Global momentum and economic impact of the 1.4/1.5 GHz band for IMT

A report for
the GSMA

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About Plum

Plum offers strategy, policy and regulatory advice on telecoms, spectrum, online, and audio-visual media issues. We draw on economics and radio spectrum engineering, our knowledge of the sector and our clients' perspectives to shape and respond to convergence.

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Executive Summary

This paper shows that:

- There is now widespread commitment for 1427-1518 MHz to become a global IMT band. Designation of the band for IMT services is supported by almost all countries in ITU Region 1 (excluding Russia and CIS countries) and ITU Region 2. In ITU Region 3 (Asia Pacific) the position is more fragmented with 11 countries currently supporting release of at least 40 MHz in the band.[1]
- The potential economic benefits from IMT services use of the first 40 MHz of the band (downlink) likely to be released (i.e. 1452-1492 MHz) could amount to at least USD40bn globally, based on stated country positions at the time of writing.
- A further USD9bn of benefit could be realised if those Asia Pacific countries not supporting 1452-1492 MHz moved to support use of the band for IMT services.[2]
- A further 40 MHz (downlink) five years later could add another 20% (i.e. around USD10bn) to these benefit estimates.
- Much of the band has little use in many countries meaning it could be made available in a relatively short timescale with limited disruption to other services and at low cost. The centre block of 40 MHz could be made available in a 2018-2020 timescale and the surrounding 40 MHz could be available in many countries by 2025.

A positive outcome at WRC-15 supporting the use of the 1.4/1.5 GHz band will allow national regulators to move forward to make the band available for IMT services.

1 Why is 1350-1400 MHz/1427-1518 MHz being considered for IMT services?

WRC-15 (Agenda Item A1.1) is to identify additional frequency bands for International Mobile Telecommunications (IMT). 1350-1400 MHz and 1427-1518 MHz[3] are two candidate bands that are receiving growing global support as IMT service bands. In this paper we refer to these bands as 1.4/1.5 GHz.

The frequency range 1427-1518 MHz is already used for commercial IMT services in Japan. In other countries the frequency ranges are mainly used for fixed links and radar, and in some countries programme making and special events (PMSE) and aeronautical telemetry services use part of the band (particularly in China, Russia and the US). See Figure 1. However, some or all of the bands are often lightly used by existing services - for example, in Europe the block 1452-1492 MHz was

[1] The more countries there are that support this multi-country proposal, the greater the benefits from economies of scale.

[2] This additional benefit represents the value of the spectrum from neutral countries (such as India, Laos, Sri Lanka, Philippines and Myanmar) as well those countries that currently oppose the adoption of the 1452-1492 MHz frequency range (such as Pakistan, Indonesia and Bangladesh). However, all of our analysis excludes China which is opposed to the adoption of the frequency range for IMT. Therefore, China's contribution is neither reflected in the baseline USD40bn nor in the additional USD9bn of benefit.

[3] In Japan this frequency range is configured as the following pairing: 1427.9-1462.9/1475.9-1510.9MHz – this encompasses 3GPP bands 11 and 21. In Europe the frequency range is configured as a centre block of 40 MHz of 1452-1492 MHz – this is 3GPP Band 32 – and 1427-1452MHz and 1492-1518MHz whose configuration is still to be decided.

allocated for digital audio broadcasting (terrestrial and satellite[4]) but was not used and so has been harmonised for IMT services.

Figure 1: Existing uses of the frequency range 1300-1525 MHz[5]

MHz	Region 1	Region 2	Region 3
1300-1350	Military, astronomy, radar (civil), satellite navigation (Earth to space), fixed links	Aeronautical	Aeronautical, radar, satellite navigation
1350-1400	Military, low capacity fixed links, astronomy	Radar, fixed links, medical telemetry, satellite (Earth to space), mobile, aeronautical	Aeronautical, radar
1400-1427	Satellite (passive Earth exploration), astronomy, space research	Satellite (passive Earth exploration), astronomy, space research	Satellite (passive Earth exploration), astronomy, space research
1427-1429	Military, low capacity fixed links	Medical telemetry, fixed links	Fixed links, aeronautical, mobile
1429-1452	Military, low capacity fixed links	Fixed telemetry, land mobile telemetry, satellite (space to Earth), mobile, fixed links, digital multichannel systems	Fixed links, aeronautical, mobile, maritime
1452-1492	Supplemental downlink for mobile, digital audio broadcasting, fixed links	Aeronautical, fixed links, digital multichannel systems	Fixed links, aeronautical, broadcasting satellite, mobile, maritime
1492-1518	Military, low capacity fixed links, PMSE	Aeronautical, fixed links, digital multichannel systems	Fixed links, aeronautical, mobile, maritime
1518-1525	Military, fixed links, satellite mobile	Aeronautical, fixed links, satellite mobile	Guard band, fixed links, maritime

The 1.4/1.5 GHz frequencies are very attractive for IMT services, because they:

- Offer a considerable amount of bandwidth (up to 80 MHz downlink in total)[6];

[4] 1452-1479.5 MHz for terrestrial networks - Under the Maastricht 2002 Special Agreement as revised in Constanta 2007 (MA02revC007) the arrangement contains technical characteristics for T-DAB and multimedia systems to operate in the 1.4 GHz Band. 1479.5-1492 MHz for satellite networks – see ECC Decision of 17 October 2003 on the designation of the frequency band 1479.5 -1492 MHz for use by Satellite Audio Broadcasting systems, ECC/DEC(03)02.

[5] Sources: GSMA ; '*The European Table Of Frequency Allocations And Applications In The Frequency Range 8.3 kHz to 3000 GHz (ECA Table)*', May 2014, http://www.erodocdb.dk/docs/doc98/official/pdf/ERCRep025.pdf ; "*Assessing The Socio-Economic Impact Of Identifying The L-Band For IMT Services*", September 2014 http://www.gsma.com/spectrum/wp-content/uploads/2014/11/GSMA-Bluenote-Report-on-Assessing-the-socio-economic-impact-of-identifying-the-L-Band-for-IMT-services.-Oct2014.pdf ; USA *National Frequency allocation table*, http://transition.fcc.gov/oet/spectrum/table/fcctable.pdf ; '*APT Survey Report On Frequency Bands In Relation To Study On WRC-15 Agenda Item 1.1 No. APT/AWG/REP-50*', September 2014.

- Are at a relatively low frequency range and hence provide good coverage outdoors and in buildings;
- Could be made available relatively quickly because of the limited existing use of the band; and
- Could be harmonised on a global basis thereby offering significant scale economy benefits[7].

These characteristics mean that use of the band for IMT provides a low cost way to expand mobile broadband capacity to meet rapidly growing demand, and to enhance rural coverage and improve service quality.

2 What is the status of global commitment to the band?

There is now sufficient commitment for 1427-1518 MHz to become a global IMT band. Figure 2 summarises the status of global commitment to identification of the frequency range 1427-1518 MHz for IMT services based on public statements by each country or region[8]. As can be seen, there is almost unanimous support for the band in the Americas and in Europe (excluding Russia and CIS countries), Africa and the Arab States. The situation in the Asia-Pacific region is more fragmented with support mainly coming from higher income countries in the region.

Japan already uses the 1427-1518 MHz band for IMT services. In Europe, the 28 countries of the European Union support 1427-1518 MHz for IMT and in 2013, a European harmonisation measure was agreed for the centre block 1452-1492 MHz[9] and relevant technical conditions for use of the band have been finalised[10]. The centre block (1452-1492 MHz) has been auctioned in Germany and Italy and has been traded in the UK in a form suitable for use by IMT services[11]. Regulators in Cyprus, France, Ireland and Slovenia are consulting on auctioning the 1452-1492 MHz band for IMT. CITEL, representing all of the Americas, supports designation of 1427-1518 MHz although in the US current use of the band by aeronautical telemetry means it will not be used for IMT services.

The EU, plus the Americas (less the US), sub-Saharan Africa and Japan already creates a market opportunity in excess of 2.1 billion people. There is a further market of at least 340 million people as a result of support for the band by the Arab states and the scope for economies of scale will increase with the support of the Asia-Pacific region as well.

[6] Greater benefits occur when the band is configured as downlink only because most traffic is in the downlink and the band can be aggregated with other frequency bands.

[7] There are relatively few globally harmonised bands at frequency ranges offering good coverage i.e. at 2.1 GHz and below. The main global bands are parts of 700 MHz and 900 MHz, 1.8 GHz and 2.1 GHz.

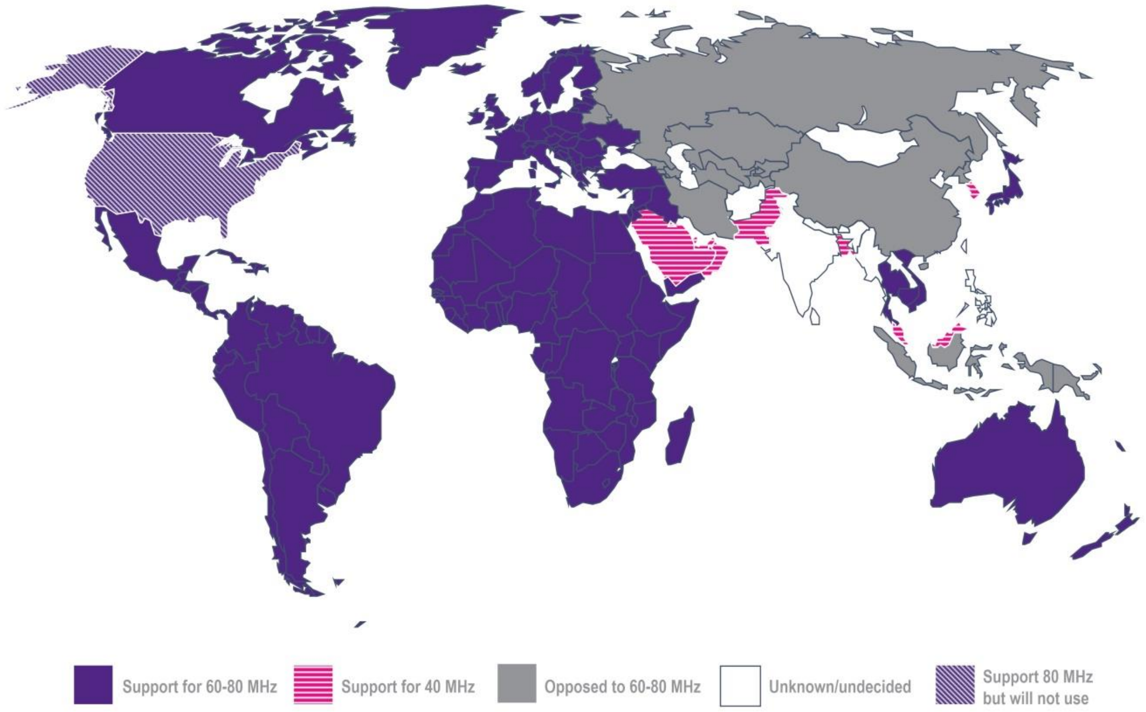
[8] See for example inputs to the ITU Inter-regional workshop on WRC-15 preparation, Geneva, November 2014.

[9] ECC Decision (13)03 ECC Decision (13)03 on the harmonised use of the frequency band 1452-1492 MHz for Mobile/Fixed Communications Networks Supplemental Downlink (MFCN SDL), November 2013

[10] ECC Report 202 on the Out-of-Band emission limits for Mobile/Fixed Communication Networks (MFCN) Supplemental Downlink (SDL) operating in the 1452-1492 MHz band, September 2013; ECC Recommendation (15)01: Cross-border coordination for mobile/fixed communications networks (MFCN) in the frequency bands 1452-1492 MHz, 3400-3600 MHz and 3600-3800 MHz, 13 February 2015; ECC Report 227: Compatibility Studies for Mobile/Fixed Communication Networks (MFCN) Supplemental Downlink (SDL) operating in the 1452-1492 MHz band, January 2015.

[11] This required a variation of the technical licence conditions so the band could be used for IMT services. http://stakeholders.ofcom.org.uk/binaries/consultations/licence-variation-1.4ghz/statement/Statement_on_1.4_ghz_licence_variation.pdf

Figure 2: Status of commitment to 1427-1518 MHz for IMT services



Source: Plum Consulting

Note: CITEL, CEPT and the ATU all support the whole band (80 MHz). The ASMG common position is to support 40 MHz (1452-1492 MHz), with 12 members supporting an additional 25 MHz (1427-1452 MHz) and 5 members supporting an additional 66 MHz making 99 MHz in total (1427-1518 MHz). Indonesia supports 25 MHz only (1427-1452 MHz).

The ATU, Bangladesh and New Zealand also support 1350-1400 MHz for IMT services.

3 What spectrum might be available and when?

Equipment for use of 1427-1518 MHz is already commercially available in Japan. Whether this equipment can be used elsewhere depends on the band plans and technical conditions adopted in different countries and regions. The approach that will be taken elsewhere is not known except in the case of Europe.

The band plan and technical conditions adopted in Europe will differ from that used in Japan, and transmission equipment and consumer devices are likely to be commercially available for use of the 1452-1492 MHz band in Europe by 2018 and elsewhere by 2020. It will take longer to make available the 1427-1452 MHz/1492-1518 MHz for IMT services because of its existing use[12]. There are also additional complications in assigning the L Band without the centre 40 MHz: for example, the fragmentation reduces the amount of usable spectrum (due to guard bands). We expect that in Europe this additional spectrum could be available for commercial use by IMT services by 2022.

[12] Rearrangement of incumbent services (e.g. fixed links) may be required to make these bands available for IMT services.

Figure 3: Indicative timeline for global commercial deployment of the 1427-1518 MHz band

Source: Plum analysis

In our economic modelling we have assumed that an initial 40 MHz (downlink) will be in commercial use in Europe and Latin America in 2018 and in Africa and Asia Pacific in 2020. An additional 40 MHz (downlink) could be in use in 2022 and 2025, respectively.

4 What are the economic benefits of 1.4/1.5 GHz for IMT?

The economic benefits of 1.4/1.5 GHz for IMT include network cost savings (which may be passed on to consumers in lower prices) and improved coverage and quality of service for consumers[13]. We have focussed on the most readily quantifiable benefits – namely network cost savings – and hence our estimates are conservative and should be taken to be indicative[14].

To derive estimates of the value of the first 40 MHz in the band, namely 1452-1492 MHz we:

- Used estimates that already exist in several published studies for Europe[15], the Middle East and North Africa and Latin America and the Caribbean[16]. Where necessary these estimates were adjusted for differences in the assumed timing of the availability of the 1.4 GHz/1.5 GHz band for IMT services.
- Modelled values for sub-Saharan Africa and Asia Pacific based on examples of two large countries in each region that could potentially use the band, namely South Africa and Nigeria and India and Indonesia respectively.
- In the case of high income countries in the Asia Pacific region we applied European per capita values. Japan is excluded from these estimates because it already uses the band (i.e. is unaffected by the harmonisation activity)[17].
- Derived two estimates for the Asia Pacific region – one estimate based on the current stated support of countries in the region and a second estimate assuming all countries except China decide in time to use the band for IMT services as a result of its global use..

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[13] The estimation of benefits does not include assessment of indirect effects

[14] A number of simplifying assumptions around population distribution have been made in the models to make them tractable.

[15] Europe is defined as the European Economic Area i.e. the 28 EU member states plus Iceland, Liechtenstein and Norway. We used mid-point values for avoided cost that were obtained in the European study conducted in 2011. http://www.plumconsulting.co.uk/pdfs/Plum_June2011_Benefits_of_1.4GHz_spectrum_for_multimedia_services.pdf

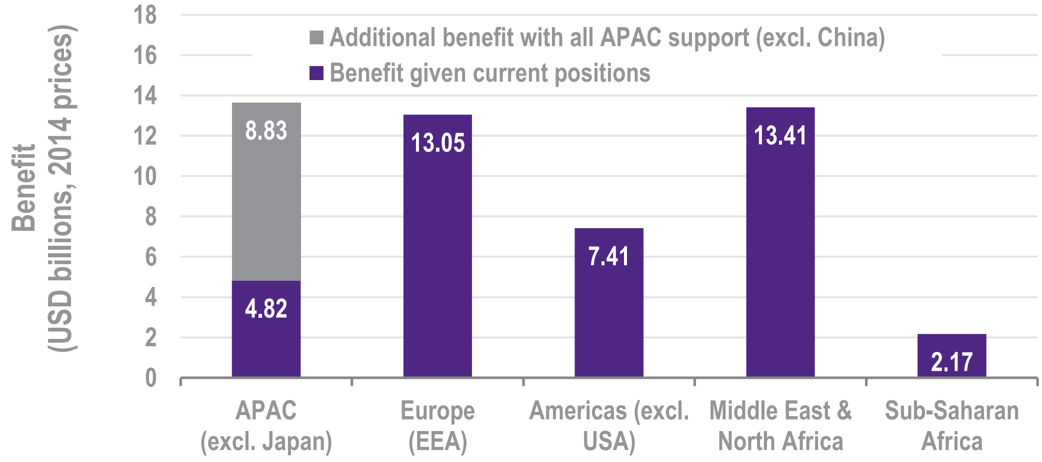
[16] http://www.plumconsulting.co.uk/pdfs/Plum_Oct2012_The_economic_benefits_from_deploying_1.4_GHz_spectrum_in_the_MENA_region.pdf; http://www.gsma.com/spectrum/wp-content/uploads/2014/11/GSMA-Bluenote-Report-on-Assessing-the-socio-economic-impact-of-identifying-the-L-Band-for-IMT-services.-Oct2014.pdf

[17] We assume only 20MHz downlink capacity is available in China because part of the band is used for mobile for emergency services.

The regional estimates are summarised in Figure 4. The total implied benefit based on current stated positions of countries is around USD41bn (shown in purple in Figure 4). A further USD9bn of benefit could be realised if those Asia Pacific countries not supporting 1452-1492 MHz moved to support use of the band for IMT services. (These calculations exclude China which is opposed to use of the band. Unlike other countries in Asia Pacific opposing use of 1452-1492 MHz, China is able to take a unilateral position on standards and frequency bands.)

While the costs of making the spectrum available are not known in many cases, for Europe they are almost zero and for Latin America they have been estimated (by BlueNote) to be 5% of the benefits.

Figure 4: Indicative estimates of the economic benefits from use of 40 MHz (downlink) at 1.4/1.5 GHz for IMT services from 2018/2020



Source: Plum Consulting, BlueNote Management Consulting

There is also the potential for a further 40 MHz of downlink capacity in the band that may be able to be released in the 2022-2025 timeframe. The incremental value of this spectrum is less certain however and our modelling suggests it could be around 20% of the value of the first 40 MHz when expressed in 2014 prices[18].

5 What needs to happen next?

To realise these benefits, countries should support (or as a minimum not oppose) the designation of the 1.4/1.5 GHz band for IMT services at WRC-15. Importantly, the fragmented position of countries in the Asia Pacific region in respect of the 1452-1492 MHz band could result in the loss of USD9bn in economic benefits.

Following WRC-15, there is likely to be a need for some further work on technical conditions around use of the band and possibly standardisation activity in 3GPP (depending on the band plans adopted). Harmonisation will allow industry to be more certain of investment and the scale of the potential market enabled by the band. It will then be up to regulators to determine national process for making

[18] Future values are discounted at 10% p.a. The 10% discount rate is used as it is not clear where the benefits go – it is appropriate to use a commercial rather than a social discount rate under these conditions.

the band available for commercial services. A positive outcome at WRC-15 supporting the use of the 1.4/1.5 GHz band will allow national regulators to move forward to make the band available for IMT services.

Appendix A: Modelling methodology and assumptions

A.1 Overall approach

The scope and timescale for this study was limited to using existing estimates of the economic benefit of the 1.4/1.5 GHz band plus modelling where existing estimates were not available.

For those countries/regions where we used existing estimates the approach was as follows:

- For Europe, the values from Plum's L-band report for Qualcomm and Ericsson[19] were used to set the range. The representative benefit amount was taken to be the midpoint in the range between the low and high benefit numbers from the report, which are EUR3.5bn and EUR22.6 respectively. This medium value was then converted to USD in 2014 prices and adjusted for an expected release date of 2018 as well as for inflation.
- For high-income Asia Pacific countries[20], the per-capita benefit for Europe was used as the basis for calculating the total benefit. The per-capita figure was grossed up by the population of the relevant countries to generate the total benefit for the sub-region.
- For Middle East and North Africa, the value (USD18.5bn) from a previous Plum report on the benefit of L-band in the region for Ericsson and Qualcomm[21] was used. This was adjusted for the new timing of release and for inflation.
- The total benefit for Americas (excluding the USA) comprises the benefit for Latin America and Caribbean islands and the benefit for Canada. The benefit for Latin America and the Caribbean sub-region is taken to be the estimate from Bluenote Consulting report for the GSMA[22]. Because Bluenote's number is based on cost savings from a downlink bandwidth of 35 MHz, this should give a conservative value of a benefit estimate for the 40 MHz of the middle block in the L-band, which we are considering. The figure for Canada was derived from Plum's number for Europe. As with high-income Asia Pacific countries, the per-capita benefit for Europe was grossed up using Canada's population to estimate the total benefit for Canada.

In all the above cases, the discount rate used to make adjustments for a new timing of release is 10%, and the inflation rate used is 2% per annum.

The modelling approach and assumptions used for other regions/countries are described in the remainder of this Appendix.

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

[20] These are countries with per-capita GDP of greater than USD10,000 on a PPP basis and include Australia, Korea, Malaysia, New Zealand, Singapore and Taiwan.

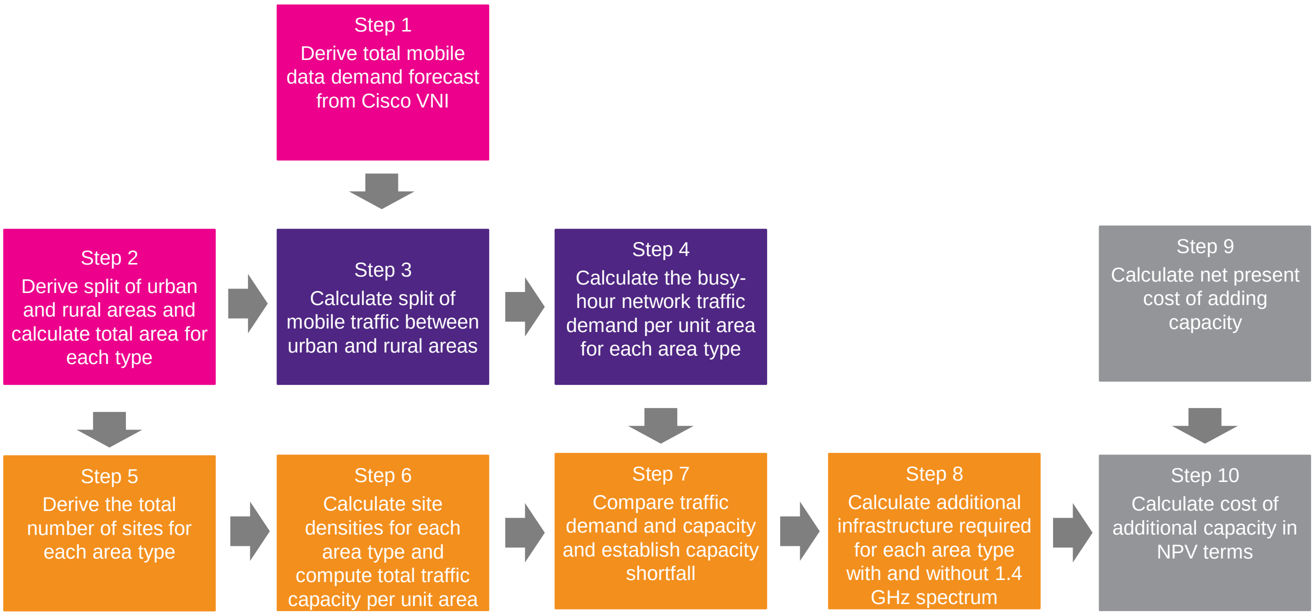
[21] http://www.plumconsulting.co.uk/pdfs/Plum_Oct2012_The_economic_benefits_from_deploying_1.4_GHz_spectrum_in_the_MENA_region.pdf

[22] http://www.gsma.com/spectrum/wp-content/uploads/2014/11/GSMA-Bluenote-Report-on-Assessing-the-socio-economic-impact-of-identifying-the-L-Band-for-IMT-services.-Oct2014.pdf

A.2 Modelling methodology steps

Figure A1 gives an overview of the methodology used in the calculation of costs of additional infrastructure for the purpose of estimating the benefit.

Figure A1: Overview of cost calculation methodology



The description of the steps used for benefit calculation for developing Asia Pacific countries and African countries is as follows:

Step 1: The total mobile data traffic demand forecasts for each country are derived from Cisco VNI 2014 projections. Cisco produces country-level forecasts for India, Indonesia and South Africa. For these countries, Cisco's projections are directly extrapolated to construct future mobile data usage forecasts to 2030. For Nigeria, the regional data for Middle East and Africa[23] is used as the basis for building the forecasts. This regional projection is extrapolated to 2030 and then pro-rated by Nigeria's relative population. The resulting values are then halved to reflect the fact that Nigeria is a low-income country in the region.

Step 2: We divide the total landmass of each country into two area types – urban and rural – based on the urban population percentage from the UN World Population Prospects 2014 and population density data set from the Gridded Population of the World. The Gridded Population of the World data set contains estimates of the population by district to 2015 for each country, as well as the district's land area in square kilometre. The population density for each individual district is computed from this, and all the districts are sorted in descending order of population density. To determine the size of the total urban areas, all land areas representing districts with the highest population densities that contain the total urban population are added together. The totality of the populated districts outside urban areas is then considered to represent rural areas. From this we have the total areas in square kilometres for the two area types that are under mobile coverage.

[23] Excluding Saudi Arabia and South Africa

Step 3: The numbers of subscribers in each country's urban and rural areas are calculated based on estimates of the ratio of urban-to-rural mobile penetrations from various GSMA sources[24,25] and subscriber data from GSMA Intelligence. These subscriber bases are then used to calculate the split of the total mobile data demand forecasts between urban and rural areas. It is assumed here that the urban to rural traffic ratio mirrors the urban to rural subscriber ratio.

Step 4: Once calculated, the urban and rural mobile data volumes from Step 3 are used to obtain the busy hour mobile data demand per unit area in each area type.

Step 5: The total number of mobile sites for each area type is computed. Total sites in each country are estimated based on per-operator site count estimates from Aetha's reports on the benefits of releasing 2.7-2.9GHz spectrum in Indonesia and Nigeria for the GSMA[26]. For India and South Africa, total sites were estimated based on information from local sources including the regulator and local operators. Aetha also published a traffic vs site distribution in their 2.7-2.9GHz reports. The curve is used to determine the proportion of sites that are urban based on output from Step 3. This urban site percentage is then used to derive the total urban sites. The rest of the sites are assumed to be rural sites.

Step 6: Urban and rural site counts from Step 5 are divided by the sizes of urban and rural areas to calculate the site densities. Each area type's site density is used to compute the total traffic capacity per square kilometre based on network assumptions such as spectral efficiency and the number of spectrum bands deployed. All technical assumptions used for network capacity calculation can be found in Section A.3.

Step 7: We compare the traffic capacity per square kilometre from Step 6 with the traffic demand per square kilometre from Step 4. Note that we modelled downlink capacity only. This is the binding constraint – i.e. downlink capacity is what constrains the network's capability to handle traffic.

Step 8: Where demand is greater than network capacity, we add infrastructure for each area type. There are two scenarios here:

- Scenario 1 in which there is no 1.4 GHz. Here additional base stations are added
- Scenario 2 in which, initially, 1.4 GHz is deployed to expand capacity on existing base stations. When all existing base stations are upgraded with the 1.4 GHz band we then expand capacity by adding more base stations. The additional base stations will use all bands (including the 1.4 GHz spectrum) until capacity matches traffic demand.

The output of this step is the amount of additional infrastructure required to meet demand.

Step 9: We calculate the net present cost of

- Adding a site under Scenario 1, and then
- The combined net present cost of new 1.4 GHz antennas, radio equipment and the net present cost of an additional site with 1.4GHz band under Scenario 2

The output of this step is the net present costs of addition of capacity to meet demand.

Step 10: We multiply the net present costs from Step 9 by the amount of additional infrastructure required from Step 8 to get the additional infrastructure costs and then calculate the difference

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24 www.gsma.com/mobilefordevelopment/wp-content/uploads/2012/06/gsma_rural.pdf

25 https://gsmaintelligence.com/research/2012/03/urbanisation-driving-mobile-growth-in-bric-countries/326/

26 http://www.gsma.com/spectrum/economic-benefits-of-portion-of-2-7-2-9ghz-from-mobile-services/

between the two scenarios for each area type. This is the avoided cost per square kilometre in NPV terms. The total cost savings for each area type are then computed by multiplying the cost per square kilometre by the area type's total land area. These are then multiplied by the total area of each area type to get the total benefits that accrue to each area type. These two benefit values are added together to calculate the total benefit for the country.

This methodology has been applied to India and Indonesia in Asia Pacific, and Nigeria and South Africa in sub-Saharan Africa in order to compute an estimate of the benefit for each country. These countries were chosen because they are large and can be taken as representative for groups of low and middle incomes countries in each region.

The computed value of per-capita benefit for Indonesia is then used as a proxy for the benefit per person in middle-income developing Asia Pacific countries[27], while per-capita benefit for India is used as the basis for computing the total benefit for the rest of developing Asia Pacific[28]. It should be noted that only countries that show some level of support for the band have been included in this analysis. To derive an estimate for all of Asia Pacific, the benefits from middle-income countries and the rest of Asia Pacific are added to the benefits from high-income countries[29], for which the per capita benefit from the release of the 1.4 GHz band is assumed to be the same as in EEA.

For Africa, the per-capita value for South Africa is used as a proxy for middle-income sub-Saharan African countries[30], while the value for Nigeria is assumed to be representative of the rest of sub-Saharan Africa.

A.3 Modelling assumptions

A.3.1 Demographic and market assumptions

Table A-1 shows the values that have been used in the models for the input variables relating to demographics and the market.

[27] These include Thailand, Sri Lanka, Indonesia and the Philippines.

[28] These include Pakistan, Vietnam, Laos, Cambodia, Bangladesh and Myanmar. Note China is excluded from the analysis.

[29] These include Australia, South Korea, Malaysia, New Zealand, Singapore and Taiwan.

[30] These include Equatorial Guinea, Gabon, Mauritius, Seychelles, Botswana, Angola, South Africa and Namibia

Table A-1: Demographic and market assumptions

Parameter	Value used	Source
Total population 2015 (million people)		UN World Urbanization Prospects 2014 revision
Indonesia	256	
India	1,282	
Nigeria	184	
South Africa	53	
Percentage of urban population		UN World Urbanization Prospects 2014 revision
Indonesia	54%	
India	33%	
Nigeria	48%	
South Africa	65%	
Number of unique mobile subscribers in urban areas in 2015 (million subscribers)		GSMA Intelligence
Indonesia	104	
India	231	
Nigeria	53	
South Africa	30	
Ratio of urban to rural mobile penetration	2	Various GSMA presentations and commentary pieces[31][32]
Total mobile population coverage		GSMA publications including Mobile Observatory 2012 & 2013 and Mobile Economy 2014
Indonesia	85%	
India	87%	
Nigeria	80%	
South Africa	95%	

A.3.2 Network assumptions

The network, traffic and spectrum efficiency assumptions are stated in Table A-2. Values for parameters that directly affect the overall capacity in the network are taken from public sources, which are cited next to these parameters in the table.

[31] https://gsmaintelligence.com/research/2012/03/urbanisation-driving-mobile-growth-in-bric-countries/326/

[32] www.gsma.com/mobilefordevelopment/wp-content/uploads/2012/06/gsma_rural.pdf

Table A-2: Network assumptions

Parameter	Value used	Source
Percentage of traffic in busy hour	10%	Estimated based data from Heikkinen and Berger[33]
Percentage of traffic in the downlink 2012 2015 2020 2025 2030	 86% 89% 90% 90% 90%	 Plum 2011 study for Ericsson and Qualcomm[34]
Percentage of network capacity that is usable accounting for mismatch of supply and demand in some locations	80%	Plum's estimate
Overhead allowed to maintain quality of mobile data service	50%-70%	Plum's estimates
Sectors per BTS	3	
Spectrum efficiency(bps/Hz/cell)[35] 2014 2030	 0.55 1.6	 Plum's estimates based on vendors' view
Year on year change in spectrum efficiency between 2012 and 2023 (bps/Hz)	0.05-0.1	Plum's estimates based on conversation with vendors
Average number of operators by country Indonesia India Nigeria South Africa	 4 8 4 4	Plum's estimates based on information on regulators' websites and other public sources
Number of sites in 2014 by country Indonesia India Nigeria South Africa	 175,000 800,000 32,000 29,000	Plum's estimates based on information on regulators' websites and Aetha's reports for the 2.7GHz commissioned by the GSMA
Rate of site growth per annum Indonesia India Nigeria South Africa	 1%-5% 1%-10% 1%-10% 2%-10%	Plum's estimates

[33] http://dspace.mit.edu/bitstream/handle/1721.1/62579/MIT-CSAIL-TR-2011-028.pdf?sequence=1

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

[35] The lower value is for 2012 and the higher value is for 2022.

A.3.3 Infrastructure cost assumptions

Table A-3 shows the values that have been used in the models for the input variables relating to infrastructure cost.

Table A-3: Infrastructure cost assumptions

Network cost type	Value used	Source
Annual discount rate	10%	Plum's estimate based on WACC numbers used by mobile operators globally
CAPEX per band - cost of each set of antennas and RF (USD '000)	12	Plum's estimates based on data benchmarks data from NSN and Aetha [36]
Base station CAPEX (USD '000)	85	
CAPEX of 1.4 GHz antennas and RF (USD '000)	12	
Site establishment cost (USD '000)		Plum's estimates based on data benchmarks data from NSN and Aetha
Civil works	15	
Installation and commissioning	2	
Backhaul Capex		Plum's estimates based on data benchmarks data from NSN and Aetha
Urban (fibre-based product)	4	
Rural (microwave)	15	
OPEX as % of CAPEX		Analysys Mason, Plum's estimates based on conversations with vendors
Non-backhaul	5%	
Backhaul		
Urban	30%	
Suburban/rural	15%	
Site rental per year (USD '000)		Plum's estimates
Urban	8	
Suburban/rural	2	

A.3.4 Traffic forecast assumptions

Table A-4 shows the traffic forecasts used for the models.

Table A-4: Country's traffic forecasts (PB/month)

Year	Indonesia	India	Nigeria	South Africa
2015	92	255	23	56
2020	712	2,165	76	316
2025	1,936	5,167	360	780
2030	3,150	7,770	930	1,400

[36] http://www.gsma.com/spectrum/economic-benefits-of-portion-of-2-7-2-9ghz-from-mobile-services/

A.3.5 Spectrum assumptions

The spectrum assumptions made below do not directly reflect the situation in each country but are representative for middle and low income countries in the Asia Pacific and the African regions.

Mobile spectrum assumptions for Indonesia – middle income country

The table below shows the total amount of downlink spectrum assumed to be available and in use in the different bands for **mobile data service** for the entire market (MHz). In all tables we assume for all TDD spectrum bands that 2/3 of all the timeslots and bandwidth are used for downlink transmission.

Band	2014	2016	2018	2020	2022	2024	2026	2028	2030
450MHz	0	5	5	5	5	5	5	5	5
700MHz	0	0	0	45	45	45	45	45	45
850MHz	5	10	15	15	15	15	15	15	15
900MHz	10	15	20	20	20	20	20	20	20
1.4GHz	0	0	0	40	40	40	40	40	40
1.8GHz	0	10	30	50	60	60	60	60	60
1.9GHz	5	5	5	5	5	5	5	5	5
2.1GHz	60	60	60	60	60	60	60	60	60
2.3GHz TDD	0	20	40	60	60	60	60	60	60
2.6GHz TDD	0	0	0	0	0	0	0	0	0
2.6GHz	0	0	0	70	70	70	70	70	70

The table below shows the total amount of downlink spectrum assumed to be reserved and in use in the different bands for **mobile voice service** for the entire market (MHz)

Band	2014	2016	2018	2020	2022	2024	2026	2028	2030
900MHz	15	10	5	5	5	5	5	5	5
1800MHz	75	65	45	25	15	15	15	15	15

Mobile broadband spectrum assumptions for India – low income country

The table below shows the total amount of downlink spectrum assumed to be available and in use in the different bands for mobile data service for the entire market (MHz)

Band	2014	2016	2018	2020	2022	2024	2026	2028	2030
450MHz	0	0	0	0	0	0	0	0	0
700MHz	0	0	0	45	45	45	45	45	45
850MHz	0	0	0	5	10	10	10	0	10
900MHz	0	0	0	5	10	15	15	15	15
1.4GHz	0	0	0	40	40	40	40	40	40
1.8GHz[37]	0	0	0	20	40	50	50	50	50
1.9GHz	5	5	5	5	5	5	5	5	5
2.1GHz[38]	20	40	40	40	40	40	40	40	40
2.3GHz TDD	0	0	40	40	40	40	40	40	40

[37] It is assumed that a total of 120MHz will be released. We understand there is a Memorandum of Understanding which states that not all of the spectrum will be freed up by the military.

[38] It is assumed that a total of 80MHz will be released in this band.

The table below shows the total amount of downlink spectrum assumed to be reserved and in use in the different bands for **mobile voice service** for the entire market (MHz)

Band	2014	2016	2018	2020	2022	2024	2026	2028	2030
850MHz	10	10	10	5	0	0	0	0	0
900MHz	15	15	15	15	10	5	5	5	5
1800MHz	40	40	40	20	15	10	10	10	10

Mobile broadband spectrum assumptions for Nigeria – low income country

The table below shows the total amount of downlink spectrum assumed to be available and in use in the different bands for mobile data service for the entire market (MHz)

Band	2014	2016	2018	2020	2022	2024	2026	2028	2030
700MHz	0	0	0	10	30	30	30	30	30
800MHz	0	0	0	0	0	0	0	0	0
850MHz	0	5	5	5	5	5	5	5	5
900MHz	0	5	10	15	15	15	15	15	15
1.4GHz	0	0	0	40	40	40	40	40	40
1.8GHz	0	10	30	70	70	70	70	70	70
1.9GHz	0	5	10	10	10	10	10	10	10
2.1GHz[39]	40	40	40	40	40	40	40	40	40
2.6GHz TDD	0	0	0	0	0	0	0	0	0
2.6GHz	0	0	40	40	40	40	40	40	40

[39] Only part of the band is expected to be released given the observed difficulty in making spectrum available in Nigeria.

The table below shows the total amount of downlink spectrum assumed to be reserved and in use in the different bands for **mobile voice service** for the entire market (MHz).

Band	2014	2016	2018	2020	2022	2024	2026	2028	2030
900MHz	25	20	15	10	10	10	10	10	10
1800MHz	75	65	45	5	5	5	5	5	5

Mobile broadband spectrum assumptions for South Africa – middle income country

The table below shows the total amount of downlink spectrum assumed to be available and in use in the different bands for mobile data service for the entire market (MHz)

Band	2014	2016	2018	2020	2022	2024	2026	2028	2030
700MHz	0	0	0	30	30	30	30	30	30
800MHz	0	0	30	30	30	30	30	30	30
900MHz	10	20	25	25	25	25	25	25	25
1.4GHz	0	0	0	40	40	40	40	40	40
1.8GHz	10	30	40	60	65	65	65	65	65
1.9GHz	0	0	0	0	0	0	0	0	0
2.1GHz	60	60	60	60	60	60	60	60	60
2.3GHz TDD	0	0	0	0	0	0	0	0	0
2.6GHz TDD	0	0	0	0	0	0	0	0	0
2.6GHz	0	0	70	70	70	70	70	70	70

The table below shows the total amount of downlink spectrum assumed to be reserved and in use in the different bands for **mobile voice service** for the entire market (MHz)

Band	2014	2016	2018	2020	2022	2024	2026	2028	2030
900MHz	23	13	8	8	8	8	8	8	8
1800MHz	38	18	20	15	10	10	10	10	10