Buletin Pos dan Telekomunikasi Vol. 13 No.2 (2015) 115-132

The estimation of spectrum requirements to meet the target of Indonesia broadband plan in urban area

Estimasi kebutuhan spektrum untuk memenuhi target rencana pita lebar Indonesia di wilayah perkotaan

Kasmad Ariansyah
Pusat Penelitian dan Pengembangan Sumber Daya dan Perangkat Pos dan Informatika
Jalan Medan Merdeka Barat No.9 Jakarta 10110, Indonesia
email: kasmad.ariansyah@kominfo.go.id

INFORMASI ARTIKEL

Received 08-Desember-2015
Revised 21-Desember-2015
Accepted 22-Desember-2015

Kata kunci :
Estimasi
Kebutuhan spektrum
Rencana Pita Lebar Indonesia
Wilayah perkotaan

ABSTRAK

Pemerintah Indonesia telah mengesahkan Rencana Pita Lebar Indonesia menjelang akhir tahun 2014. Dokumen tersebut berisi panduan dan arah pembangunan pita lebar nasional dan berisi berisi target-target pencapaian berkelanjutan antara tahun 2014-2019. Terkait target capaian pita lebar nirkabel, ketersediaan dan kecukupan spektrum frekuensi merupakan salah satu hal yang sangat penting. Studi ini dilakukan untuk mengestimasi kebutuhan spektrum frekuensi dalam rangka memenuhi target capaian Rencana Pita Lebar Indonesia khususnya layanan pita lebar nirkabel di wilayah perkotaan. DKI Jakarta dipilih sebagai sampel wilayah perkotaan. Analisis dilakukan dengan menghitung luas cakupan BTS, mengestimasi jumlah potensi pengguna, mengestimasi kebutuhan spektrum dan membandingkannya dengan spektrum yang sudah dialokasikan untuk mendapatkan jumlah kekurangan spektrum. 3G dan 4G diasumsikan sebagai teknologi yang digunakan untuk memenuhi sasaran pita lebar bergerak. Hasil analisis menunjukkan pada rentang tahun 2016-2019 akan terjadi kekurangan spektrum di wilayah perkotaan sebesar 2x234.5 MHz sampai dengan 2x240.5MHz (untuk mode FDD) atau sebesar 313 MHz sampai dengan 321 MHz (untuk mode TDD). Spektrum frekuensi merupakan sumber daya yang reusable, dengan mengasumsikan kebutuhan spektrum di perdesaan lebih rendah dibanding kebutuhan di perkotaan, maka estimasi ini dapat pula digunakan untuk menggambarkan kebutuhan spektrum di Indonesia secara keseluruhan.

Keywords:
Estimation
Spectrum requirement
Indonesia Broadband Plan
Urban area

ABSTRACT

Indonesian government has issued Indonesia Broadband Plan (IBP) at the end of 2014. IBP provides guidance and direction for the development of national broadband and contains targets in the period of 2014 to 2019. Relating to wireless broadband target, the availability and the adequacy of spectrum is very important. This study was conducted to estimate the spectrum requirements to meet the Indonesia broadband plan target especially the target of mobile broadband in urban area. DKI Jakarta was taken as sample of urban area. Analysis was done by calculating the coverage of BTSs, estimating the number of potential users, estimating the required spectrum and comparing it with the allocated spectrum to obtain the number of spectrum shortage. 3G and 4G were assumed as technologies used to meet mobile broadband target. The result showed that there will be a shortage of spectrum in the period of 2016 to 2019 approximately 2x234.5 to 2x240.5MHz(for FDD mode) or 313 MHz to 321 MHz (for TDD mode). Spectrum is reusable resource and by assuming that spectrum requirements in rural area is lower than that in urban, this estimastion can also be used to portray spectrum requirements in Indonesia as a whole

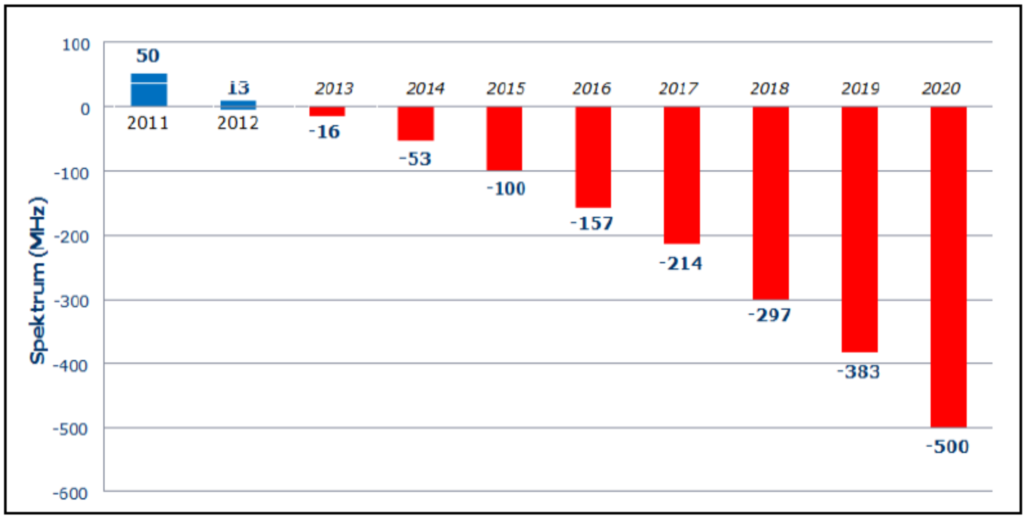
DOI: 10.17933/bpostel.2015.130202

1. Introduction

Over the last few decades, information and communication technology (ICT) has grown rapidly and has become an enabler of developments in various sectors, such as education, government, healthcare, logistics, trade and others, known as e-learning, e-government, e-health, e-logistics and e-commerce, especially after the presence of broadband technology which enables high-speed data access with a relatively smaller latency. The presence of broadband technology is also believed to contribute positively to economic growth in a country. According to Kim, Kelly, & King (2010), at the global level, an increased penetration of broadband of 10% accelerated the economic growth of low- and medium-income countries by 1.38% and 1.21% in high-income countries. In a similar study, McKinsey & Company (2009) estimated that every 10% increase in broadband penetration of households would drive the growth of a country's GDP by 0.1% to 1.4%. For Indonesia, a study conducted by Katz (2012) concluded that a 1% increase in broadband technology penetration would have an impact of reducing unemployment growth by 8.6163%. Similarly, the GSMA (Boston Consulting, 2010) stated that the construction of mobile broadband network at 700 MHz band would stimulate an increased productivity for the service industry and the manufacturing industry by 0.4% and 0.2%, respectively. In addition to the benefits from an economic standpoint, results of the study also suggested a correlation between the presence of broadband services and the social life. Results of a study conducted by the SQW Group estimated time savings of 60 million hours per year in the UK with the presence of faster broadband services to facilitate teleworking. This occurs due to the fact that with teleworking the time needed to travel to workplace can be used for the family or other social activities. The same study also showed a positive contribution of broadband services to the environment. Teleworking and teleconference that can be facilitated by broadband services will reduce the use of transportation means, which will reduce CO_2 emissions. Given the many benefits generated, the construction of broadband networks is a necessity and a national program. The Indonesian government has launched the Indonesia Broadband Plan (RPI) in 2014 prepared by the Bappenas by involving all stakeholders including the government, the private sectors and the communities. Through the RPI document, the Indonesian Government sets the target broadband access speed in the time span from 2014 to 2019 which is divided into two regional classifications, urban and rural areas. Each group is subdivided into the categories of fixed access and mobile access. The mobile access speed for the urban areas in 2015 is targeted to reach 512 Kbps with a penetration rate of 100% and increased to 1 Mbps beginning in 2016. As for the rural areas, the target access speed of 512 Kbps with a target penetration rate of 35% is expected to be achieved in 2016 and increased to 40% in 2017. Beginning in 2018, the mobile access speed for rural areas is targeted to increase up to 1 Mbps with a penetration rate of 35% and 52% in 2019 (Presidential Regulation of the Republic of Indonesia No. 96 of 2014). In order to meet the target mobile broadband access, availability and adequacy of the frequency spectrum as a medium for data transmission on wireless access is absolutely necessary. Despite the other options to keep up the increasing growth in data traffic by increasing the efficiency of frequency spectrum (upgrade of technology) and further intensifying the reuse of the spectrum (Clarke, 2014), increased allocation of radio frequency is claimed to be more advantageous since it can reduce investment. Setiawan (2013) argued that the digital dividend of 2x45 MHz from spectrum refarming at the 700 MHz band would be able to reduce investment by IDR 147 trillion. Similarly, the FCC (2010) stated that an increased spectrum allocation in 2014 of 275 MHz would save capital investment of USD 120 billion.

The International Telecommunication Union (ITU) has released the estimated spectrum requirement for 2020 that ranged from 1,340 MHz to 1,960 MHz (ITU-R M.2290-0, 2013). However, Indonesia cannot necessarily use the estimate as a reference of spectrum requirement in Indonesia, given the fact that the density of users, penetration and service access speed requirements and other parameters that are used vary considerably from country to country, including Indonesia. A critique of the ITU's estimated results was launched by LS Telecom (2014), arguing that the traffic requirement was overestimated. Beutler and Ratkaj

(2014) found a gap in the estimate, especially with regard to the input assumptions and mathematical approach used. In Indonesia, a study to analyze the frequency spectrum requirement has already been done. According to Aditya Yoga Perdana (2009), with the use of two 4G (LTE and Wimax) technologies, in the period of 2015-2017 Indonesia would require an additional spectrum allocation of 15 MHz to 150 MHz. An additional allocation requirement would continuously grow between 470 MHz and 750 MHz for the period of 2018 to 2019 and continue to increase to 1,230 MHz to 1,735 MHz by 2020. However, those estimated frequency spectrum requirements were based on the such input parameters as data access speed requirement per user that referred to the target access speed in India which was very much different from the target broadband plan in Indonesia. In addition, the study was also conducted long before the launch of the government regulation on Indonesia broadband plan. In 2014, the Director General of SDPPI said that the spectrum deficit in Indonesia would occur from 2013 by 16 MHz and would continue to increase from 2014 to 2020 by 53 MHz, 100 MHz, 157 MHz, 214 MHz, 297 MHz, 383 MHz and 500 MHz, respectively, as shown in Figure 1 (Director General of SDPPI, 2014). The estimated spectrum deficit was based on the assumption that data traffic growth for those periods was 60% per year and site growth was 28.8% per year. Although the estimate was presented at the 2014 National Coordination Meeting of the Ministry of Telecommunications and Information Technology, the study was conducted in previous years prior to the launch of Indonesia Broadband Plan. The present study attempted to estimate the frequency spectrum requirements for urban areas in Indonesia until 2019 using a different approach, namely the goals of Indonesia Broadband Plan as the input parameters and not taking the current and future traffic growth trends into account. In addition, the spectrum requirements estimated in the present study did not incorporate the spectrum requirements for voice communications into the calculation. The voice frequency spectrum requirements to be discussed at the end of this paper were merely based on assumptions by reference to some existing papers. Due the difficulty of obtaining factual data regarding the number of sites per operator and distribution for each category of the type of site (macro, micro and in building). Thus, the present study took an ideal approach by performing coverage dimensioning in order to obtain the maximum area that could be served by a site that eventually would provide the maximum number of users served by a site. Although Indonesia Broadband Plan contains the target achievement between 2014 to 2019, the present study only estimated the spectrum requirements beginning in 2016. It was based on the consideration that the study was conducted in the second half of 2015, so that the study results cannot be used as inputs in the current year.



Assumptions: Data traffic growth of 60% per year and site growth of 28.8% per year

Figure 1. Estimates of spectrum requirements from 2011 to 2019 (Directorate General of SDPPI, 2014)

2. Literature review

There are differences in the definition of broadband access speed in the respective countries in the World. In 2015, the Federal Communications Commission (FCC) redefined the minimum speed for broadband services, amounting to 25 Mbps for downloading and 3 Mbps for uploading. This definition of speed increased from the previous definition that established broadband services as ones with a downloading and uploading speed of 4 Mbps and 1 Mbps, respectively. The redefinition was carried out as part of a progress report of the implementation of broadband services in the United States. In Indonesia, the definition of broadband access is the internet access with assured connectivity, durability and information security as well as triple-play capability with a speed of least 2 Mbps for fixed access and 1 Mbps for mobile access. This definition is stipulated in Presidential Regulation No. 96 of 2014 on the Indonesia Broadband Plan from 2015 to 2019.

2.1. Broadband in the world

In 2010, ITU and UNESCO established a committee called the Broadband Commission for Digital Development aimed at promoting the spread of high-speed and large-capacity broadband technology with the large economic and social benefits. Deployment of broadband network is also claimed to accelerating the achievement of the Millennium Development Goals (MDGs). The Broadband Commission has several targets to achieve by the end of 2015: All countries should have a national broadband plan or include broadband as part of universal access; the price of broadband services should be affordable (less than 5% of the average income per month); 40% of households in developing countries have access to internet and penetration of internet users worldwide of 50% (Broadband Commission, 2014). In Indonesia, there were reportedly as many as 88.1 million internet users until the end of 2014. The number was equal to 34.9% of the total population in Indonesia. Thus, in order to achieve the MDGs, it takes effort to increase penetration by 15.1% (APJII, 2015). Figure 1 shows the estimated teledensity of mobile broadband service user by the end of 2014 which describes the rate of penetration of broadband services per 100 inhabitants. Penetration is highest in European countries (64%), followed by the US (59%) and the Commonwealth of Independent States (CIS) (49%). Those three percentage penetration are above the world's average annual percentage which is in the range of 32%. Meanwhile, the Arab, Asia Pacific and Africa countries have a percentage penetration of broadband services of 25%, 23%, and 19%, respectively. Despite the lowest penetration of broadband services in Africa, but the growth rate is the highest compared to other countries (ITU-D Statistics, 2014).

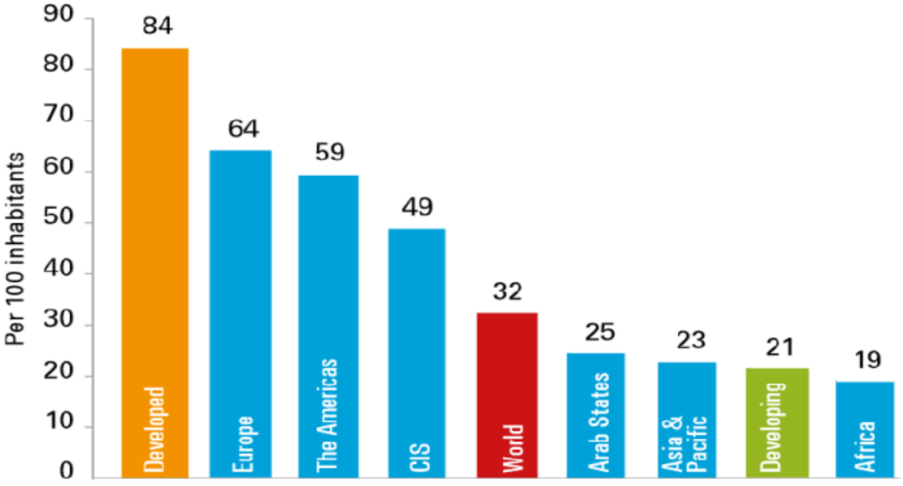


Figure 2. Estimated mobile broadband users per 100 inhabitants (ITU-D Statistics, 2014)

In order to provide an obvious direction in achieving the target of providing broadband services, the government needs to develop and establish policy documents related to the implementation of broadband services that contain measurable goals and detailed strategies to achieve targets in and how to evaluate the achievement in a certain period. In 2014, there were 140 countries with a national broadband plan. Growth in the number of countries with a broadband plan from 2005 through 2014 is presented in Figure 3.

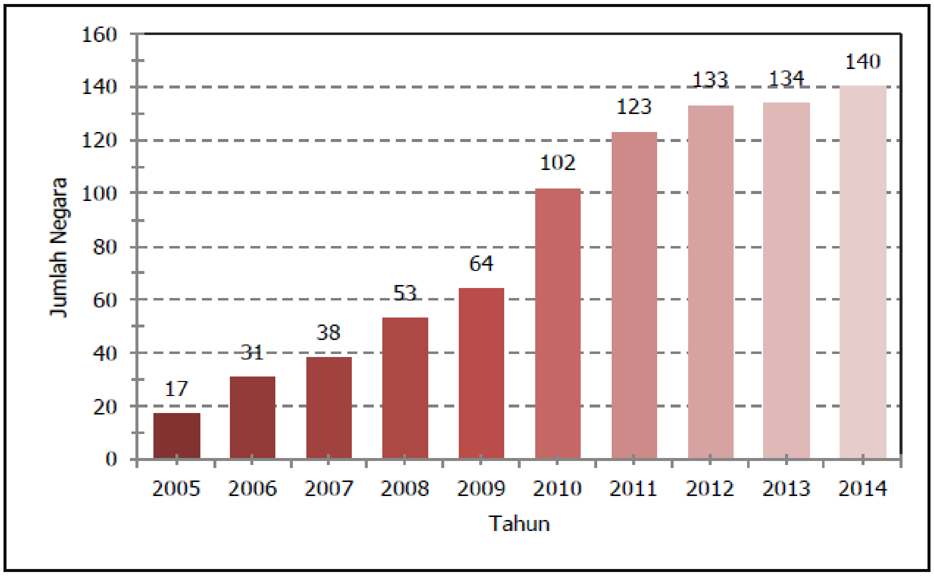


Figure 3. Number of countries with a broadband plan (Biggs, 2014)

2.2. Indonesia Broadband Plan

As with other countries in the world, Indonesia as a country with a quite high growth rate of data communications service usage already formulates and sets its broadband plan as set out in the Presidential Regulation No. 96 of 2014. The 2014-2019 Indonesia Broadband Plan (RPI) was drawn up to provide guidance and direction for the development of national broadband. Synergy and collaboration constitute the keys to the success of national broadband development. In addition to setting the target data access speed for each category of areas, namely urban and rural, the RPI also sets the target maximum service price of 5% of the average monthly income at the end of 2019 and the target achievement of development in 5 (five) priority sectors which include e-Government, e-Health, e-Education, e-logistics and e-Procurement. Table 1 presents the target broadband access speed in Indonesia for 2014 through 2019 for the category of mobile access.

Table 1. Target mobile broadband access speed in Indonesia

Jaringan akses	2014	2015	2016	2017	2018	2019
Urban						
Mobile access						
Speed	512 kbps	512 kbps	1 Mbps	1 Mbps	1 Mbps	1 Mbps
Penetration	93%	100%	100%	100%	100%	100%
Rural						
Mobile access						
Speed	128 kbps	256 kbps	512 kbps	512 kbps	1 Mbps	1 Mbps
Penetration	27%	31%	35%	40%	45%	52%

Source: (Bappenas, 2014)

2.3. Related studies

Numerous studies have been conducted to estimate the frequency spectrum requirements with a variety of objectives and methods used. Rana and Hong (2014) sought to analyze the method of calculating spectrum requirements for the International Mobile Telecommunication (IMT) system developed by the International Telecommunication Union (ITU), namely ITU-R Rec.M1768. According to them, the method was less appropriate when used to estimate the spectrum requirements in developing countries given that the parameters used tended to be available in most countries with a high income and development index. Based on these considerations, Rana and Hong attempted to present an alternative approach to calculation of spectrum requirements based on parameters that could be applied to developing countries. In the study, they sought to apply it to calculating the spectrum requirements in Bangladesh in 2010, 2015 and 2020 to compare it to the results obtained by using the ITU's method. In conclusion, the authors estimated that the spectrum requirement in Bangladesh in 2020 would be 1,220 MHz. This estimate differed from that obtained by using the ITU's method, which was about 1,160 MHz and 1,720 MHz for low and high density, respectively.

Clarke (2014) tried to quantify the economic and technical challenges associated with the fulfillment of the network capacity to keep pace with the growth in demand in the United States. The methods of increased capacity discussed in the study included increasing the spectrum allocation, intensifying spectrum reuse and using technology with higher spectral efficiency (upgrade of technology). In the conclusion the author stated the possible significant spectrum deficit after 2016. In order to keep the deficit under control, the author recommended immediate allocation of additional spectrum of 300 MHz as proposed in the US broadband plan. In addition, in order to keep the wireless service business continues to run well, the analysis showed the need for an additional spectrum allocation of 560 MHz in the period between 2014 through to 2022.

The Coleago Consulting (Coleago Consulting, 2013) conducted a study for GSMA to create a model to estimate the future spectrum requirement and apply it to four (4) different countries, namely the United Kingdom, Brazil, China and the United States. The proposed model required the input parameters such as the real number of macro BTS already installed (N) and the potential future density growth, traffic number (T), the load multiplier factor for very high density site (M) as well as the capacity of each BTS (C). Using this model, the UK, Brazil, China and the United States were estimated to require spectrum of 2,074 MHz, 2,080 MHz, 1,844 MHz and 1,939 MHz, respectively.

Several other studies have also been conducted to estimate the spectrum requirements in a particular country and the estimation results are presented in Table 2.

Table 2. Estimation results of spectrum requirements in several countries presented at the WP 5D meeting

Source	Metodology	Estimation Results Presented in October 2012	Presented in January 2013
(a)	(b)	(c)	(d)
FCC	New	Additional 275 Mhz in 2014	-
Australia	New	1,081 MHz in 2020	-
Russian Federation	New	1,065 MHz in 2020	-
Japan	ITU M.1768	2,020 MHz in 2020	1,140-1,700 MHz in 2020
Da Tang Telecom, Technology & Industry Holding Co. Ltd, etc	ITU M.1768	1,700-2,100 in 2020	-
Huawei Technologies Co. Ltd., etc.	ITU M.1768	1,240-1,880 MHz in 2020	-

		Estimation Results	
Source	Metodology	Presented in October 2012	Presented in January 2013
(a)	(b)	(c)	(d)
GSMA	New	1,600-1,800 in 2020	1,600-1,800 MHz in 2020
India	New	Additional 500 MHz in 2020	-
Telefon AM-LM Ericsson, etc.	ITU M.1768	-	1,160-1,840 MHz in 2020
China	ITU M.1768	-	1,490-1,810 in 2020

Source: (Pang, Wang, Li, & Huang, 2013)

3. Method

The method for calculating spectrum requirements used by Yuniarti (2015) begins with the assumption of access speed requirements for each of the officers involved in Public Protection and Disaster Relief (PPDR), followed by network dimensioning, calculation of user density and calculation of spectrum requirements for the purposes of PPDR in 400 and 800 MHz bands. Rana and Hong (2014) calculated the spectrum requirements using ITU-R-Rec.M1768 with some adjustments related to the assumptions of access speed, rate of increase in penetration and population density. Chung *et al*. (2007) estimated the spectrum requirements by using the ITU's method to modify the value of spectral efficiency and user density. Yoon *et al*. (2012) calculated the spectrum requirements for IMT-2000 technology development and the technology afterwards. In the calculation process, Yoon *et al*. (2012) analyzed the effects of traffic distribution, spectral efficiency and flexible spectrum usage margin to the spectrum requirements. In the present study, spectrum requirements and deficits in urban areas were estimated using the steps as shown in Figure 4.

The data to be analyzed were secondary data obtained from a variety of trusted sources, such as previous studies, Indonesian government agencies as well as related international agencies. Based on the flowchart in Figure 4, frequency spectrum requirements to meet the target broadband plan in urban areas in Indonesia was calculated using the following stages:

a. Determining areas with the highest frequency requirements

   This stage commenced by selecting urban areas as a sample calculation, considering that urban areas have a higher density than the rural areas. In addition, the target penetration and the target data access speed for urban areas were also higher than those of rural areas. This stage was followed by determining the urban areas with the highest levels of density, assuming that the higher the density of population, the greater the data service requirements would be. As a result, the frequency spectrum requirements are also higher. Each frequency channel can be reused by another BTS under certain rules; thus, when an area with the highest requirement can be met, then an area with lower requirement would be met as well.

b. Determining the number of people potentially using broadband services

   The step to be done is to obtain the growth of population in the area determined in step (a) between 2016-2019. The number of people potentially using broadband services is the projected total population minus the number of people less likely requiring broadband services.

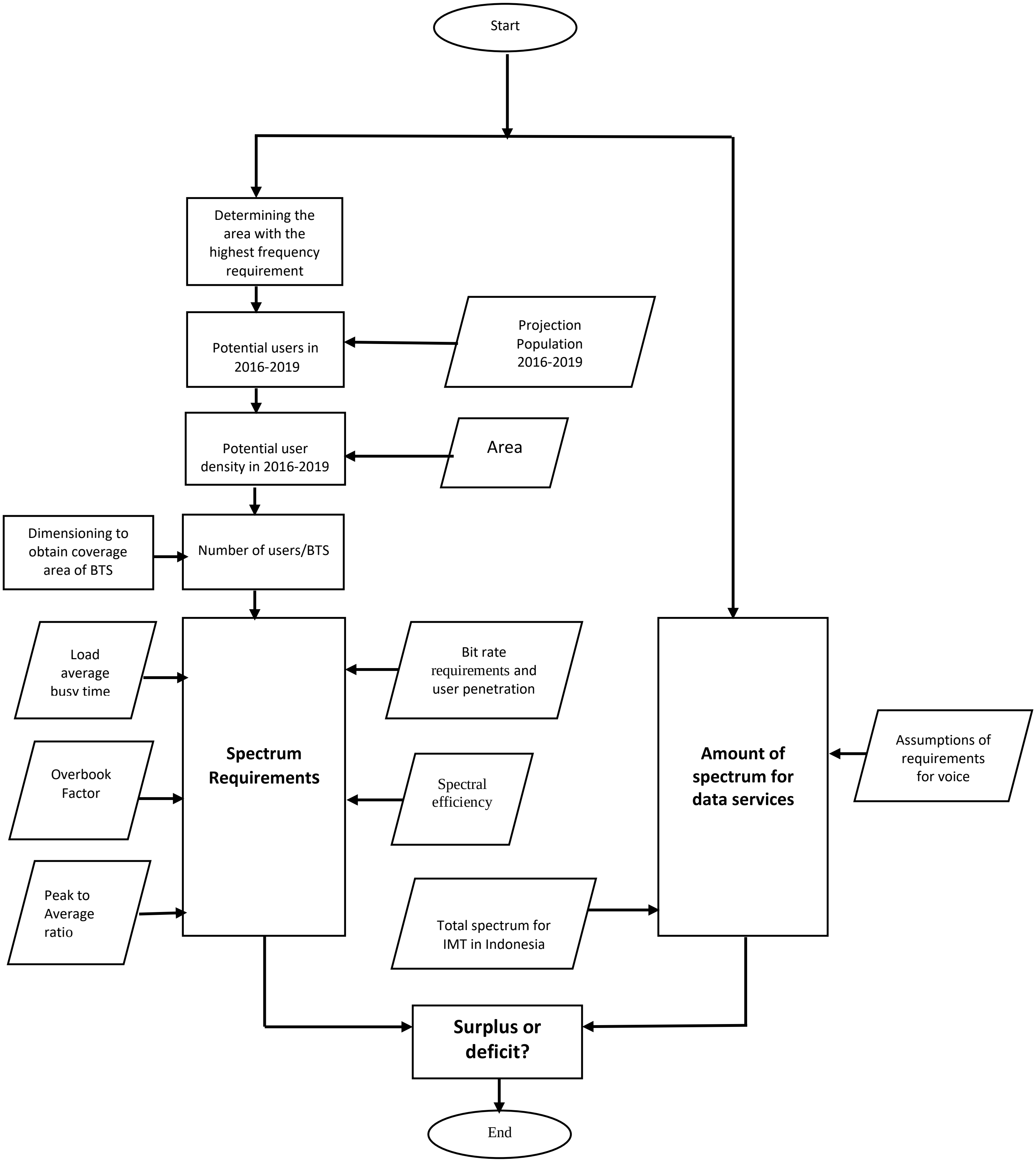


Figure 4. Flowchart of spectrum requirement calculations

a. Calculating density of potential broadband service users
   This phase was carried out by dividing the number of potential users acquired in the previous stage by the area occupied.
b. Calculating coverage of a BTS
   The coverage area of a BTS could be calculated by network dimensioning to obtain the maximum coverage of a BTS. As with the study by Coleago Consulting (2013), the present study only took macro BTS into account.
c. Calculating the number of users per BTS
   After the estimated potential user density (the number of potential users per km^2) was obtained in stage (c) and the coverage area BTS was obtained in stage (d), the number of potential users that could be served by a BTS can be calculated using equation (1).

   Equation (1):

   $$Subs = A \; x \; dens$$

   Where *Subs* is the number of users per BTS (person), *A* represents the coverage area of BTS (km^2) and *dens* is the density of potential users (person/km^2).

f. Calculating the frequency requirements
   According to Holma & Toskala (2011) there are 2 (two) approaches to calculating the number of users that can be served by a BTS adjusted to input data available. The first approach is the traffic volume-based dimensioning as shown in equation (2). The second approach is the data rate based-dimensioning as shown in equation (3).

   Equation 2:

   $$Subs \quad \frac{Cell\ capacity\ [Mbps]}{\frac{8.192Mbit}{GB}\ x usage[GB]}\ x\ Sectors\ x \frac{seconds}{Hour}\ x \frac{days}{month}\ x \frac{max\ load\ (\%)}{busy\ hour\ share\ (\%)}$$

   Equation 3:

   $$Subs \quad \frac{Cell\ capacity\ [Mbps]\ x\ max\ load\ (\%)\ x\ sectors}{User\ data\ rate\ [Mbps]\ x\ overbooking\ factor}$$

   The parameters in the above equations consist of *cell capacity* that indicates the capacity of a cell/sector in Mbps unit; *usage* is the average traffic use per person per month in GB unit. The Traffic used in the calculation is the traffic in the downlink direction. According to the NSN (Nokia Siemens Networks, 2010), if the average users consume 5GB per month, then 3.8 GB are used for communications in the downlink direction. *Sectors* is the number of sectors in a single BTS and *seconds per hour* is the number of seconds per hour or 3600 seconds, *days per month* is the number of days in a month, which is determined to be 30, *max load* is the maximum load of the network to maintain the quality of service (QoS) and minimize latency. The value of *max load* used in the present study refers to Coleago Consulting (2013) ranging from 50% to 70%, and this study took the mean value of 60%. *Busy hour share* indicates the percentage of the total daily traffic occurring at busy hour. Holma & Toskala (2011) provides the value of *busy hour share* parameter of 15%, while the NSN (Nokia Siemens Networks, 2010) of 7%. Equation (3) contains another parameter, *user data rate*, indicating data access speed requirement per user and *overbooking factors* that indicates the maximum number of users who can use a channel simultaneously. Huawei (Huawei Technologies, 2010) adds a parameter *peak to average ratio* (PAR), performed to anticipate the surge in traffic during busy hour. Equations (2) and (3) can be used to calculate the frequency requirements by reversing the parameter number of users originally as the output to become input parameter, and then calculating the amount of *cell* capacity required. The amount of frequency spectrum required is obtained by dividing cell capacity by spectral efficiency the value of which depends on the technology used. Spectral efficiency which has bit/s/H/cell unit indicates how efficiently a technology uses frequency in a wireless communication process. Data available for the present study as listed in Indonesia Broadband Plan are data access speed per user, as shown in Table 1, and the number of users per BTS to be obtained by means of network dimensioning. By determining the PAR value of 20%, the frequency spectrum requirement (*freq*) can be calculated by modifying equation (3) into equation (4).

Equation 4:

$$Freq \qquad \frac{Subs\ \ x\ User\ data\ rate\ [Mbps]\ x\ overbooking\ factor\ x\ (1 + 20\%)}{max\ load\ [\%] x\ sectors\ x\ spectral\ efficiency[bps\ /Hz\ /cell]}$$

g. Calculating the spectrum already allocated based on information from the Director General of SDPPI and assuming the use of spectrum for voice communications, in order to obtain the total amount of spectrum for data communications.
h. Comparing the results obtained in step (f) and step (g) in order to obtain the amount of spectrum deficit or surplus.

4. Result and Discussion

Analysis was performed by following the steps described in the methodology section.

4.1. Determining areas with the highest frequency requirements

Based on the BPS data (BPS, 2014), in 2013 DKI Jakarta was the province with the highest population density in Indonesia with a population density of 15,015 inhabitants per km 2, followed by West Java, Banten, East Java and Central Java with a population density of 1,282, 1,185, 1,147, and 1,104 per km^2, respectively. It is seen that the density difference between Jakarta and other provinces is large and, based on the same source, DKI Jakarta has always been the most populous province in Indonesia. In addition, Jakarta is also a city with the highest level of mobility and economic activity in Indonesia as well as that with a penetration rate of wireless telecommunications services greater than most other regions. Given these considerations, frequency requirements would be calculated by selecting Jakarta as an area of the focus of analysis.

4.2. Determining the number of people potentially using broadband services

Penetration of smartphone usage and data services in Jakarta was highly massive and there was no longer age limit for users. However, in order to avoid overestimation and to describe the condition of urban areas in Indonesia in general, in the present study the number of people potentially using broadband service was a projected total number of population that referred to the BPPN projections (BPPN, BPS, and UNPFA, 2013), with an exception of the population younger than 9 years old and over 65 years. The figures are presented in Table 3.

Table 3. Potential users of broadband access services

Year	BPPN, BPS, dan UNPFA projection			Potential broadband users
	Total population	0-9 years old	> 65 years old	
(a)	(b)	(c)	(d)	(e)
2016	10,277,600	1,814,400	399,300	8,063,900
2017	10,374,200	1,827,700	425,000	8,121,500
2018	10,467,600	1,833,300	453,000	8,181,300
2019	10,557,800	1,829,700	483,600	8,244,500

Source: Data compiled from population projections by BPPN (2013)

Since the entire area of Jakarta is urban and the targets penetration for 2016-2019 for urban areas is 100%, the target number of population served by mobile/wireless broadband access is the same as the projected potential broadband users presented in Table 3.

4.3. Calculating density of potential broadband service user

This stage is done by dividing the number of people potentially using broadband services in all areas of Jakarta by the total area of Jakarta. Based on Regulation of Minister of Home Affairs No. 39 of 2015, DKI Jakarta consisting of 6 (six) regencies/cities, namely the Administrative Regency of Kepulauan Seribu, Jakarta Pusat Municipality, Jakarta Barat Municipality, Jakarta Utara Municipality, Jakarta Timur Municipality and Jakarta Selatan Municipality, has an area of 664,01 Km^2. Assuming that the population potentially using broadband access services are spread evenly across the area of DKI Jakarta and that DKI Jakarta area would not change during the period of 2016-2019, the potential user density would be obtained as presented in Table 4.

Table 4. Potential user density in Jakarta from 2016 to 2019

Year	Potential broadband service users	DKI Jakarta area (Km2)	User density potential
(a)	(b)	(c)	(d) = (b)/(c)
2016	8,063,900	664,01	12,145
2017	8,121,500	664,01	12,231
2018	8,181,300	664,01	12,322
2019	8,244,500	664,01	12,417

Source: Data compiled from step 4.2 and MOHA data (Regulation of the Minister of Home Affairs No.39 of 2015)

4.4. Calculating coverage of a BTS

In order to determine the coverage of a BTS, the Maximum Allowable Path Loss (MAPL) or the maximum path loss occurring in the process of sending and receiving information between a transmitter and receiver should be determined first. The calculation of MAPL is presented in Table 5. MAPL was calculated on uplink direction (UE to BTS) considering that the the transmitting power of the EU was much smaller than that of BTS. This was to ensure the signal strength received on both directions (uplink and downlink) was above or equal to the sensitivity level of the device.

Table 5. Calculation of maximum path loss

Variable	Unit	Value	Symbol
Transmitter (UE)			
UE TX Power	dBm	23	A
Tx antenna gain	dBi	0	B
Body Loss	dB	1	C
EIRP (dBm)	dBm	22	d=a+b-c
Receiver (Base Station)			
Noise figure	db	5	e
Thermal noise	dbm	-106.99	F=k*T*B
Receive noise floor	dbm	-101.99	g=e+f
SINR	db	-7.00	h
Receiver sensitivity	dbm	-108.99	i=g+h
Interference margin	db	2.00	j
Cable loss	db	2.00	k
Rx antenna gain	dbi	12.00	l
MHA		2.00	m
Maximum path loss	dB	139.99	n=d-i-j+k+l-m
Log-normal fading margin	dB	7.30	o
Soft handover gain	dB	2.00	p
Indoor loss (dB)	dB	0.00	q
MAPL	**dB**	**134,69**	**r=n-o+p-q**

The value of the parameter thermal noise in table 5 is a logarithmic product of the Boltzmann constant (k), temperature (T), and bandwidth (Hz). The logarithmic equation and the value of thermal noise with k value of 1.38 x 10^{-23} J/K, a temperature of 290 K and a bandwidth of 5 MHz are presented in equation 5.

Equation 5:

$$\begin{aligned} \textit{Thermal noise} &= 10\,x\,(\log(1.38\,x\,10^{-23}) + \log(290) + \log(5{,}000{,}000)) \\ &= -137.45 \text{ dB} = -106.99 \text{ dBm} \end{aligned}$$

The maximum distance of an EU emission can be obtained by first determining the appropriate propagation model. Based on the ETSI (2015), there are 44 working frequency bands of E-UTRA. The lowest frequency is at the lower limit of band 31 of 452.5 MHz, the highest frequency is at the upper limit of band 43 of 3,800 MHz band. In the present study, the middle frequency (between the highest and lowest frequencies) was used as the input value of the variable frequency, which was 2,100 MHz. Antenna height was set at 30 m for BTS antenna and 1.5 m for user antenna. Referring to the ECC-CEPT's guide for the selection of propagation models (ECC-CEPT, 2008), the extended Hatta propagation model or the Okumura-Hatta propagation model is the most suitable for use in this study. The Hatta-Okumura model equation for frequencies of 2000 MHz to 3000 MHz is shown in equations (6) to (10).

Equation 6:

$$\begin{aligned} L_u = {} & 46{,}3 + 33{,}9 log\,(2000) + 10\log\left(\frac{f}{2000}\right) - 13{,}82\log(\max\{30, Hb\}) \\ & + [44{,}9 - 6{,}55\, Log(\max\{30, Hb\})]\,(\log(d))^{a} - a(Hm) - b(Hb) \end{aligned}$$

Equation 7:

$$a(Hm) = (1{,}1\log(f) - 0{,}7).\min\{10; Hm\} - (1{,}56\log(f) - 0{,}8) + \max\{0; 20\log\ (\frac{Hm}{10})\}$$

Equation 8:

$$b(Hb) = \min\{0; 20\log(\frac{Hb}{30})\}$$

Equation 9:

$$a = \begin{cases} 1 & d \leq 20\ km \\ 1 + (0{,}14 + 1{,}87x10^{-4}xf + 1{,}07x10^{-3}Hb)(\log\frac{d}{20})^{0{,}8} & 20\ km < d < 100\ km \end{cases}$$

Where:

Lu = MAPL = Total loss (dB)

f = Frequency (MHz)

h_b = Height of base station antenna (m)

h_m = Height of mobile station antenna (m)

d = distance between MS and BS (km)

Equation 10:

$$d = \log^{-1}\left(\frac{MAPL - 46{,}3 - 33{,}9\log(2000) - 10\log\left(\frac{f}{2000}\right) + 13{,}82\log(\max\{30, Hb\}) + a(Hm) + b(Hb)}{44{,}9 - 6{,}55\,Log(\max\{30, Hb\})}\right)$$

Note: Equation (10) is derived from equation (6) to calculate the distance of range from BTS

Using equation (10), the maximum distance between BTS and UE (d) could be obtained, which is 0.81 km. Equation (11) was used to obtain the maximum coverage area per base station used, assuming that all BTS had three sectors. Thus, the coverage area of a BTS was 1,271 km^2.

4.5. Calculating the number of users per BTS

User density per BTS is the product of coverage area of a BTS obtained from step (4.4) and the potential user density (the value obtained in step (4.3)). Using equation (1), users per BTS between 2016 and 2019 was obtained, which was 15,440, 15,549, 15,665 and 15,786 individuals, respectively.

4.6. Calculating the frequency requirements

The next stage was to calculate the amount of frequency spectrum required to keep pace with the growth in data traffic in urban areas. The present study used frequency reuse (1,1,3), meaning that in one cluster there is 1 (one) BTS with 3 (three) sectors with the same frequency channel. Referring to equation (4), calculation of spectrum requirements would require input values such as the number of users per BTS, the target access speed per user, penetration, overbooking factor and spectral efficiency. The number of users per BTS was obtained in step 4.5, while the access speed per user and the percentage penetration was adjusted to the target Indonesia Broadband Plan as shown in Table 1. In this study, the overbooking factor was set at 20, meaning that a single service could be used jointly by a maximum of 20 customers.

Sri Aryiyanti (2015) estimated that LTE penetration for Jakarta Selatan area for the periods of 2016 to 2019 was 5.11%, 6.08%, 7.24% and 8.63%, respectively. The present study assumed that the estimated penetration of 4G LTE in the whole area of Jakarta was the same. Thus, the estimated penetration for South Jakarta would reflect the estimated penetration throughout DKI Jakarta. In addition to LTE, the fulfillment of the target RPI for wireless data communication can also be done using 3G technology. Thus, this study took 3G technology into account. moreover, 3G is predicted to remain dominating DKI Jakarta, even Indonesia. The 3G technology should be able to meet the target capacity and coverage not served by LTE, which amounted to

94.89%, 93.92%, 92.76% and 91.37% of the total potential users of broadband services. The present study did not take 2G technology into account since the data access speed offered has not been able to meet the target RPI.

The next parameter was the spectral efficiency. Since there were two technologies used, then the spectral efficiency value used was the combination of both by weighting the value of the spectral efficiency of 3G and 4G technology with their respective penetration rate. The 3G technology itself continued to grow beginning from the 99 release and continued to increase in terms of spectral efficiency. Due to the limited real data obtained, it was assumed that the 3G technology used in Indonesia was several latest release technology consisting of HSDPA MRxD, HSPA+ 64 QAM and HSPA+ with MIMO-efficiency that had *downlink* spectral efficiency of 0.9 b/s/Hz/cell and 1.05 b/s/Hz/cell, respectively, with an average of 1.2 b/s/Hz/cell. With regard to the use of 4G technology the LTE 2x2 MIMO rel.8 was used, which had a spectral efficiency of 1.4 b/s/Hz/cell (Rysavy, 2014; Rysavy Research, 2013). Weighting each technology against the penetration rate produced a combined efficiency for 2016-2019 of 1.07 b/s/Hz/cell, 1.07 b/s/Hz/cell, 1.08 b/s/Hz/cell and 1.08 b/s/Hz/cell, respectively. Based on equations and input values discussed earlier, the estimated spectrum requirements were obtained as presented in Table 6. It is seen that the frequency spectrum requirements are relatively constant. Additionally, since population growth of DKI Jakarta for 2015-2020 was relatively small, which was an average of 0.9% (BPPN *et al*., 2013), it was also caused by the target penetration and broadband access speed was the same for the periods of 2016 to 2019, amounting to 1 Mbps per user with penetration of 100%. An Increase in spectral efficiency also had no much effect since the increase was not significant from year to year. This was because the penetration of 3G technology (with a smaller spectral efficiency) was projected to dominate relative to 4G.

Table 6. Frequency spectrum requirements

Year	Number of users per BTS	RPI target		Spectral efficiency (bit/Hz/cell)	Downlink frequency spectrum requirement (MHz)
		Speed (Mbps)	Penetration (%)		
(a)	(b)	(c)	(d)	(e)	(f)
2016	15,440	1	100%	1.07	482
2017	15,549	1	100%	1.07	484
2018	15,665	1	100%	1.08	486
2019	15,786	1	100%	1.08	488

Source: Data processed

The Director General of SDPPI in his presentation at the National Coordination Meeting of the Ministry of Telecommunications and Information Technology dated 20 November 2014 stated that in 2014 spectrum of 390 MHz was already allocated, consisting of allocations for downlink and uplink, except for the 2300 band which used the TDD technique, so that uplink and downlink used the same frequencies. However, in fact, the spectrum requirement for downlink direction was much greater since the traffic load it borne was also much greater. The present study assumed downlink communications in TDD technique, in which the 2300 band used 75% of the total spectrum allocated. In the FDD technique, downlink and uplink use a different frequency and the amount of allocation for each of it is a half of the total spectrum allocated. With this assumption, the total downlink spectrum allocation in 2014 was 180 MHz plus to 22.5 MHz originating from 2300 MHz TDD band in order to obtain a total of 202.5 MHz. The presentation of the Director General of SDPPI also showed that in 2015 a total spectrum of 120 MHz was planned to be allocated, in which 40 MHz was from the 800 MHz band, 20 MHz from 2100 MHz band and 60 MHz from 2300 MHz band. The 800 MHz band and the 2100 MHz band used the FDD technique so that the allocation in the *downlink* direction amounted to a half of the total allocation. The 2300 MHz band used the TDD techniques and, as previously assumed, the downlink direction used 75% of the total spectrum allocated. Using those assumption, the total amount of spectrum allocation for downlink up to 2015 was 202.5 MHz in 2014 coupled with 75 MHz in 2015 in order to obtain a total of 277.5 MHz. Calculation of spectrum allocated can be seen in Table 7. Of the total allocations in 2014, 202.5 MHz as shown in Table 7 column (d) was assumed in the 900 MHz band, in which three operators occupying the bands allocated 5 MHz of their frequency for data communication purposes and the remaining 10 MHz for voice communications. At the 1800 MHz band, four operators were assumed to allocate 5 MHz (4x5 MHz) of the frequency they occupy for voice communications and the rest for data communications. For operators that use CDMA technology, voice and data communications use the same spectrum. In addition, the access speed requirements for voice communications were very small, equivalent to a data rate of 16 kbps (Nokia Siemens Networks, 2010). This amount is far below the target data access speed in the Indonesia broadband plan document of I Mbps. With these considerations there is no specific allocation for voice communications to CDMA operators. Using these assumptions, the total spectrum allocation for data communications is the total amount of spectrum of 202.5 MHz minus 30 MHz allocated specifically for voice communications (10 MHz from the 900 MHz band and 20 MHz from the 1800 band) or 172.5 MHz. In 2015, that amount increased by 75 MHz, to reach 247.5 MHz. With such a model of spectrum allocation, the spectrum deficit in the downlink direction in 2016 to 2019 would be 234.5 MHz, 236.5 MHz, 238.5 MHz, and 240.5 MHz, respectively. These deficits would be doubled when the technique used is the FDD technique and when the TDD technique is used the spectrum requirement would be 4/3 or 133.33% of the deficit (assuming the use of downlink direction spectrum of 75% of the total spectrum). Results of the estimation of spectrum requirements and deficits for the periods of 2016 to 2019 in the present study are relatively the same, in contrast to those of Perdana (2009) and Setiawan (2013). Although the estimation results of Perdana (2009) and Setiawan (2013) differ in terms of quantity, but the requirement trend is the same, being likely to rise. This is because the parameters used as input by Perdana (2009) and Setiawan (2013) were also assumed to continue to increase every year. Perdana (2009) assumed that the data access speed requirements increase significantly from year to year and referred to the target speed access in India which was of course different from that in the RPI document. On the other hand, Setiawan (2013) used the input parameters such as traffic estimates assumed to continue to increase by 60% per year. The estimation results of the present study are also different from those generated by the ITU (ITU-R M.2290-0, 2013). Although it is acknowledged that there are differences in the time estimate benchmark, the ITU estimated the requirements in 2020 whereas this study up to 2019; however, the contrasting different estimation makes it impossible to generate the same estimated amount even though the estimation results of this study is continued up to 2020. One distinguishing factor is that the different target access speed in the estimation ITU included the high-speed, even very-high speed, multimedia service category requiring data access speed well above the target broadband speed in Indonesia. The relatively same input parameters for 2016 to 2019 in terms of both speed and penetration (as mentioned in the Indonesia broadband plan) is one of the factors that makes the estimates generated by this study tend to be flat. The growth rate of the population did not have a large impact on the final result given that the value averaged only 0.9% per year (BPPN *et al.*, 2013). Likewise, the increased spectral efficiency did not change much. That was because until 2019 the penetration of 4G (LTE) technology is projected to increase significantly.

Clarke (2014) claimed that increasing network capacity, in addition to increasing spectrum allocation, can also be done by increasing the number of towers. Calculation results indicated that if in 2016 the number of towers increases by 10%, then the total spectrum requirement would fall by 9% and if the number of towers increases by 20%, the total spectrum requirement would decrease by 17%. Data service access in urban and rural areas is relatively different in which the urban areas tend to be higher both in terms of penetration, type of service used, frequency of use and intensity of use. Thus, spectrum requirements in urban areas also tend to be higher than that in rural areas. Therefore, spectrum can be reused, meaning that the same frequency can be used in some different geographical areas by considering the possible interference. Thus, the estimated spectrum requirements generated by the present study can be used as a reference for national spectrum requirements in Indonesia.

Table 7. Spectrum allocation in Indonesia

No.	Frequency band	Spectrum allocation 2014 (MHz)		Additional allocation plan 2015 (MHz)	
		Total	Assumed allocations for downlink	Total	Assumed allocations for dwonlink
(a)	(b)	(c)	(d)	(e)	(f)
1	450	15	7.5		
2	800	32	16	40	20
3	900	50	25*		
4	1800	150	75*		
5	1900	100	50	20	10
6	2100	13	6.5		
7	2300 TDD	30	22.5**	60	45**
	Total	**390**	**202.5**	**120**	**75**

Source: Data compiled from the presentation of the Director General of SDPPI (2014)

* Voice communications are assumed to use 10 MHz from the 900 MHz band and 20 MHz from the 1800 MHz band

** In the TDD band, spectrum allocations for downlink direction are assumed to be 75% of the total

5. Conlusions and recommendations

5.1. Conclusions

In order to meet the target Indonesia broadband plan in urban areas (beyond the spectrum requirements for voice communications) between 2016 and 2019, spectrum frequencies of 482 MHz to 488 MHz in the downlink direction would be required with spectrum deficits in the downlink direction in the same periods of 234.5 MHz, 236.5 MHz, 238.5 MHz and 240.5 MHz, respectively. In order to fulfill it, doubled spectrum would be required if the FDD technique is used and 313 MHz, 315 MHz, 318 MHz and 321 MHz, respectively, if the TDD technique is used. Adding 10% sites in 2016 would reduce spectrum deficits by 9% and if the number of sites are increased 20%, the deficit would be reduced by 17%.

There were no significant differences in the spectrum requirements for the period of 2016-2019. In addition to the same target penetration and access speed in the period, an increase in population growth in the Jakarta area as an area used as the urban area sample would relatively small.

Assuming that the requirements in rural areas are smaller than that those of urban areas, estimation results in the present study could also describe the spectrum requirements in the national scope.

5.2. Recommendations

The current allocation of frequency spectrum should be reviewed, especially in the frequency range specified as the frequency band for IMT in order to obtain information about the range of bands allows for being allocated to meet the spectrum security, so that the target Indonesia Broadband plan, particularly for wireless broadband services, can be reached.

To confirm that the spectrum requirements generated by the present study can illustrate the national spectrum requirements, studies estimating the spectrum requirements in rural areas is warranted with reference to the target RPI.

6. Acknowledgements

The author would like to thank to all those parties who have contributed both directly and indirectly to this study, in particular the Puslitbang SDPPI that facilitated this study.

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