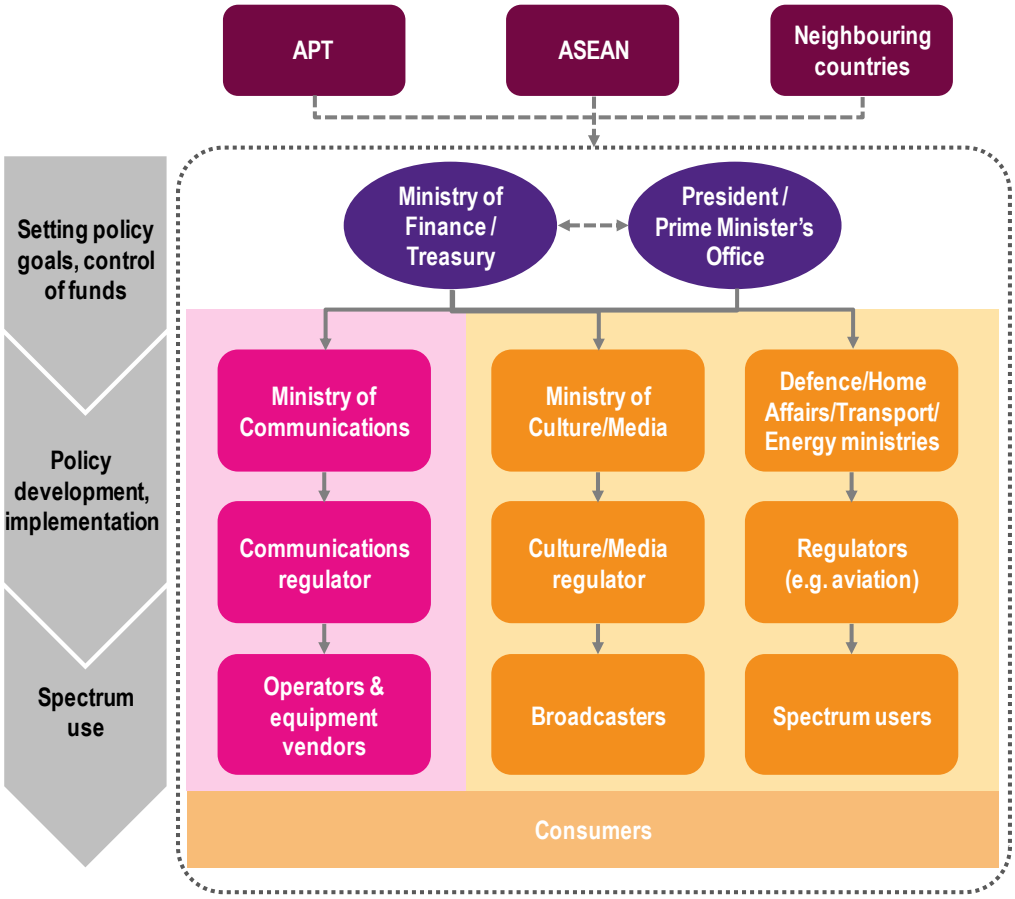
Leadership and oversight is generally provided at this high level within government because:

i. Changes to spectrum allocation and assignment have the potential to materially affect a wide range of existing and future users of spectrum;

ii. Government decisions need to be coordinated across different departments and regulators, as well as those representing the government's position at international forums; and,

iii. Making spectrum available for broadband services is of significant strategic value for the economic development of ASEAN and South Asian countries.

Figure 6-1: Entities involved in spectrum policy development and assignment



The task of spectrum policy development and implementation is the responsibility of the communications ministries and regulators. A description of the activities undertaken by regulators and ministries in selected countries is provided in Appendix B and summarised below. This information highlights that regulators and ministries are actively involved in forecasting spectrum demand and implementing processes that redistribute spectrum for broadband services:

- Australia – The Australian Communications and Media Authority (ACMA) is responsible for managing access to the radiofrequency spectrum. The ACMA's current spectrum policy and management plans are given in its Five Year Outlook 2012-2016. These outlooks have been produced every year since 2008 and include an assessment of the current use of spectrum, demand trends, international developments and actions the ACMA plans to undertake over the forthcoming five years. (see Appendix B.1.1)
- Hong Kong – The Office of the Communications Authority (OFCA) publishes spectrum release plans on an annual basis. These plans provide details of the bands that may be released in a forthcoming 2-year period. (see Appendix B.1.2)
- India – The Ministry of Communication and IT has published a National Telecom Policy (2012)[34] that envisages a central role for mobile communications and accordingly proposes a number of

[34] The Ministry of Communication and IT, National Telecom Policy 2012, June 2012

actions aimed at facilitating further spectrum release for mobile services and to support backhaul in rural areas. In particular periodic spectrum audits, spectrum release targets for 2017 and 2020 and liberalisation of spectrum use have been proposed. (see Appendix B.1.3)

- Japan – The Ministry of Internal Affairs and Communications (MIC) acts as the regulatory body and spectrum management authority for Japan's telecommunications industry. It is wholly responsible for radio spectrum allocation to stakeholders in the market. The Radio Department in MIC regularly assesses the usage efficiency of assigned radio spectrum in order to determine whether frequencies are needed for their present purpose. (see Appendix B.1.4)
- New Zealand – In 2012 the Ministry of Business, Innovation and Employment (MIBE) launched a consultation on its five-year spectrum outlook. This document gave a view on future spectrum related developments and identified the MBIE's key policy and management projects for the next five years. (see Appendix B.1.5)
- Singapore – The regulator (IDA) publishes a Radio Spectrum Master Plan which sets out its spectrum management priorities for a four year period. The Plan is periodically updated. (see Appendix B.1.6)
- Denmark – The Danish Ministry of Commerce and Growth undertook a review of demand for spectrum and produced a draft spectrum strategy published on 26 October 2011. [35] (see Appendix B.2.3)
- France – The French government and regulators have undertaken national inventories of spectrum use in 2010 and 2011 with a view to identifying opportunities for spectrum supply to meet potential user demands. In addition future spectrum requirements for a range of services have been assessed for the period up to 2020 for the Ministry of Economy. (see Appendix B.2.4)
- Ireland – The regulator ComReg produces a spectrum strategy statement every two years. (see Appendix B.2.5)
- Netherlands – The Netherlands regulator, Agentschap Telecom (Ministry of Economic Affairs, Agriculture and Innovation), undertakes three regular activities aimed at understanding current spectrum use and to provide information for their future spectrum strategy. (see Appendix B.2.6)
- Sweden – The Swedish regulator PTS produces a spectrum release plan on an annual basis, called a Spectrum Orientation plan. The plan describes current and planned use of the radio frequency spectrum in Sweden. (See Appendix B.2.7)
- United Kingdom – The UK regulator Ofcom has not developed spectrum release targets; however, it has assessed ways of meeting demand for capacity from mobile broadband services as part of its consideration of the future use of the 700 MHz frequency range. There has also been a programme of activity led by government to audit government spectrum use, with a view to improving efficiency taking account of current and future requirements. (see Appendix B.2.8)
- Canada – In March 2013, Industry Canada, the country's spectrum manager, published the Commercial Mobile Spectrum Outlook, providing its overall approach and planned activities to ensure appropriate spectrum resources are available to meet the demand for commercial mobile services over the next five years and thereby support the resulting economic and social benefits for Canada. (see Appendix B.3.1)

[35] http://www.itst.dk/nyheder/nyhedsarkiv/2011/horing-over-udkast-til-frekvensstrategi.

- United States – The main activities regarding the release and repurposing of spectrum are being conducted under the National Broadband Plan, which is administered by the Federal Communications Commission (FCC) in conjunction with the National Telecommunications and Information Administration (NTIA). (see Appendix B.3.2)

6.4 New approaches to spectrum management

More efficient use of spectrum can sometimes be achieved by relaxing regulatory restrictions on the way the spectrum is used. In particular, restrictions on the technology or service deployed, the sharing of spectrum or the trading of spectrum can block actions by operators to enhance the efficiency with which they use the spectrum. While there can be costs to making such changes, spectrum management agencies in North America, Europe and leading Asia Pacific countries have all moved to adopt more liberal regulatory approaches that involve one or more of[36]:

- Allowing operators to re-farm spectrum to new technologies
- Spectrum sharing between operators
- Mobile operators sharing spectrum held by other services
- Spectrum trading and leasing

Regulators in ASEAN and South Asia should consider adopting similar policies in addition to any spectrum release plans. The sub-sections below discuss these policies and the benefits they offer in more detail.

6.4.1 Re-farming and technology neutral licences

Historically spectrum licences in many countries specified the technology and service that could be offered by licensees in addition to controls on technical aspects of emissions. Such licences are now seen as inflexible. This did not matter greatly when technology and markets changed slowly. However, mobile services have experienced rapid technology innovation and market change - regulation has often not kept up with these changes and this has imposed costs on industry and consumers. For example, obligations to use 3G technology in a particular band could block an early opportunity to deploy technically more efficient LTE technology.[37]

As a consequence there is now a trend around the world towards issuing flexible, technology neutral licences that allow operators to choose when new technologies and service innovations should be introduced. For example, all spectrum licences for mobile services in Australia and the US are technology neutral. In Europe regulators are expected to liberalise the use of technology specific 2G

[36] For a further discussion, see "New Approaches to Spectrum Policy" OECD Working Party on Communication Infrastructures and Services Policy, 10 June 2013.

[37] An Ofcom study estimated that initial 4G deployments will deliver improvements of 3.3 times in spectrum efficiency compared to typical high end 3G configurations, and that spectrum efficiency in 4G networks will grow by approximately 5.5 times between 2010 and 2020. Source: http://stakeholders.ofcom.org.uk/market-data-research/other/technology-research/2011/4G-Capacity-Gains/

licences[38] and new licences are expected to be technology flexible whilst meeting the least restrictive technical conditions specified in European harmonisation measures.

The benefits of such policies are clear but there can also be costs e.g. increased interference in adjacent bands and possible competitive impacts if some and not all operators are able to change technology. Any such costs need to be identified and dealt with in advance e.g. by requiring no change in out of band emissions or addressing competitive issues by releasing more spectrum or other pro-competitive measures such as requiring wholesale access[39]. In any event, new spectrum usage rights within the mobile bands should be assigned on a technology neutral basis.

6.4.2 Sharing spectrum between operators to increase the available block size

It is increasingly important that spectrum policy allows mobile operators to access reasonably large contiguous blocks of spectrum because this allows cost effective provision of mobile broadband services at higher speeds[40]. For example, 2G technology has a block size of 200 kHz, while 3G technology has a practical minimum block size of 2x5 MHz, and 10 MHz and larger blocks are often required. LTE services are most cost effectively provided with a 2x20 MHz block size.

When spectrum is released, attempts to introduce competition in the market (e.g. through spectrum caps or set-asides) should take into account technical implications. Governments that adopt policies which restrict the assignment of large, contiguous spectrum blocks are likely to see slower and more costly broadband provision than in regions and countries with better policies.

In addition for spectrum that is already assigned the only practical way of achieving larger block sizes will often be to allow mobile operators to share spectrum, for example by operating common network infrastructure and radio access networks. This should be permitted by regulators unless there is a significant negative impact on competition.

6.4.3 Sharing spectrum with other services

Experience in Europe and the US shows that the costs of clearing some bands can be high (e.g. in the US it has been estimated that it would cost $18bn to move defence use from part of the 2 GHz band to allow the provision of 3G/4G services). It is for this reason that industry and spectrum managers are examining options for sharing spectrum with existing users as a way of releasing more spectrum for mobile services.

Sharing approaches mainly involve providing access to frequency bands which are partly occupied by various fixed or broadcasting uses and whether the vacant spectrum can be accessed subject to controls over the location of use and frequencies used. For example:

[38] Under the amended GSM Directive - http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:274:0025:0027:EN:PDF

[39] http://www.gsma.com/publicpolicy/wp-content/uploads/2012/03/gsma_licensing_report.pdf

[40] In the forthcoming 700 MHz auction in Canada the regulator has included a specific rules relating to generic licences that ensure that winners of block A and block B or C licences are awarded contiguous spectrum. More generally the Combinatorial Clock Auction format can be designed to include an assignment stage in which bidders can bid to obtain contiguous spectrum blocks.

- **Licensed shared access**: Under these arrangements an existing users, such as the Ministry of Defence, may allow licensed access to a band it manages where the nature of access may vary by location. There could be exclusion areas where no transmissions are permitted and other areas where the power of transmissions may depend on the proximity to defence installations. It is envisaged access to spectrum by the licensee would be controlled by a geo-location database, as this would allow temporary changes to defence use of the spectrum to be accommodated. It is possible that the 3.5 GHz band in the US[41] and the 2.3 GHz band in Europe[42] will be released on this basis.
- **White space devices**: allows vacant spectrum in specific locations in the UHF TV band – called *"white space"* - to be accessed by devices operating on a licence exempt basis under the control of a centralised database, which will tell the device the frequencies it may use in a specific location at a regulated transmission power. The database holds information on all existing use of the band. Under the UK regulations the maximum power is determined by the nature of nearby digital television use, whereas in the USA regulations propose fixed power limits for white space devices[43].

Whether these specific policies are suitable for ASEAN and South Asia may be less of a concern than ensuring that new approaches are considered by policy makers to ensure these regions are not disadvantaged when compared to Europe and North America.

6.4.4 Spectrum trading

Many countries have adopted policies for spectrum trading and leasing as a way giving incumbent users a financial incentive to share their spectrum and move spectrum from low to high values uses. In the US and the EU spectrum used by mobile services is tradable and can be leased, while in the Asia Pacific region this is the case in Australia and New Zealand. While such policies do not replace the need to consider managed spectrum reallocations as a way of releasing spectrum for mobile services, they can provide a useful way forward in certain circumstances where incumbent users are reluctant to share their spectrum (e.g. in the UK the Ministry of Defence has proposed both selling and leasing its some of its spectrum) or where the historic assignments have become sub-optimal as a result of market changes.

[41] http://www.fiercebroadbandwireless.com/story/fcc-35-ghz-will-become-small-cell-band/2012-12-12

[42] At the 75th WG FM meeting in September 2012 a new project team FM 53 on Reconfigurable Radio Systems (RRS) and Licensed Shared Access (LSA) was created. FM 53 will also carry on the work of CG CRS (Cognitive Radio Systems). The focus is on three main areas – white space devices in the UHF band, LSA and reconfigurable radio systems.

[43] 4 Watts for fixed devices and 100mW for portable devices.

Appendix A: Main frequency bands harmonised for mobile services

The frequency bands harmonised for mobile services in Europe are listed in Table A-1. Many of these bands are used in Africa, Asia and the Middle East and to a lesser extent in Latin America.

Table A-1: Harmonised frequency bands for mobile services in Europe

Band Identifier	Frequencies	Bandwidth available	Comment
450 MHz	450-457/460-467 MHz	2x7 MHz	Mainly used for private mobile radio
800 MHz	791-821/832-862 MHz	2x30 MHz	Often referred to as the digital dividend
900 MHz	880-915/925-960 MHz	2x35 MHz	
1800 MHz	1710-1785/1805-1880 MHz	2x75 MHz	
2100 MHz	1920-1980/2110-2170 MHz 1900-1920 MHz 2010-2025 MHz	2x60 MHz 20 MHz unpaired 15 MHz unpaired	The unpaired bands may be assigned but are not used as there is no equipment
2.6 GHz	2.5-2.69 GHz	2x70 MHz 50 MHz unpaired	Configured as 2.5-2.57/2.62-2.69 GHz FDD and 2.57-2.62 GHz TDD

The frequency bands harmonised for mobile services in the US and generally used in Canada, Mexico and some countries in Latin America are listed in Table A-2. The 850 MHz band is also used in the Asia Pacific region.

Table A-2: Harmonised frequency bands for mobile services in the US

Band Identifier	Frequencies	Bandwidth available	Comment
700MHz	698-716/728-746 MHz 746-757/776-787 MHz 716-728 MHz	2x18 MHz 2x11 MHz 12 MHz unpaired	Often referred to as the digital dividend D Block 758-763/ 788-793 MHz set aside for national public safety broadband network is not included
850 MHz	817-824/862-869 MHz 824-849/869-894 MHz	2x7 MHz 2x25 MHz	
1900 MHz	1850-1910/1930-1990 MHz	2x60 MHz	
AWS	1710-1755/2110-2155 MHz 2000-2020/2180-2200 MHz	2x45 MHz 2x20 MHz	2000-2020/2180-2200 MHz recently liberalised for mobile use[44]
2.3 GHz	2305-2315/2350-2360 MHz	2x10 MHz	
2.6 GHz	2496-2690 MHz	194 MHz	

Several of the harmonised bands in Table A-1 and Table A-2 are used in the Asia Pacific (including ASEAN and South Asia), e.g. 450 MHz, 900 MHz, 1800 MHz, 2100 MHz (EU) and 850 MHz (US). There are also some additional bands harmonised for use in specifically in Asia.

Table A-3 lists all bands used including bands specific to Japan, but it should be noted that in most Asian countries only a subset of the bands are used. There are issues with overlaps between bands and the use of different technologies which may interfere and mean only partial use is possible.

[44] http://www.fcc.gov/document/aws-2000-20202180-2200-mhz-aws-4-order-adopted

Table A-3: Harmonised frequency bands used in Asia

Band Identifier	Frequencies	Bandwidth available	Comment
450 MHz	450-457/460-467 MHz 479-483.5/489-493.5 MHz	2x7 MHz 2x4.5 MHz	
700 MHz	703-748/758-803 MHz	2x45 MHz	Often referred to as the digital dividend. Likely also to be adopted in Latin America
850 MHz	824-849/869-894 MHz	2x25 MHz	
850 MHz (Japan)	815-845/860-890 MHz	2x15 MHz	
900MHz	880-915/925-960 MHz	2x35 MHz[45]	
1500 MHz (Japan)	1428-1463/1476-1511 MHz	2x35 MHz	
1700 MHz (Japan)	1750-1785/1845-1880 MHz	2x35 MHz	
1800 MHz	1710-1785/1805-1880 MHz	2x75 MHz	
1900 MHz (Indonesia)	1903.125 -1910/ 1983.125-1990 MHz	2x6.875 MHz	
2100 MHz	1920-1980/2110-2170 MHz 1900-1920 MHz 2010-2025 MHz	2x60 MHz 20 MHz unpaired 15 MHz unpaired	The unpaired bands may be assigned but are not used as there is no equipment
2.3 GHz	2.3-2.4 GHz	100 MHz	Assigned in Asia but there are US and European initiatives around use of the band
2.6 GHz	2.5-2.69 GHz	2x70 MHz 50 MHz unpaired	

[45] Where E-GSM is available.

Appendix B: Spectrum plans and policy development

Information on spectrum plans and policy development and all international and regional comparisons are based on publicly available information on current allocations and future availability as of June 2013. Where national administrations have developed, or are developing, plans for future availability which are not yet published these, inevitably, are not included.

B.1 Asia Pacific

B.1.1 Australia

The Australian Communications and Media Authority (ACMA) is the public body that is responsible for managing access to the radiofrequency spectrum Australia. The ACMA's current spectrum policy and management plans are given in its Five Year Outlook 2012-2016.[46] These outlooks have been produced every year since 2008 and include an assessment of the current use of spectrum, demand trends, international developments and actions the ACMA plans to undertake over the forthcoming five years.

In 2011, the ACMA began its mobile broadband project in response to the rapidly growing demand for spectrum from this service. The ACMA estimated that up to 300MHz of additional spectrum will be required to support mobile services by 2020, with up to 50% of this bandwidth being required by 2015.[47] In addition to the 700 MHz (703-748/758-804 MHz) and 2.5 GHz frequencies (2.5-2.57/2.62-2.69 GHz) auctioned in April 2013:

- Up to 30MHz could be released for mobile services if the 803-960 MHz band is reorganised. ACMA has proposed several options for expanding the 850 MHz band (825-845/870-890 MHz) to include frequencies in the ranges 807 MHz – 825 MHz and 852 MHz – 870 MHz (i.e. so as to include additional 3GPP bands)[48]. This will require existing fixed and land mobile services to be migrated to other bands and is expected to become available in the 2017-2019 timeframe.
- Up to 83 MHz could be freed up in the 1.5 GHz band. The ACMA has proposed two new planning arrangements in the band for the provision of mobile services. These are the use of frequencies in the range 1427.9 MHz – 1462.9 MHz paired with 1475.9MHz and 1510.9 MHz, and the use of the unpaired segment 1452 MHz – 1492MHz as a supplemental downlink.[49] It is possible Australia will seek harmonisation of these frequencies at WRC-15.
- Up to 200 MHz could be freed up in the 3.4 GHz band. Licences for broadband wireless access in the 3.4 GHz band will expire in December 2015 and a new technical framework will be developed based on 3GPP configurations.[50]

[46] http://www.acma.gov.au/WEB/STANDARD/pc=PC_410352.

[47] http://www.acma.gov.au/webwr/_assets/main/lib312084/ifc13_2011_toward_2020-future_spectrum_requirements_errata.pdf.

[48] The 803-960MHz band – exploring options for future change, Discussion paper, ACMA, December 2012.

[49] http://www.acma.gov.au/WEB/STANDARD/pc=PC_410368

[50] http://www.acma.gov.au/webwr/_assets/main/lib312084/ifc13_2011_toward_2020-future_spectrum_requirements_errata.pdf.

B.1.2 Hong Kong

In Hong Kong the regulator OFCA publishes spectrum release plans on an annual basis[51]. These plans provide details of the bands that may be released in a forthcoming 2 year period.

In addition the regulator conducted the first review of government spectrum use in 2009/10 and published a redacted report – reviews are to happen every three years.[52] This review focused on bands for which there is potentially competing use (i.e. the band is congested now (greater than 75% occupancy) or could become so in future (50-75% occupancy and demand is growing)) and bands where there is low government utilisation of a reserved band (below 25% occupancy).

The review of public sector spectrum use recommended that:

- 12 underutilised bands for land mobile at VHF that were reserved for government use are opened up for shared use with commercial users;
- The 4.94-4.99 GHz band is to be vacated by existing users to make way for a wideband PPDR network;
- A link length policy is to be applied to government fixed links[53] to relieve congestion in fixed link bands below 10 GHz; and
- Government land mobile users will be encouraged to use more efficient technologies in bands at VHF (142-142.8 MHz and 150.05-150.75 MHz) and UHF (440-458MHz, 459.5-460MHz, 406.1-430 MHz).

B.1.3 India

The National Telecom Policy 2012[54] envisages a central role for mobile communications and accordingly proposes a number of actions aimed at facilitating further spectrum release for mobile services and to support backhaul in rural areas. In particular it is proposed that:

- There will be a periodic audit of spectrum use and every five years a roadmap for spectrum availability will be prepared
- An additional 300 MHz of spectrum will be made available for IMT services by 2017 and a further 200 MHz by 2020
- Adequate spectrum will be made available to meet current and future demand for microwave access and backhaul
- Spectrum use will be liberalised in terms of the technology and service that may be provided
- Spectrum pooling, sharing and later trading will be permitted through the development of an appropriate regulatory framework

[51] The 2012-2014 plan can be found at http://tel_archives.ofca.gov.hk/en/freq-spec/plan2012.pdf

[52] Executive Summary, Review on Efficiency of the Use of Spectrum for Government Services, OFTA published November 2010 http://tel_archives.ofca.gov.hk/en/freq-spec/govt_review.pdf

[53] Lower bands contain numerous short links which could in principle use higher frequencies and which are denying the potential use of the spectrum for long links to outlying islands where there is no alternative. Government links have preferential access to hilltop sites in Hong Kong.

[54] The Ministry of Communication and IT, National Telecom Policy 2012, June 2012

- Use of white spaces by low power devices will be considered and bands that may be used by low power devices on a licence exempt basis will be identified.

These targets have been included in the draft version of the government's 12th Five Year Plan (2012-2017).[55]

As a first step towards implementing these proposals the National Frequency Allocation Plan Review committee (which reports into the Ministry of Communication and IT) has initiated a review of future spectrum demand from stakeholders on a band by band basis[56]. Submissions were requested by 22 January 2013.

These initiatives follow earlier work (in 2010) by the Telecoms Regulatory Authority of India (TRAI) who estimated spectrum demand for mobile and fixed wireless services in the range 500-660 MHz and as high as 800 MHz by 2014 (with voice service requiring around 274 MHz).[57] This compares with current availability for telecoms of between 287.2-453.6 MHz.

It was estimated that 40% to 55% of spectrum in identified IMT bands is with Government agencies including Defence and the Department of Space. Under a business as usual policy assumption, the TRAI expected that only an additional 85 MHz is likely to be available for telecommunications by 2014.

The TRAI anticipated that a substantial quantity of spectrum would be reallocated from public sector use including defence and space. Specific spectrum held by the public sector which might be released for telecommunications is identified as follows (in addition to some of the expected 85 MHz):

- 8-9 MHz from defence at 450-470 MHz
- All 108 MHz at 698-806 MHz, with 24 MHz coming from defence
- 2x20 MHz from defence in the 1800 MHz band
- In the 2300-2400 MHz band 60 MHz not currently available to commercial operators should be re-farmed including 24 MHz with government agencies and 36 MHz with users such as State electricity boards
- In the 2500-2690 MHz band 150 MHz is with the Department of Space with 80 MHz earmarked for broadcast satellite services and 70 MHz for mobile satellite services (the remaining 40 MHz is for local and microwave multichannel distribution systems).
- In the 3.4-3.6 GHz band 200 MHz is assigned to the Department of Satellite. It is proposed that the feasibility of mitigating interference problems be clarified.

In total TRAI considers that it should be possible to vacate about 350-400 MHz of spectrum from current users most of which would be from defence and space.

B.1.4 Japan

The Ministry of Internal Affairs and Communications (MIC) acts as the regulatory body and spectrum management authority for Japan's telecommunications industry. It is wholly responsible for radio

[55] http://dot.gov.in/sites/default/files/communication%20plan_0.pdf

[56] http://www.dot.gov.in/wpc/2012/minutes%20of%201st%20NFAP%20review%20committee11122012.pdf

[57] TRIA. May 2010. "Spectrum management and licensing framework." Page 17 and Table 1.5. http://www.trai.gov.in/WriteReadData/trai/upload/Recommendations/118/FINALRECOMENDATIONS.pdf

spectrum allocation to stakeholders in the market. The Radio Department in MIC regularly assesses the usage efficiency of assigned radio spectrum in order to determine whether frequencies are needed for their present purpose. The outcomes of the assessment are then used in the revision of policies on radio frequency assignment.[58]

Since 2004, the usage situation for radio frequencies has been reviewed annually based on results obtained from the Radio Wave Usage Conditions Survey.[59] There is a three year cycle of reviews of bands below 770 MHz, bands between 770 MHz and 3.4 GHz and bands above 3.4 GHz. The 2011 survey focused on the use of frequency bands below 770MHz.

In the February 2010 plan, the MIC proposed to release new spectrum bands for mobile communications – the targets were to release at least 300 MHz in the range 300-5000 MHz by 2015 and a cumulative total of at least 1500 MHz by 2020. The frequency bands identified for release were as follows:

- By 2015: 72 MHz in the 700 MHz digital dividend (now complete); 20 MHz in the 1.5 GHz band and 200 MHz in the 3.4 GHz band
- 2020: 1.2 GHz in the 3.6-4.2 GHz and 4.4-5 GHz bands.

B.1.5 New Zealand

In 2012 the Ministry of Business, Innovation and Employment (MIBE) launched a consultation on its five year spectrum outlook. This document gave a view on future spectrum related developments and identified the MBIE's key policy and management projects for the next five years. In relation to mobile broadband it was noted that in New Zealand over 900 MHz of spectrum is already assigned in bands that are internationally harmonised for delivery of this service (all frequency bands are service and technology neutral) and that any further allocations will need to be in internationally harmonised bands. The activity in 3GPP aimed at extending the 850 MHz band[60] was noted and the MIBE will consider the possibility of allocating the resulting bands once they have been standardised.

In addition in January 2013 the MBIE carried out a white space spectrum feasibility study to investigate the amount of spectrum available for white space use in the UHF TV band. The study confirmed that there is white space spectrum available, particularly in rural New Zealand. Based on the current usage of the UHF TV band, there is at least 24 MHz of contiguous spectrum available in the South Island and at least 16 MHz of contiguous spectrum available in the North Island[61]. The MBIE is interested in hearing from parties with commercial proposals to use the white space spectrum.

[58] http://www.deljpn.ec.europa.eu/data/current/2005-speech-19e-inada.pdf

[59] http://www.soumu.go.jp/main_sosiki/joho_tsusin/eng/Releases/NewsLetter/Vol20/vol20_24/vol20_24.html#p3

[60] This relates to the bands 814-849/859-894MHz and 806-824/851-869 MHz.

[61] http://www.rsm.govt.nz/cms/policy-and-planning/projects/white-space-spectrum

B.1.6 Singapore

In November 2012 the IDA published a Radio Spectrum Master Plan which describes the current allocations and assignments for various wireless services and outlines plans to review existing and planned services on an on-going basis.[62]

No target on the amount of spectrum to be made available for mobile broadband has been set, but the following are listed as priority bands for review within the next four years:

- High priority (within 1-2 years): 174-230 MHz (digital broadcasting); 410-430 MHz (digital trunked radio)
- Medium priority (within 2-4 years): 400-410 MHz, 440-450 MHz (land mobile radio); 494-790 MHz (analogue and digital broadcasting); 1710-1785/1805-1880 MHz, 2010-2025 MHz (cellular mobile); 1885-1900 MHz (cordless systems/cellular mobile); 31.8-33.4 GHz, 37-40 GHz, 40.5-43.5 GHz, 51.4-52.6 GHz (high density fixed services).

Singapore announced in June that it supports the APT 700MHz band plan, together with Brunei Darussalam, Indonesia and Malaysia, and expects to release the band for mobile services in 2020[63].

B.2 Europe

B.2.1 Spectrum targets

The European Commission adopted its proposal for a first *Radio Spectrum Policy Programme (RSPP)* on 20 September 2010, and the European Parliament and Council approved the RSPP on 15 February 2012. The RSPP seeks to create a co-ordinated and strategic spectrum policy at the EU level.

The RSPP is due to run from 2012 to the end of 2015, though its principles and objectives will endure beyond that date. It has the following main features.

- Member States are required to release the European harmonised “digital dividend” (790-862 MHz) by 2013. More generally tight deadlines will be set for authorising the use of harmonised spectrum.
- There will be a spectrum inventory conducted by the European Commission to identify potential bands in the frequency range 400 MHz to 6 GHz that can be harmonised for wireless broadband. The inventory is intended to identify bands that are currently used inefficiently and might be released on a harmonised basis across Europe.
- By 2015 the inventory aims to identify 1200 MHz of spectrum for wireless broadband services including existing wireless broadband allocations. A prototype inventory study has been conducted[64] but the full inventory has still to be done.

[62] http://www.ida.gov.sg/~/media/Files/PCDG/Licensees/SpectrumMgmt/FreqAllocAssign/RSMP.pdf

[63] http://www.straitstimes.com/breaking-news/singapore/story/four-asean-countries-agreed-using-tv-spectrum-4g-services-20130618

- The promotion of flexible spectrum use including collective and shared use. In support of this approach, the EU is funding R&D activity around the use of cognitive radio for a range of applications including wireless broadband. The findings from the EC spectrum inventory study will be used to identify spectrum-sharing opportunities. At the CEPT level a new project team on Reconfigurable Radio Systems (RRS) and Licensed Shared Access (LSA) has been created to support these initiatives.
- Enhanced EU coordination in international spectrum negotiations.

The basis for the RSPP target to identify 1200 MHz of spectrum for wireless spectrum by January 2015 has not been made public. On the face of it the 1200 MHz target seems ambitious, however it includes spectrum already planned to be assigned for wireless broadband across Europe which totals 625 MHz and there is an additional 400 MHz in the 3.4-3.8 GHz frequency range that is being harmonised[65]. This suggests finding a further 200 MHz of spectrum will meet this objective.

A draft Opinion from the Radio Spectrum Policy Group identifies the following bands as candidates for meeting future spectrum demand for wireless broadband, most of which would not be available until after 2015[66]:

- 470-790MHz – this is the entire UHF TV band and the report recommends that a long term strategy for the band is required. In respect of the 694-790MHz part of the band there is a draft mandate from the European Commission to CEPT[67] to undertake technical work required for wireless broadband use of 700MHz in advance of any policy decisions on future use of the band. At a policy level possible approaches to achieving re-organisation of the band have also started to be debated at a European level[68].
- 1375-1400 MHz, 1427-1452 MHz, 1452-1492 MHz – the first two bands could be paired while the third band is likely to be configured for downlink only. In September 2012 CEPT started the regulatory work to harmonise the 1.4 GHz band for a SDL[69]. An ECC Decision including the technical rules for harmonised use of the band is expected by September 2013[70].

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[64] http://ec.europa.eu/information_society/policy/ecomm/radio_spectrum/_document_storage/studies/inventory_2012/cion_spectrum_inventory_final_report.pdf

[65] Harmonisation work undertaken by CEPT on these bands resulted in ECC Decision (11) 06. The main elements of the decision are:

- In the 3.4-3.6 GHz range member states may choose either a TDD or a FDD band plan. This will be reviewed by the end of 2013 with a view to settling on a preferred frequency arrangement.
- In the 3.6-3.8 GHz range a TDD band plan is recommended.

Further technical work is being undertaken by CEPT on the block edge masks as the current technical restrictions are regarded as unduly restrictive.

[66] https://circabc.europa.eu/d/d/workspace/SpacesStore/9367e691-df81-408c-a17e-ef895449bd7f/RSPG13-511_Rev1_Draft%20Opinion%20Wireless%20Broadband.pdf; https://circabc.europa.eu/sd/d/02b8e0db-957c-4a86-9f82-8d361290c5cd/RSPG13-511_Annex%202_Rev1_Candidate%20bands%20for%20wireless%20broadband%20docx.pdf

[67] https://circabc.europa.eu/sd/d/9ef9311a-5b0e-4e80-b92c-e387cb885d6d/RSCOM12-37rev1_Mandate_CEPT_700_MHz_draft_updated.pdf.

[68] Draft RSPG Report on proposed spectrum co-ordination approach for broadcasting in the case of reallocation of the 700MHz band, RSPG12-433, October 2012

[69] See Minutes of the 75th WG FM Meeting. Note: in CEPT, SDL is referred to as Mobile/Fixed Communication Networks (MFCN) Supplemental Downlink (MFCN SDL).

[70] CEPT FM 50 is to develop least restrictive technical conditions for SDL use at 1452-1492 MHz and this work is expected to be completed in May 2013.

- 1800-1900 MHz: this band is already harmonised but is used for DECT services
- 1980-2010/2170-2200 MHz – this band is assigned to mobile satellite services though in many EU countries these services are not operational
- 2.3-2.4 GHz – This band is used by programme makers and military and aeronautical systems in some countries. CEPT is examining the possibility of developing harmonised implementation measures for mobile broadband including (1) least restrictive technical conditions, taking into account the existing standardisation framework and activities at the worldwide level, and an appropriate frequency arrangement and (2) regulatory provisions based on licensed shared access ensuring the long term incumbent use of the band in the territory of the administrations that wish maintain such use.
- 3.8-4.2 GHz – the band is used by satellite services and it has been suggested that sharing options should be examined.
- 5350-5400 MHz, 5725-5875 MHz and 5875-5925 MHz –the possibility of using the bands for Wi-Fi is to be examined.

B.2.2 Shared spectrum innovations

In September 2012 the European Commission published a Communication on "promoting the shared use of radio spectrum resources in the EU"[71]. In it the Commission outlines its objective to foster collective and shared use of spectrum through the principles of least onerous authorisations, efficient use, effective management, and technology and service neutrality. In particular the following steps are proposed to foster innovations that can share spectrum more efficiently:

- Developing a common approach to identify beneficial opportunities to share spectrum in the internal market;
- Providing economic incentives and legal certainty for users to develop and deploy technologies that can share spectrum, for example based on sharing contracts;
- Authorising shared spectrum access with guaranteed rights of use as a tool for regulators to leverage economies of scale for wireless innovations in the internal market in order to encourage spectrum sharing and to foster more efficient use of spectrum;
- Supporting wireless innovation by monitoring and extending the harmonised licence-exempt internal market bands.

B.2.3 Denmark

The Danish Ministry of Commerce and Growth undertook a review of demand for spectrum and produced a draft spectrum strategy published on 26 October 2011.[72] This work identified the need for 300 MHz more spectrum for by 2020 and another 300 MHz by 2025 to support a 100 Mb/s broadband

[71] http://ec.europa.eu/information_society/policy/ecomm/radio_spectrum/_document_storage/com/com-ssa.pdf

[72] http://www.itst.dk/nyheder/nyhedsarkiv/2011/horing-over-udkast-til-frekvensstrategi

objective.[73] All bands between 400 and 4200 MHz were reviewed. The conclusions are given in Table B-1: . The potential for release of some of these bands will depend on European harmonisation initiatives.

Table B-1: Candidate bands for wireless broadband services in Denmark

Frequency band	Bandwidth	Timescale	Candidate band?/Comments
470-790 MHz	320 MHz	2020	Possible candidate, but further evaluation and EU level decisions required. Band not available until 2020
1427-1452 MHz	25 MHz	2016	Yes/Need to consider existing users e.g. radio links, Defence
1452-1492 MHz	40 MHz	2014	Yes/Requires a change in media policy
1492-1518 MHz	36 MHz	2016	Yes/Need to consider existing users e.g. radio links, Defence
1525-1559 MHz and 1626.5-1660.5 MHz	68 MHz	Unknown	Not likely to be available for broadband services because of GMDSS
1785-1805 MHz	20 MHz	2014	Yes/depends on European strategy for PMSE use in the band
2300-2400 MHz	100 MHz	2015	Yes/Used for OB/ENG, audio links and wireless cameras, and fixed links
3800-4200 MHz	400 MHz	2020	Yes/relatively little use for fixed satellite communications

B.2.4 France

The French government and regulators have undertaken national inventories of spectrum use in 2010 and 2011 with a view to identifying opportunities for spectrum supply to meet potential user demands. The inventory is to be updated annually and considered three distinct groupings of frequencies: below 223 GHz, 223 MHz-5 GHz and above 5 GHz. The results of the inventory are not published, but ANFr has reported that few bands are unused, and some are under study in CEPT and some are reserved for future use and a large part of the spectrum is already shared.[74]

In addition future spectrum requirements for a range of services have been assessed for the period up to 2020 for the Ministry of Economy. The estimates range from 570-670 MHz additional spectrum for a range of wireless communications services (government and commercial) and a possible reduction in requirements for TV broadcasting of up to 150 MHz. Up to 450MHz could be required for mobile

[73] The future need for broadband frequencies in Denmark, Analysys Mason, May 2011.

[74] See presentation: “Spectrum inventory Lessons learned and next steps”, by D Chauveau, ANFr at http://ec.europa.eu/information_society/policy/ecomm/radio_spectrum/get_involved/activities/index_en.htm#past_workshops

broadband services on top of the digital dividend and 2.5 GHz band, depending in the scenario considered.[75]

ANFr published a review of fixed links bands in 2010.[76] The 1375-1400 and 1427-1452 MHz bands might be candidate bands for mobile broadband services as there are a limited number of microwave links using 25 KHz channels for private mobile radio backhaul. There is a need to find a new band for existing links.

B.2.5 Ireland

The Irish regulator Comreg produces a spectrum strategy statement every two years. The latest statement[77] foresees the potential spectrum release opportunities in the 400MHz - 6GHz frequency range shown in the table below.

Table B-2: Band planned for release in Ireland 2012-2014

Spectrum band	Timing/potential for release	Notes
1452-1492 MHz	Release subject to EU harmonisation measure being finalised	Significant interest in the band
1900-1905/1915-1920 MHz	Not under consideration	No interest
2010-2015 MHz	Potential to release	Limited interest
2300-2400 MHz	Consider once CEPT/EU harmonisation work is finalised	Considerable interest in this band
2500-2690 MHz	Limited options due to incumbents rights issues	Considerable interest in this band

B.2.6 Netherlands

The Netherlands regulator, Agentschap Telecom (Ministry of Economic Affairs, Agriculture and Innovation), undertakes three regular activities aimed at understanding current spectrum use and to provide information for their future spectrum strategy. These activities are:

- An annual review of all spectrum use by non-public sector users which is published.[78]
- A review of trends in electronic communications and the implications for spectrum use and the regulator's work plan (the document is called ECD Radar 2012-206). The first review was undertaken in 2011 and looked out over the period 2012-2016. 30 action points were identified including actions around the possible need for more spectrum for mobile and licence exempt use.

[75] Assessment of Spectrum Needs in France by 2020, TERA, September 2011.

[76] "Besoin en spectre du service de radiocommunication, ANFr, 2010".

[77] Strategy for managing the radio spectrum 2011-2013, November 2011, Comreg 11/89.

[78] The latest review can be found at http://www.agentschaptelecom.nl/binaries/content/assets/agentschaptelecom/Frequentiemanagement/staat-van-de-ether-2010

- A three yearly review of spectrum use by government users which is not published. In this review, government users are required to justify their current and future spectrum requirements. The underlying philosophy is that these users should have sufficient spectrum to meet their needs but no more.

B.2.7 Sweden

The Swedish regulator PTS produces a spectrum release plan on an annual basis – it is called a Spectrum Orientation plan.[79] The plan describes current and planned use of the radio frequency spectrum in Sweden.

In the 400MHz - 6GHz frequency range the following bands have been identified for further analysis and/or possible release:

- 450-470 MHz; 871-876 MHz; 916-921 MHz have been identified as possible IMT bands.
- The following bands have been identified as being available for possible award in 2013 for WAPECs: 1452 - 1492 MHz; 2010 – 2025 MHz; 2300 – 2400 MHz.
- 1785 - 1805 MHz and 2700 - 2900 MHz have also been identified for possible award for IMT or PMSE applications.
- 3400-3600 MHz and 3800-4200 MHz are for further analysis.

In addition, S-band (2 GHz) is considered as vacant after the failure of Solaris Mobile in launching commercial satellite services in the country and the absence of any plans from Inmarsat for launching commercial services despite having a licence. Some changes are also envisaged in 3.4-3.6 GHz, 3.8 - 4.2 GHz and possibly 4.2 - 5.0 GHz in future.

PTS is also undertaking work to develop a spectrum strategy, and expects to publish the results from their inventory and demand analysis in 2013.[80] The PTS spectrum strategy will have the following elements:

- An inventory of spectrum use in 2013 based on numbers of assignments in each band.
- A forecast of potential spectrum demand in 2020.
- The development of principles and tools to be used to analyse the spectrum inventory data to arrive at an evidenced strategy that will optimise public welfare in light of future demands.
- Reviewing spectrum management tools and technical rules with a view to promoting more efficient spectrum use.

[79] http://www.pts.se/upload/Ovrigt/Radio/draft-orientation-plan-121011.pdf

[80] See presentation Spectrum Strategy Work in Sweden, Lena Liman, PTS, http://ec.europa.eu/information_society/policy/ecomm/radio_spectrum/get_involved/activities/index_en.htm#past_workshops

B.2.8 UK

The UK regulator Ofcom has not developed spectrum release targets however it has assessed ways of meeting demand for capacity from mobile broadband services as part of its consideration of the future use of the 700MHz frequency range.[81]

There has also been a programme of activity led by government to audit government spectrum use, with a view to improving efficiency taking account of current and future requirements.[82] As a result of this work, the UK government announced plans in October 2010 to release at least 500 MHz of government spectrum below 5 GHz over the coming ten years. This announcement was followed in March 2011 by a consultation document setting out some concrete proposals for bands that might be released.[83] When deciding which bands to release, the government proposed to look at bands that would meet expected demand, provide value, and are feasible to be released. Before making a decision on the release of any band, the government will need to carry out a cost-benefit analysis.

In December 2011, an update[84] on progress was published indicating the potential releases being examined and their timing. These are shown in Table B-3. In addition to the bands shown in the table, the 4.2-4.4 GHz and 2.9-3.4 GHz bands may be examined in the longer term. Most of these bands are managed by the Ministry of Defence.

Table B-3: Bands allocated to UK government users that might be released in the future

Band	Potential release (MHz)	Timing	Possible uses
Currently prioritised for release			
2310-2390 MHz	40	160MHz by 2016 and remaining 40MHz by 2020	Public mobile
3400-3600 MHz	160		Public mobile
Sharing possibilities[85]			
1427-1452 MHz, 4800-4900 MHz	Up to 100 MHz	Under consideration	PMSE, machine to machine applications
Longer term releases to be investigated further			
2700-3100 MHz	Up to 100 MHz	2016 onwards	Dependent on future studies
4400-5000 MHz	50 MHz	2016 onwards	Dependent on future studies

[81] http://www.ofcom.org.uk/static/uhf/real-wireless-report.pdf; http://stakeholders.ofcom.org.uk/binaries/research/technology-research/shortage.pdf

[82] Martin Cave. December 2005. "Independent Audit of Spectrum Holdings." http://www.spectrumaudit.org.uk/pdf/20051118%20Final%20Formatted%20v9.pdf.

[83] DCMS. 31 March 2011. "Enabling UK growth – Releasing public spectrum." http://www.dcms.gov.uk/images/publications/Spectrum_Release.pdf

[84] http://www.culture.gov.uk/images/publications/Spectrum-Public-Update-December-2011.pdf

[85] Details are given on the Ministry of Defence website http://www.mod.uk/DefenceInternet/AboutDefence/WhatWeDo/ScienceandTechnology/Spectrum/OtherSharingBands.htm.

B.3 North America

B.3.1 Canada

Industry Canada, the Canadian spectrum manager, has undertaken a spectrum inventory (in 2010) and a spectrum demand study (in 2011)[86]. The inventory provided the base data for the demand study which forecast demand for spectrum over the period 2011-2015. The study identified a requirement for 300 - 500MHz of spectrum for mobile broadband services by 2015.

In March 2013, Industry Canada published the *Commercial Mobile Spectrum Outlook*[87] which provides an overview of Industry Canada's overall approach and planned activities to ensure appropriate spectrum resources are available to meet the demand for commercial mobile services over the next five years and thereby support the resulting economic and social benefits for Canada.

Industry Canada has set an objective of allocating a total of 750 MHz of spectrum to commercial mobile services by the end of 2017. Taking into account the already-announced auctions of 700MHz and 2.5 GHz spectrum, Canada has plans in place to have a total of 528 MHz of spectrum available for commercial mobile services. This means that an additional 222 MHz of spectrum will have to be allocated to commercial mobile services over the next five years in order to meet the 750 MHz objective.

Industry Canada identified 300-415 MHz of additional spectrum in the following bands that could potentially be allocated to commercial mobile services by 2017:

- AWS bands – up to 100MHz
- 2.3 GHz band – 20MHz
- 600 MHz band – 80-120 MHz
- 3500 MHz – 100-175 MHz

In most cases these bands will need to align with bands being planned for release in the US (see below).

The increasingly important role of Wi-Fi in delivering traffic by offloading data traffic from cellular networks onto wired networks has been recognised by Industry Canada. As a result, it is taking steps to provide additional spectrum for licence-exempt equipment, specifically by allowing the use of TV white spaces, and examining the potential of making additional spectrum available in the 5 GHz range for use by licence-exempt equipment.

Beyond 2017, Industry Canada expects that mobile data traffic will continue to grow and this will result in additional spectrum requirements. It has suggested that at least 1000 MHz of mobile broadband spectrum will be required by the start of the next decade. As a result, Industry Canada will continue to monitor developments, both in Canada and abroad, and will update its plans accordingly.

[86] http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/h_sf01848.html

[87] http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf09444.html

B.3.2 United States

At present the main activities undertaken in the US around the release/repurposing of spectrum are those being undertaken under the umbrella of the National Broadband Plan (administered by the Federal Communications Commission (FCC)) which has a target to release 300 MHz by 2015 and related activities being carried out by the National Telecommunications and Information Administration (NTIA) which is tasked to release 500 MHz by 2020.

In February 2012, the US Congress passed a key piece of legislation[88] which included a number of important spectrum related provisions as follows:

- FCC granted authority to conduct voluntary incentive auctions of underutilised spectrum made available by current holders for provision of new services.
- Allocation of 10 MHz of spectrum (700 MHz D-block at 758-763/788-793 MHz) for a nationwide, interoperable broadband network for public safety use.
- Clearing of federal spectrum between 1675 MHz and 1710 MHz. The NTIA is to submit a report identifying 15 MHz for reallocation from federal use to non-federal (commercial) use.
- Unlicensed use allowed in the 5 GHz band[89] and guard bands.

The frequency bands under consideration are as follows:

- National Broadband Plan: 120 MHz from the VHF and UHF TV bands (under 700 MHz); 758-763/788-793 MHz; 1850-2000 MHz; 2020-2025 MHz; 2120-2180 MHz; 2155-2175 MHz; 1755-1850 MHz; 1525-1559/1626-1660 MHz; 1610-1626/2483-2500 MHz; 2000-2020/2180-2220 MHz; 2.3 GHz.
- NTIA: 406.1-420 MHz; 1300-1390 MHz; 1675-1710 MHz; 1755-1780 MHz; 1780-1850 MHz; 2200-2290 MHz; 2700-2900 MHz; 2900-3100 MHz; 3100-3500 MHz; 3500-3650 MHz; 4200-4400 MHz and 5350-5470 MHz.

B.3.2.1 National Broadband Plan

For the bands identified under the National Broadband Plan, the timeline and actions for the release of bands are more concrete than those for the NTIA. The progress made so far is as follows:

- 120 MHz from broadcast TV bands (470-608 MHz; 614-698 MHz) – incentive auctions are planned for 2014;[90] FCC is currently consulting on the 600 MHz band plan[91]
- 10 MHz in 700 MHz band (D-block) – In March 2013 the FCC published proposed technical rules the new public safety broadband network for consultation.[92]
- 60 MHz from AWS bands (1915-1920/1995-2000 MHz; 2020-2025/2175-2180 MHz; 2155-2175 MHz). The 1755-1850 MHz band may be paired with 2155-2175 MHz, but the former is only likely

[88] Middle Class Tax Relief and Job Creation Act of 2012, http://docs.house.gov/billsthisweek/20120213/CRPT-112hrpt-HR3630.pdf

[89] 5350–5470 MHz and 5850–5925 MHz.

[90] http://wireless.fcc.gov/incentiveauctions/learn-program/index.html

[91] http://www.fcc.gov/document/wtb-seeks-supplement-record-600-mhz-band-plan

[92] http://transition.fcc.gov/Daily_Releases/Daily_Business/2013/db0312/FCC-13-31A1.pdf

to be available on a shared basis due to high costs of moving existing federal users.[93] FCC has proposed to auction the 1915-1920/1995-2000 MHz (AWS-2 H Block) in 2013.[94] The federal bands 1695-1710 MHz and 1755-1780 MHz could also be auctioned in September 2014.[95]

- 90 MHz from Mobile Satellite Spectrum (1525-1559, 1610-1626.5, 1626.5-1660.5, 2000-2020, 2180-2200, 2483.5-2500 MHz). In December 2012 the FCC adopted revised uses for the 2000-2020/2180-2200 MHz band (AWS-4) which enables 40 MHz to be used for mobile broadband.[96]
- 30 MHz from the 2.3 GHz WCS band – FCC has revised technical rules including out-of-band emission limits to enable mobile broadband use while protecting neighbouring aeronautical mobile telemetry and satellite radio operations. In October 2012, the FCC adopted revised rules to enable wireless communications service (WCS) licensees to use 20 MHz of spectrum in the 2.3 GHz band (2305-2315/2350-2360 MHz) for wireless broadband services while protecting adjacent Satellite Digital Audio Radio Service (SDARS) services.[97] Another 10 MHz (2315-2320, 2345-2350 MHz) can be used for fixed wireless services.
- In December 2012, the FCC published proposed rules to facilitate the deployment of small cell and database technologies in the 3550-3650 MHz band on a shared basis.[98] Spectrum sharing in this context refers to the use of automated techniques to facilitate the coexistence of disparate unaffiliated spectrum dependent systems that would conventionally require separate bands to avoid interference. The proposed sharing arrangement is based on the three tier hierarchy model for access outlined in the PCAST report (see below). The FCC has also proposed integrating the 3650-3700 MHz band within this arrangement with protections for incumbent FSS operations.

B.3.2.2 NTIA plans

In parallel the NTIA has been working with the Policy and Plans Steering Group (PPSG) to identify candidate bands. It sets out a process to assess and evaluate bands and to identify necessary actions to meet the 500 MHz target. In October 2010, NTIA published its 10 Year Plan[99] along with a fast-track evaluation of 1675-1710 MHz, 1755-1780 MHz, 3500-3650 MHz, 4200-4220 MHz and 4380-4400 MHz bands[100]. The report recommends that 115 MHz (1695-1710 MHz; 3550-3650 MHz) be made available for wireless broadband use in the next five years. NTIA has since submitted three interim reports on their progress in April 2011[101] and October 2011[102] and November 2012[103].

The prioritisation and subsequent evaluation of the candidate bands are based on a variety of factors, including:

[93] http://www.ntia.doc.gov/report/2012/assessment-viability-accommodating-wireless-broadband-1755-1850-mhz-band

[94] http://www.fcc.gov/document/aws-1915-19201995-2000-mhz-h-block-nprm-adopted

[95] http://transition.fcc.gov/Daily_Releases/Daily_Business/2013/db0321/DOC-319708A1.pdf

[96] http://www.fcc.gov/document/aws-2000-20202180-2200-mhz-aws-4-order-adopted

[97] http://www.fcc.gov/document/fcc-removes-barriers-free-spectrum-0

[98] http://www.fcc.gov/document/enabling-innovative-small-cell-use-35-ghz-band-nprm-order

[99] http://www.ntia.doc.gov/files/ntia/publications/tenyearplan_11152010.pdf

[100] http://www.ntia.doc.gov/files/ntia/publications/fasttrackevaluation_11152010.pdf

[101] http://www.ntia.doc.gov/files/ntia/publications/first_interim_progress_report_04012011.pdf

[102] http://www.ntia.doc.gov/files/ntia/publications/second_interim_progress_report_on_the_ten_year_plan_and_timetable.pdf

[103] http://www.ntia.doc.gov/files/ntia/publications/third_interim_progress_report_final.pdf

- the amount of useable bandwidth to support wireless broadband and the degree to which that spectrum is contiguous;
- industry interest in the band and the expected auction revenue, if applicable, that the band will yield;
- indirect benefits to the economy of making the band available for wireless broadband;
- the availability of comparable spectrum (or other alternative arrangements) if relocation of incumbent users is necessary;
- the estimated costs of relocating Federal incumbents to another band;
- the impact to services using global allocations that would require international negotiations to bring about reallocation; and
- the likelihood that the band can be repurposed within ten years.

The third interim annual report provides a summary of the key developments over the past 12 months:

- Release of the 1755-1850 MHz band report on accommodating commercial wireless broadband; work on developing plans for relocation of federal users, transitional arrangements and spectrum sharing is ongoing
- Changes to Commercial Spectrum Enhancement Act – expansion of statutory provisions on types of relocation and sharing costs for which affected federal agencies can receive payments from the Spectrum Relocation Fund.
- Ongoing qualitative and quantitative analysis of the 5350-5470 and 5850-5925 MHz bands for potential sharing with unlicensed devices
- 2700-2900 MHz – to consider shared use of the band providing airport surveillance radar operations can be compressed closer together within the band. This would allow part of the band to be made available on a shared basis under a geo-location database approach.
- 4200-4400 MHz – ongoing work by FAA to confirm whether, and to what extent, radio altimeters operate in the 4200-4220 MHz and 4380-4400 MHz sub-bands and the potential impact of the introduction of wireless broadband uses

In earlier work the 3.5 GHz band was been identified (3550-3650 MHz) for wireless broadband, with geographic limitations on implementation (see above).

The NTIA has also re-evaluated the selected bands for prioritisation for potential non-federal exclusive use and for potential sharing with both licensed services and unlicensed devices. These are shown in the following table.

Table B-4: Reprioritisation results for repurposing federal and shared spectrum bands

Proposed for Licensed non-federal exclusive use bands	Proposed for Non-federal/federal shared use bands	Federal sharing w/ unlicensed devices
1. 1755-1850 MHz 2. 2700-2900 MHz 3. 406.1-420 MHz 4. 1370-1390 MHz 5. 4200-4400 MHz	1. 1300-1370 MHz 2. 1675-1695 MHz 3. 2700-2900 MHz 4. 2900-3100 MHz 5. 3100-3500 MHz 6. 2200-2290 MHz	1. 5350-5470 MHz 2. 5850-5925 MHz

B.3.2.3 PCAST report on shared use of federal spectrum

In July 2012, the President's Council of Advisors on Science and Technology (PCAST) published a report urging the US President to adopt a different spectrum management approach to make available spectrum for wireless broadband. PCAST advocated a shared use approach, noting that the traditional practice of clearing government-held spectrum of federal users and then auctioning it for commercial use is not sustainable. The target to make available 500 MHz of spectrum for wireless broadband, which was set out in President Obama's 2010 memorandum,[104] was predominantly based on the traditional approach of exclusive use.

In their report PCAST found that clearing and reallocation of Federal spectrum is not a sustainable basis for spectrum policy due to the high cost, lengthy time to implement, and disruption to duties of federal bodies. The difficulties of this approach were captured in the NTIA report on the 1755-1850 MHz band which found that clearing 95 MHz of federal spectrum would take 10 years, cost US$18 billion and cause significant disruption to incumbent spectrum users.

In its place PCAST recommends a new dynamic sharing system for federal spectrum management which could potentially multiply the effective capacity of spectrum by a factor of 1,000. This would involve the implementation of a new spectrum architecture and a corresponding shift in the architecture of future radio systems based on shared, rather than exclusive, spectrum use. The new spectrum management approach, facilitated by technological developments such as small cells, cognitive radio and improvements in radio performance, would focus on specifying large frequency bands that can accommodate a variety of compatible uses and new technologies that are more efficient with larger blocks of spectrum.

The approach is based on the presumption that all bands with primary federal users should be open to the greatest practical extent to non-interfering uses. This will be done through a three-tier hierarchy for access to federal spectrum which will avoid federal users needing to vacate spectrum and does not preclude expansion of federal use. The three-tier hierarchy of use are:

- Federal Primary Access: users would register actual deployments in a database in exchange for guaranteed protection from harmful interference in deployed areas; users have an exclusive right to actual use but not an exclusive right to preclude use by other federal or private sector users

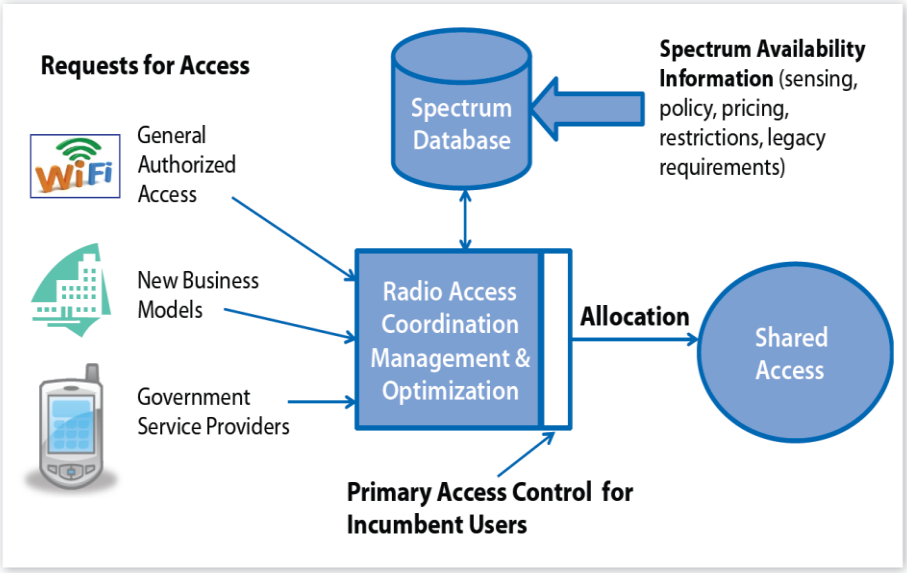
[104] http://www.whitehouse.gov/the-press-office/presidential-memorandum-unleashing-wireless-broadband-revolution

(e.g. where they have not deployed network assets or in cases where underutilised capacity can be put to use without harmful interference)

- Secondary Access: users would be issued short-term priority operating rights in a specified geographic area and would be assured of interference protection from opportunistic use; however they would be required to vacate when a user with Federal Primary Access registers a conflicting deployment in the database. There may be multiple levels of Secondary Access users with different levels of priority (depending on payments or public interest benefit)
- General Authorised Access: users would be allowed opportunistic access to unoccupied spectrum if no Federal Primary or Secondary Access users are registered in the database for a given frequency band, specific geographical area or time period. Such users are obliged to vacate once a conflicting Federal Primary or Secondary Access deployment is registered. General Authorised Access devices should be required to have cognitive radio capabilities (i.e. ability to operate on multiple bands using dynamic frequency selection so there is no dependency on access to a particular frequency). Certain bands could be subject to a device registration requirement, if needed by an incumbent Federal Primary Access system, to facilitate the location and shut down of devices causing harmful interference.

At the heart of the proposed federal spectrum access system is a database that holds information about what spectrum is occupied for a given location and time; the parameters of the signal (e.g. power, bandwidth), constraints for specific locations (e.g. no transmission in blasting zones or along international borders); and price for accessing the spectrum. The Radio Access Coordination, Management and Optimisation function provides frequency assignments and authorisations as shown below.

Figure B-1: PCAST's proposed Federal Spectrum Access System



Source: PCAST

In summary the main recommendations of the report are:

- Immediate identification of 1000 MHz of federal spectrum in which to implement the new architecture and create the first shared spectrum superhighways.

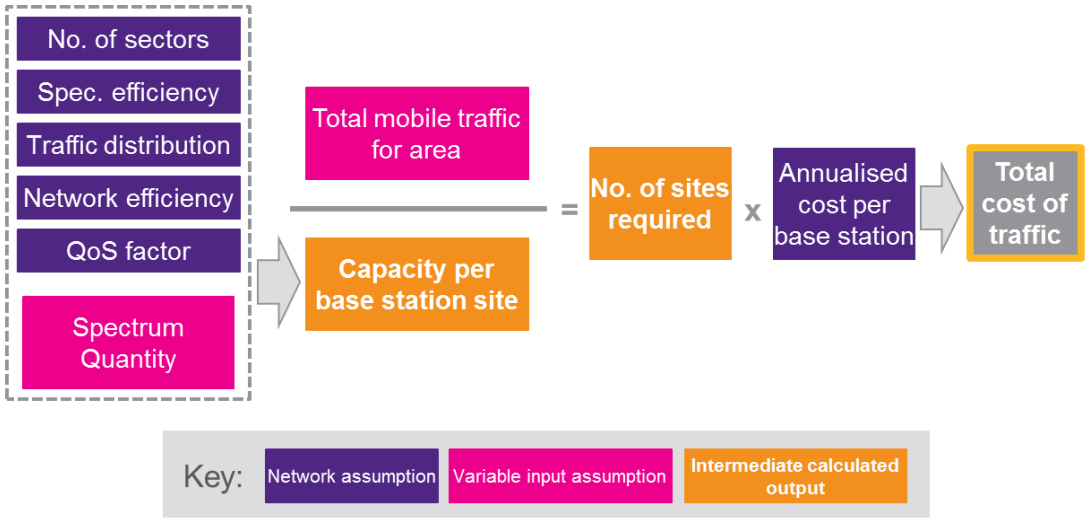
- Access to federal spectrum should be governed by a three-tier hierarchy with federal primary systems receiving highest priority and protection from interference; secondary access licensees must register deployments and use in a database and may receive quality of service protections; general authorised users would be allowed opportunistic access to unoccupied spectrum when no federal primary or secondary users are actually using a given band in a specific geographical area or time period
- Establishment of a new federal spectrum access system that will serve as an information and control clearinghouse for band-by-band spectrum registrations and conditions of use, and allow non-federal users to access utilised federal spectrum
- Federal spectrum should be divided into substantial frequency blocks with common characteristics spanning several hundred MHz instead of small dedicated blocks as at present
- Introduction of more sophisticated metrics which are able to reveal how effectively a block of spectrum can accommodate a variety of complementary services within a given area
- FCC and NTIA to establish methodologies for spectrum management that consider both transmitter and receiver characteristics to enable flexible sharing of spectrum.
- FCC and NTIA to modify rules to allow general authorised access devices to operate in two of NTIA's fast track bands – the 3550-3650 MHz band and another to be determined

The implementation timeframe proposed is over 10 years. A pilot programme over the next 3 years, which involves sharing of new low-power civil devices in over 100 MHz of federal spectrum, has been proposed.

Appendix C: Urban cost-modelling methodology

The calculation methodology for network costs in urban areas is illustrated in Figure C-1.

Figure C-1: Overview of urban network cost methodology



Source: Plum Consulting

It is assumed in that in densely populated areas, all base stations will be used to capacity in both ASEAN and the USA. The maximum capacity is not the theoretical maximum but rather the total usable capacity taking into account factors such as the need to maintain a guaranteed minimum quality of service (QoS) and the network utilisation efficiency arising from the mismatch of supply and demand.

Capacity per base station calculated from these network assumption parameters (see Table C-3) and spectrum quantity are then used to work out the implicit number of sites required to support the expected traffic. To this end, mobile traffic is estimated based on national Cisco VNI 2012 forecasts. and pro-rated using the following assumptions to arrive at the city's traffic volumes. They are then divided by the site capacity. The total cost of traffic is the product of the number of sites and annualised cost per base station. The values of the parameters used are summarised in Table C-1 to Table C-3. Downlink spectrum availability is based on data gathered for Section 1.

Table C-1: Average downlink spectrum bandwidth per operator for mobile data service

Country	2013	2015	2020
ASEAN country	23 MHz	41 MHz	59 MHz
US	46 MHz	47 MHz	137 MHz

Table C-2: Annual mobile traffic forecasts based on Cisco VNI 2012

Country	2013	2015	2020
ASEAN City	110 PB	290 PB	1128 PB
US City	110 PB	290 PB	1128 PB

Table C-3: Network parameter and cost assumptions

Parameter	Value used	Source
% traffic in busy hour	10%	Plum study for Ericsson and Qualcomm[105]
% traffic in downlink	Up to 90%	Plum study for Ericsson and Qualcomm
Discount to account for utilisation of capacity for reasonable quality of service for end user and network efficiency	50%	Plum's estimate
Sectors per BTS	3	Standard BTS configuration
Spectrum efficiency (bps/Hz) 2012 – 2020	1 – 2.23	Plum's estimate based on Ofcom publication by Real Wireless[106]
Annualised cost per BTS	US$ 39,000	Plum's estimate based on Johansson et al[107] and Ericsson's public paper

[105] http://www.plumconsulting.co.uk/pdfs/Plum_June2011_Benefits_of_1.4GHz_spectrum_for_multimedia_services.pdf

[106] http://stakeholders.ofcom.org.uk/binaries/research/technology-research/2011/4g/4GCapacityGainsFinalReport.pdf

[107] Klas Johansson, Anders Furuskär, and Jens Zander. Modelling the cost of heterogeneous wireless access networks. International Journal of Mobile Network Design and Innovation, 2(1):58–66, 2007.