Demand Forecast of 700 MHz Frequency Spectrum for LTE Mobile Broadband Services

Prakiraan Kebutuhan Spektrum di Frekuensi 700 MHz untuk Layanan Broadband Mobile LTE

Priambada Aryaguna[1], Iskandar[2]
[1,2] School of Electrical Engineering and Informatics, Bandung Institute of Technology
[1,2] Jl. Ganesha No.10 Bandung 40132 Indonesia
email:[1] priambadaaryaguna@gmail.com, [2] iskandar@stei.itb.ac.id

INFORMASI ARTIKEL

Received 22nd September 2017
Revised 8th December 2017
Accepted 8th December 2017

Kata kunci :
LTE
Model difusi Bass
Digital dividen

A B S T R A K

Spektrum frekuensi 700 MHz merupakan salah satu kandidat spektrum untuk layanan LTE di Indonesia. Pada awalnya spektrum ini digunakan untuk siaran televisi analog. Setelah periode peralihan digital, ada potensi 108 MHz bandwith *yang dapat digunakan akibat transformasi penyiaran ke TV digital dan kemudian disebut digital dividen. Pada penelitian ini, sebuah model pertumbuhan digunakan untuk memperkirakan kebutuhan spektrum frekuensi untuk LTE. Makalah ini membahas perhitungan kebutuhan spektrum untuk frekuensi untuk layanan LTE dalam parameter seperti kepadatan penduduk, jenis area dimana LTE digunakan, dan penetrasi pelanggan. Kami menggunakan model difusi Bass untuk menghitung kebutuhan spektrum di jaringan LTE. Dalam penelitian ini ada dua kandidat spektrum frekuensi yang dapat digunakan, namun dengan karakteristik dan permasalahannya sendiri. Untuk spektrum di bawah 1 GHz, ada* bandwith *25 MHz di kisaran spektrum frekuensi 800 MHz yang masih digunakan untuk layanan CDMA sampai saat ini. Spektrum 900 MHz juga memiliki* bandwith *25 MHz, namun tetap digunakan untuk layanan GSM. Spektrum frekuensi lainnya, 1900 MHz dan 2100 MHz masing-masing lebar 26 dan 60 MHz, masih digunakan untuk teknologi WCDMA dan penggunaannya masih sangat tinggi.*

Keywords:
LTE
Bass diffusion model
Digital dividend

A B S T R A C T

Frequency spectrum of 700 MHz is one of many candidates for LTE service establishment in Indonesia. At first, this spectrum is used for analog TV broadcasting. After the digital switchover period, there is 108 MHz bandwidth left because of the digital broadcasting transformation which called by digital dividend. A certain growth model is used to demand forecast the frequency spectrum needed for this digital dividend LTE. This paper aims to calculate the spectrum needs for the LTE services within a certain parameter, such as population density, type of area in which LTE is deployed, and subscriber penetration. We used Bass diffusion model to calculate the spectrum needs in LTE network. There are two frequency spectrum candidates which can be used with its own characteristics and problems. For spectrums below 1 GHz, there is a bandwidth of 25 MHz in the range 800 MHz frequency spectrum that is still used for CDMA services. The 900 MHz spectrum also has a bandwidth of 25 MHz and still used for GSM service. Another spectrum i.e. 1900 MHz and 2100 MHz, each of that have the width of 26 and 60 MHz, and still used for WCDMA technology with high utilization.

1. Introduction

Digital dividend is a number of spectrums that is released after the migration of analog services to digital TV broadcasting in the UHF frequency band [1]-[2]. In Indonesia, UHF channel used for broadcasting is starting from 470 MHz to 806 MHz. There are three phases of the digital dividend: the analog switch-off, simultaneous broadcast, and digital switchover.The lack of a single standard that regulates the amount of frequency spectrum to be allocated to digital TV broadcasts after the migration completed, brings some standards proposed by several organizations in the telecommunications world. There are two proposals of frequency channels assignments (FCA) related to digital dividend proposed to the ITU, the European Harmonized FCA (submitted by CEPT) and the Asian Pacific Telecommunity (APT) FCA. Indonesia is one of the countries that follow FCA standard proposed by APT. Spectrum estimation which is predicted in this paper is based on the frequency channel assignment of those proposals. We are unable to estimate the spectrum need without an information of frequency channel assignment developed in the international regulation for mobile broadband. Based on FCA published by APT, for the usage scenarios of FDD mode (see Fig. 1), there is a 90 MHz frequency spectrum for mobile services divided into uplink and downlink (45 MHz, respectively). The frequency spectrum is one of the potential candidates in the implementation of LTE services [3].One of the best models to describe thoroughly about the initiation and development of market adoption of the new service is Bass model. This model considers a population parameter of adopters which divided into two camps, namely innovators, as those who buy or initiate the use of new services, and imitators, those whose participation as an adopter are influenced by innovators. Bass diffusion model is defined by four main parameters as follows, Mrepresents market capacity,prepresents innovation coefficient where p > 0,qis an imitation coefficient where q ≥ 0, andtsrepresents time when a new service is introduced..

In In distinction from the Logistic growth model, the Bass model B(t) introduces the effect of innovators via coefficient of innovation p. Mathematically, the Bass diffusion model can be written by the following equation [4]. Bass model depends on the parameters, such as M – market capacity; p – coefficient of innovation, p > 0; q – coefficient of imitation, q ≥ 0 and ts – time when service is introduced.

$$B(t : M, p, q, t_s) = M \frac{1-e^{-(p+q)(t-t_s))}}{1+\frac{q}{p}e^{-(p+q)(t-t_s))}} \qquad (1)$$

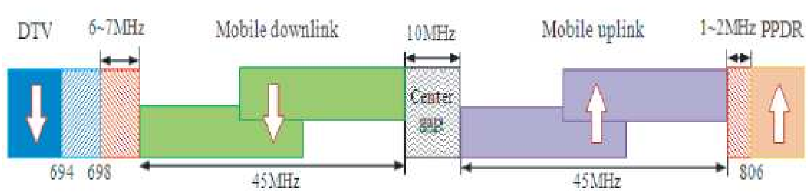

Fig. 1. FDD mode in FCA by APT.

where B is a Bass model, M – market capacity; p – coefficient of innovation, p > 0; q – coefficient of imitation, q ≥ 0 and ts – time when service is introduced.

At Bass models, the parameters M and ts are descriptive parameters and related tomarket conditions but not appropriate to p and q parameters. In addition, the parameters p and q are mutually dependent because these parameters are responsible for the curvature of the curve S. It can be said, the value of the characteristic duration of a service indirectly shaped by the values of parameters p and q. Research by Mladen Sokele [4], puts forward the idea to change the parameters p and q with two new explanatory parameters. Function parameter s describes the vertical shape of the curve while the parameter tstates transformation and time required to reach a certain level of saturation. A saturation level is expected penetration rate of v at the time ts + t. The following expression is there parametrized Bass Model with explanatory parameters instead of p and q [4].

$$B\left(t:M,s,v,\Delta t,t_s\right)=M\frac{1-\left(1+\frac{v}{s(1-v)}\right)^{-\frac{t-t_s}{\Delta t}}}{1+\left(\frac{1}{s}-1\right).\left(1+\frac{v}{s(1-v)}\right)^{-\frac{t-t_s}{\Delta t}}}\qquad(2)$$

2. Methodology

This research comprises of three processes. Fig. 2 shows the processes, those are the calculation of the number of LTE subscribers, link budget calculation, and ends with the calculation of the frequency spectrum requirements.

2.1. LTE Subscriber Calculation

The first process in the whole process of forecasting is to count the number of LTE subscribers. Fig. 3 shows the process of four composing sub-processes. The first sub-process is projecting the population in 2011 to 2021 and was followed by counting the number of potential population of 2011 – 2021. The next sub-process is to calculate the potential population density, which ended with the calculation of the number of LTE subscribers in the year 2014-2021 [5]-[6]. Actually, the number of population was derived from the projection by the historical data, i.e. in this research taken by the year starting from 2011 to the following years up to year 2021.Therefore the number of population was predicted based on about three years back of the current population number.

The population of residents is the main parameter to perform the forecasting where the data was obtained from the results of population census in 2010. Using the population growth rate listed in Table I, the growth of the population in each year can be known.The data in Table I were derived fromThe Central Bureau of Statistcs, Republic of Indonesia for the year of 2010 to 2013 and predicted using Bass Model for the following years.

Given that not all residents of a potential population capable of using LTE service when it is introduced later, it is necessary to limit the number of people taken into account by using two main parameters, the poverty index and, age groups. Poverty index can be defined as the percentage of the poor population to the total population inhabiting an area. (see Fig. 4). Meanwhile, age acts as a filter to limit the age group which estimated to be in the minority user of LTE services. There is no written standard that describes any age group that can use LTE services. However, based on the white paper "Internet Profil Indonesia", age group of 15-65 years is chosen as potential customers (as shown in Fig. 5).By leveraging data population and vast territory of each city and county, the data density can be determined. Density used in the determination of the type of area classification shown in Table 2.

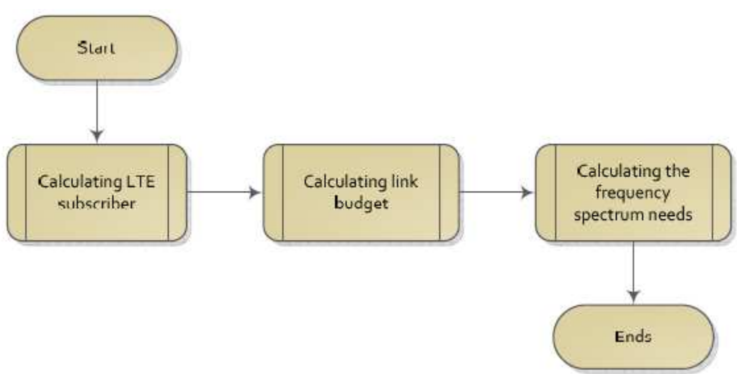

Fig. 2 Flowchart of research.

Table 1. Population Growth Rate

No.	Province	Period		
		2010-2015	2015-2020	2020-2025
1	DKI Jakarta	1.09%	0.90%	0.72%
2	Jawa Barat	1.56%	1.34%	1.12%
3	Jawa Tengah	0.81%	0.68%	0.58%
4	DI Yogyakarta	1.19%	1.08%	0.92%
5	Jawa Timur	0.67%	0.53%	0.38%
6	Banten	2.27%	1.94%	1.60%

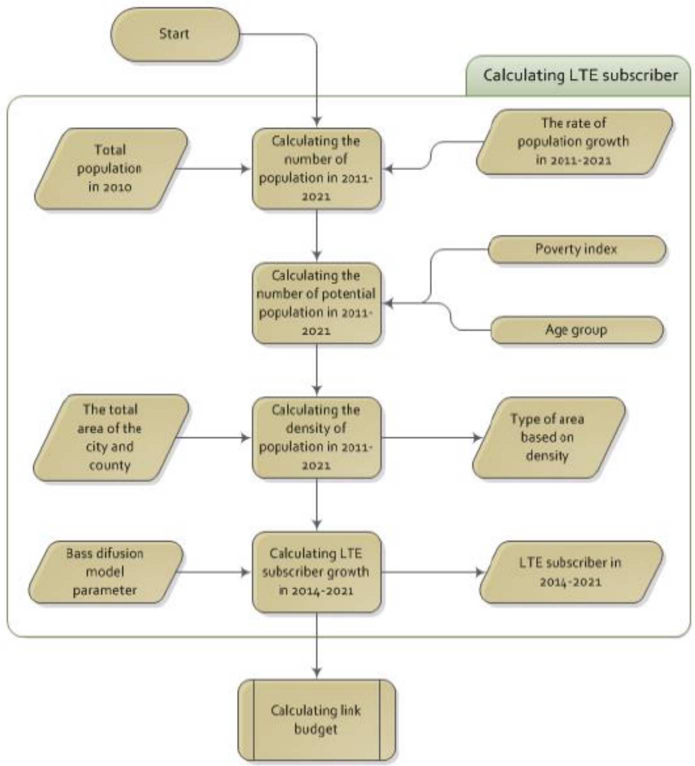

Fig. 3. "Calculating LTE subscriber" process.

Table 2. Area Type Classification.

Area Type	Population Density (ppl/km^2)
Dense Urban	> 4000
Urban	1000 – 4000
Sub Urban	300 – 1000
Rural	< 300

Based on population density data for all administrative districts in Java, not a single counties and cities found with population density below 300 people / km2. Referring to the data, it can be concluded that no rural areas existed in Java, thus the analysis and discussion only includes dense urban, urban, and sub urban. Tomodel the growth of LTE subscribers, historical data subscriber growth ever since 3G services were first introduced (2006) to the year 2013 are used [7]-[8]. Given there were dozens of telecom operators operating in Indonesia, it is necessary to narrow the scope of the data on the three largest telecom operators, Telkomsel, Indosat, and XL Axiata.

From these three annual report of 2006 to 2013, only Telkomsel is displaying data in more detail and provides estimation of data service customers (who later assumed to be 3G service subscribers), separated by the voice and other services. With LTE service subscriber growth outlook may not that much different from the previous generation technology, Telkomsel's historical 3G subscriber data was chosen as LTE subscriber growth model (see Fig. 6).

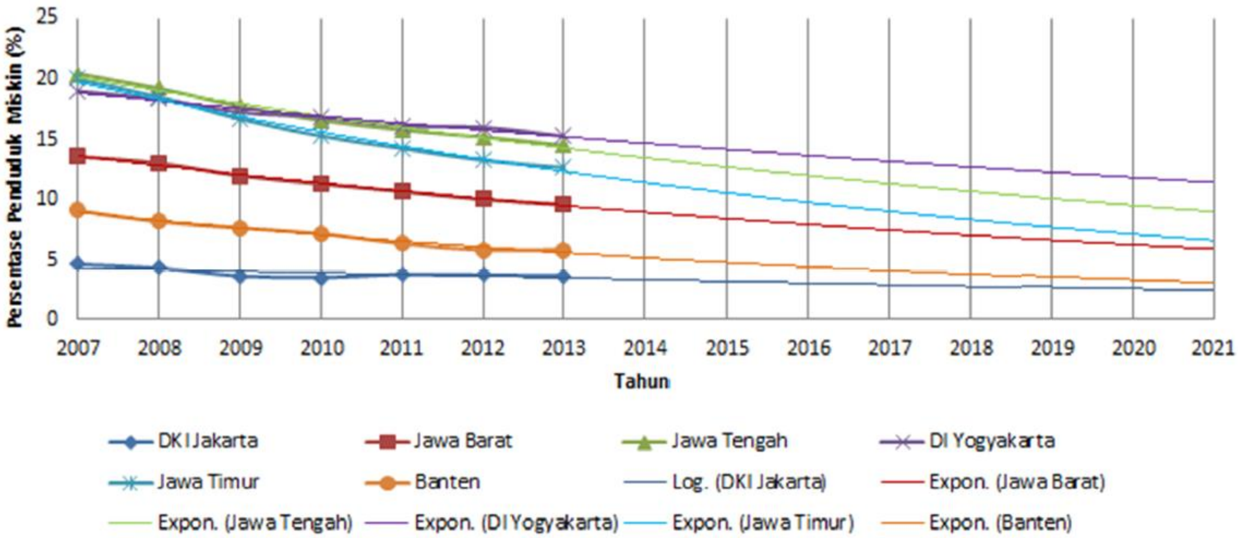

Fig. 4 Poverty index in Java Island.

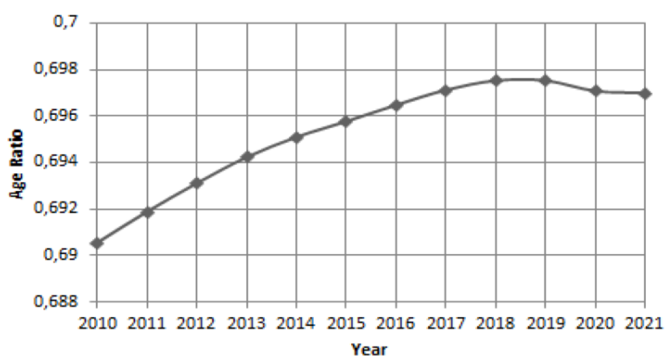

Fig. 5 The ratio of age group 15-65 years.

Table3. Bass Model Parameter.

Parameter	Bass 1	Bass 2	Bass 3
Market (M)	0.1875	0.28125	0.1875
Penetration (v)	0.5	0.57	0.95
Duration(dt)	7	4	3.9
Curve (s)	0.15	0.6	0.2

Because the growth curve in Figure 6 can't be established simply by using a model of Bass alone, three slices of Bass growth model with different characteristics was used. Each model represents the diffusion of customer growth conditions at different time segments. Using three slices of this model, a growth model that resembles the characteristics of its original value can be obtained. Three main parameters for this model are listed in Table 3.We used three different values of Bass Model to estimate the number of subscribers in order to get more precise data. For the case of Telkomsel's 3G subscriber, it is shown that by using three different parameters of Bass Model, the estimation is approaching the actual data.

Fig. 7 shows the results of forecasting with Bass models have values similar to the historical data Telkomsel's 3G customers. The biggest difference occurs only at the beginning of the growth period. However, given the growth in the early period the number of customers is relatively small, this does not significantly affect the future spectrum needs. Thus, the differences that occur are relatively acceptable.

2.2. Link Budget Calculation

Link budget calculation is divided into four sub-processes. Those are the calculation of EIRP, MAPL, radius, and area of the cell as well as the needs of the base station. The relationship between these sub-processes can be observed in Fig. 8.

Equivalent Isotropically Radiated Power (EIRP) is the amount of power radiated by an isotropic antenna to produce the highest power density observed from the direction of the antenna with a maximum gain. Meanwhile, MAPL (Maximum Allowable Path Loss) are the value of the maximum allowable path loss between the sender and the receiver to reach a specific value of Signal-to-Noise Ratio (SNR).

Calculation of EIRP and MAPL can be divided into the case of downlink and uplink. There are fundamental differences between them in the calculation process. In the downlink, eNodeB (term used to call the base station in UMTS technology) acts as a transmitter while the end user (EU) acts as a receiver. As for the uplink, the opposite thing happens. Here, the EU acts as a transmitter and eNodeB becomes the receiver.

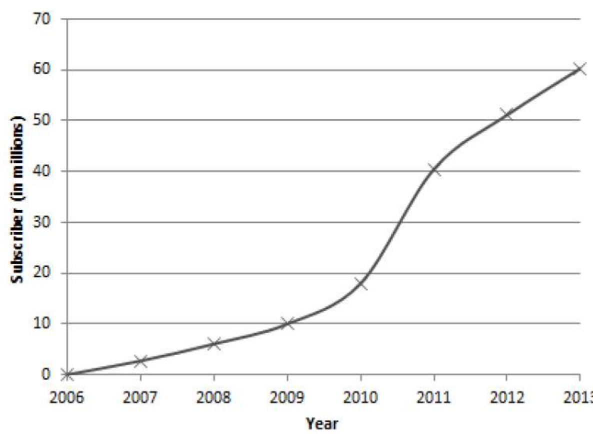

Fig. 6 Telkomsel's 3G subscriber data.

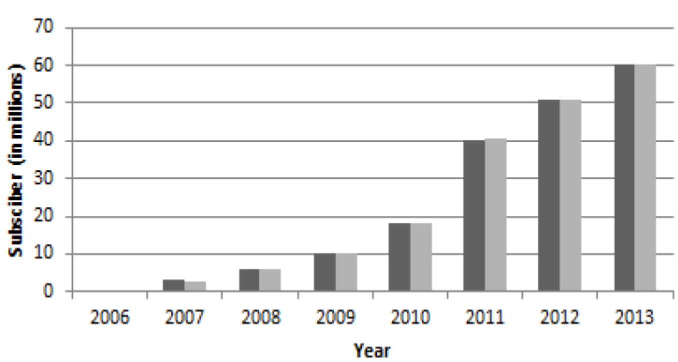

Fig. 7. Comparison of Telkomsel's data and Bass model.

Equation 3 shows the formula forcalculating EIRP whileTable IV defines parameter used in theequationanditsvalueforbothlinks. Obtaining EIRP value, MAPL canbecalculated (see Eq. 4). Table V shows MAPL value on all type of density areas.

$$EIRP = P_t + G_t - L \quad (3)$$

$$MAPL = EIRP + G_r - L \quad (4)$$

There are some differences in loss parameter between EIRP and MAPL. In EIRP, losses are mainly caused by cable and body. Feeder type and length as well as the jumper used, contribute to the value of cable loss in EIRP. In MAPL, there are interference, penetration, overhead loss and fading margin to be taken into consideration. Receiver sensitivity also determines the minimum value of information signal strength that can be processed. Thus, it will lead to a vast amount of difference in loss value between these two parameters.

Digital dividend spectrum frequency is below 1 GHz. There are several propagation models that can be used in the range of the spectrum [4]. In this research, Okumura - Hata propagation model is selected because the model is the most commonly used model for similar interests. Equation 5, 6, and 7 describes Okumura - Hata propagation model. Table 6 shows the propagation parameters used in the simulation to calculate coverage of Base Transceiver Station (BTS). All parameters are referred to the general equation of Okumura-Hata propagation model that corresponds to the area type of BTS being placed. Mobile Station antenna height correction factor $a(h_m)$ were usedbecauseitis not equal to the Okumura-Hata experiments.

$$MAPL = A + B\log(d) + C \quad (5)$$

$$A = 69.55 + 26.16\log(f_c) - 13.82\log(h_b) - a(h_m) \quad (6)$$

$$B = 44.9 - 6{,}55\log(h_b) \quad (7)$$

where A and C is a propagation constant, $f_c$is a frequency, $h_b$is a BTS height, and $a(h_m)$ is mobile station antenna height correction factor.

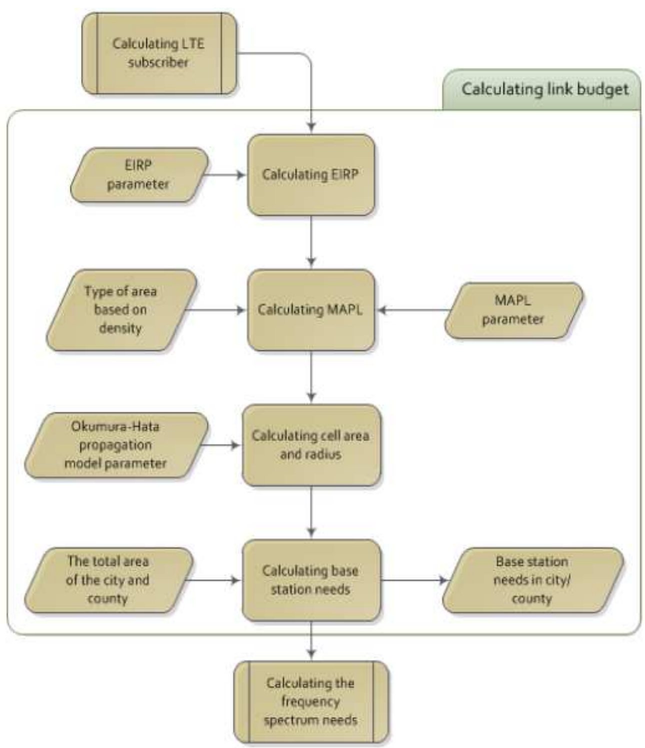

Fig. 8. "Calculating link budget" process.

Table 4. EIRP Parameter.

Parameter	**Unit**	**Downlink**	**Uplink**
Max Power Transmit (Pt)	dBm	43	23
Antenna Gain Transmit (Gt)	dBi	18	0
Loss (L)	dB	3.28	0
EIRP	dBm	57.33	23

Table 5. MAPL Parameter.

Parameter		**Unit**	**Downlink**	**Uplink**
EIRP		dBm	57.33	23
Antenna Gain Transmit (Gt)		dBi	0	18
Loss (L)	Dense Urban		-61.3573	-95.3289
EIRP	Urban	dB	-69.6373	-103.6089
	Suburban		-75.9173	-109.8889
	Dense Urban		118.6873	118.3289
MAPL	Urban	dB	126.9673	126.6089
	Suburban		133.2473	132.8889

Table 6. Okumura-Hata Propagation Model Parameter.

Parameter	Unit	Dense Urban	Urban	Suburban
F_c	MHz	700		
h_b	M	30		
h_m	M	1.5		
$a(h_m)$	dB	-0.0009	0.006	0.006
C	dB	0	0	-9.31
A	dB	123.56	123.57	123.56
B	dB	35.22	35.22	35.22

Table 7. Total Area and Radius Parameter.

Link	Parameter	Unit	Dense Urban	Urban	Suburban
Downlink	D	km	0.73	1.25	3.46
	A_{cell}	km^2	1.37	4.6	31.14
Uplink	D	km	0.71	1.22	3.38
	A_{cell}	km^2	1.31	3.87	29.71

Table 8. Monthly Average Traffic (GB).

Area Type	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Dense Urban	1.5	1.875	2.343	2.929	3.662	4.577	5.722
Urban	1.5	1.875	2.343	2.929	3.662	4.577	5.722
Suburban	1	1.25	1.562	1.953	2.441	3.051	3.814

Table 9. Additional Parameter FOR Frequency Spectrum Calculation.

Parameter	Value
Avg. Sectorspectralefficiency (bps/Hz)	1.7
Busyhouravg. Loading	0.5
Busyhourtraffic	0.1
Numberofsector per site	3
GbtoMb	8192
See in hour	3600
Days in month	30

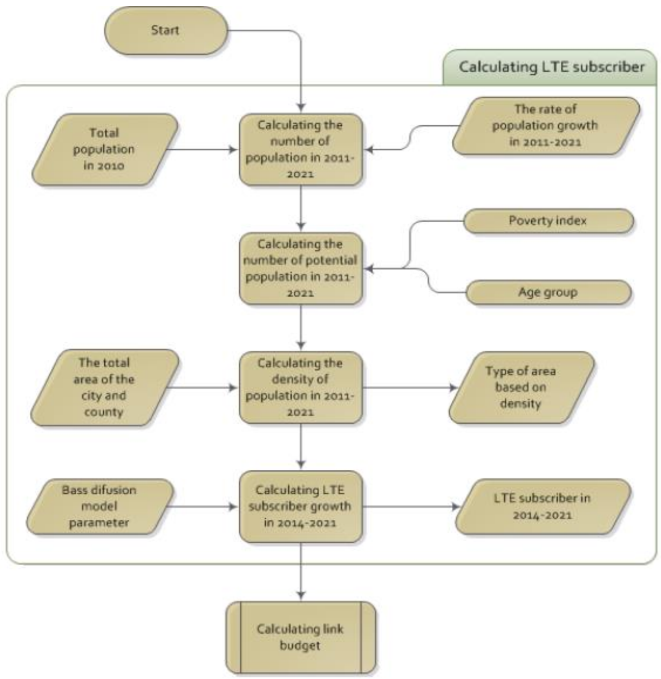

Fig. 9. “Calculating LTE subscriber” process.

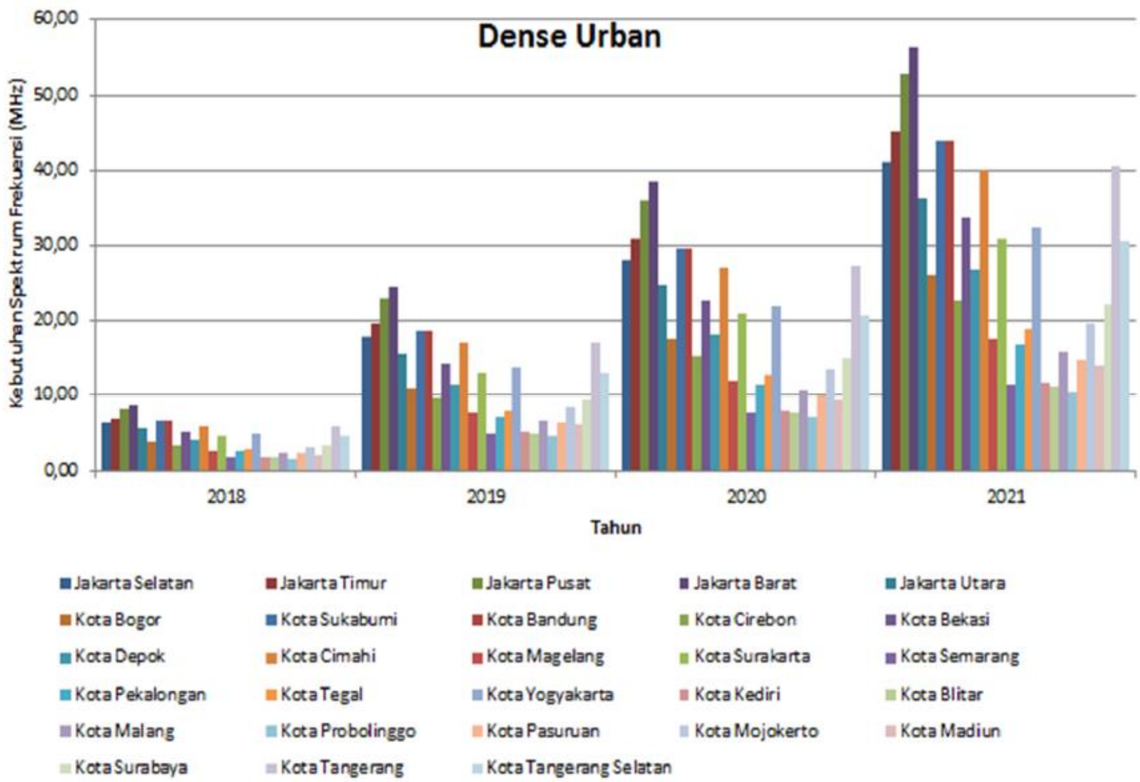

Fig. 10. Spectrum Needs in Dense Urban Areas.

By inputting the value of MAPL from Table 5 into Eq. 5, the radius of the cell can be calculated. Obtaining radius, total area can also be found. The value of these two parameters can be seen in Table 7. Upon obtaining this value, the base station requirements for each administrative area can be calculated.

2.3. Frequency Spectrum Calculation

The last component of the research workflow process is to calculate the need of frequency spectrum. This calculation requires two main inputs that are derived from the previous two processes: data of LTE subscribers and base station requirements for each administrative area. Correlation of various sub-processes contained in this third process can be illustrated with Fig. 9.Calculation of the frequency spectrum can be written in the following equation:

$$f_{need} = \frac{\sum user\, x\, conv_{GB2MB}\, x\, Avg_{UT}\, x\, BH_{Traffic}}{BS_{num}\, x\, eff\, x\, conv_{s/hr}\, x\, BH_{load}\, x\, conv_{d/m}\, x \sum sector} \quad (8)$$

Where:

f_{need} : frequency spectrum needs in a certain period(MHz),
$\sum_{user}$: the number of subscribers in certain period(people),
$conv_{GB2MG}$: GB to Mb conversion,
Avg_{UT} : average user traffic per month (GB/month),
$BH_{Traffic}$: total traffic during busy hour,
BS_{num} : the number of base station,
eff : average sector spectral efficiency (bps/Hz),
$conv_{s/hr}$: second to hour conversion,
BH_{load} : base station highest utilization during busy hour,
$Conv_{d/m}$: days to month conversion, and
$\sum_{sector}$: the number of sector in base stations.

The first parameter that must be determined is the average traffic for LTE subscribers every month. By benchmarking the average traffic in the USA, it’s value is assumed to be 1.5 GB for dense urban and urban areas, as well as 1 GB for the suburbs. CAGR (Compound Annual Growth Rate) used is 25% (see Table 8). In addition to these parameters, there are several other parameters defined in Table IX.

3. Result and Discussion

Even though the calculation of a certain model used in this research employs 2014 data as the starting point, as the availability of new 700 MHz spectrum can only be fully realized in 2018, the analysis narrowed to between 2018 and 2021.This spectrum requirement estimation is based on the methodology explained in Section II and devoted to represent the city in Indonesia that cover the different type of city, such as Dense Urban, Urban, and Sub Urban environment.

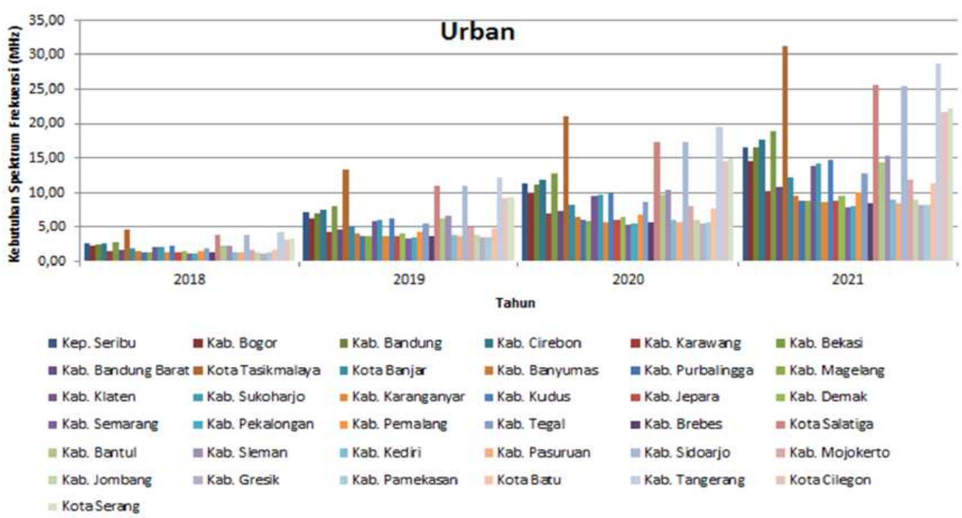

Fig. 11. Spectrum Needs in Urban Areas.

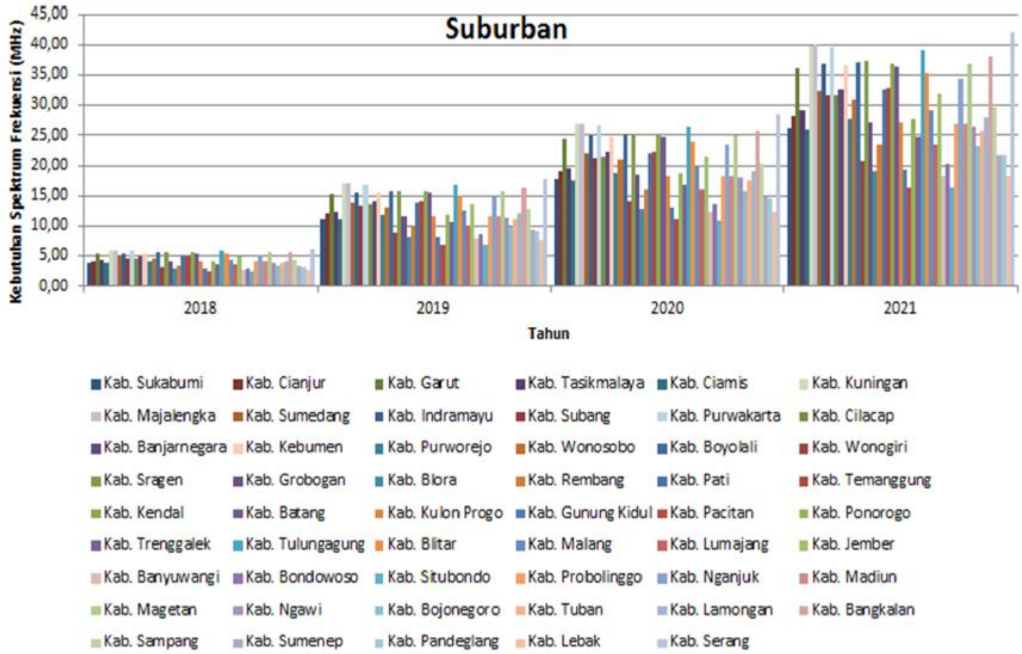

Fig. 12. Spectrum Needs in Suburban Areas.

3.1. Spectrum Needs Based on Area Density

The need of the frequency spectrum in dense urban areas is the highest when compared to other types of areas. Administrative regions in the province of Jakarta have the highest frequency spectrum needs. West Jakarta administration area is dense urban areas with the highest frequency spectrum needs. Lowest frequency spectrum needs can be found in the town of Probolinggo in East Java Province. In detail, the needs of the frequency spectrum in various cities and counties with dense urban types in Java can be observed in Fig. 10.Urban area has the frequency spectrum needs of the lowest average when compared to the other types of areas. Figure 11 details the frequency spectrum needs of each city and county with urban types in Java Island. County of Semarang in Central Java is an urban area with the lowest frequency spectrum needs. On the other hand, The City of Tasikmalaya in West Java province is urban administrative regions with the highest spectrum needs.Suburban areas have an average frequency spectrum needs lower than dense urban, but higher than urban areas. Based on the data contained in Fig. 12, County of Situbondo in East Java is the administration area with the lowest frequency spectrum needs. The highest spectrum needs can be found at Serang City in Banten Province.

3.2. Maximum Spectrum Needs

ITU-R M.1768-1 Recommendation introduced the method of calculation of the frequency spectrum by type of population density (dense urban to rural). Because each region is spatially distinct, the maximum frequency spectrum needed by an area density refers to the area with the greatest frequency spectrum needs. Given the spectrum calculation method used is closely related to population, by adopting the same principle with the ITU-R M.1768-1, highest spectrum requirements were located in areas with the highest population density. Thus, in the context of planning basedon the density, maximum spectrum need of the urban area is the spectrum needs of Tasikmalaya. The same thing applies to the planning in the context of the province of West Java. Maximum spectrum needs to be used as a reference is spectrum needs of the city of Bandung. Figure 13 shows the frequency spectrum of the maximum demand in various regions.

3.3. Frequency Spectrum Solutions

Assuming the government follows the standards set by APT, as many as 90 MHz frequency band is available for the implementation of LTE services. When using FDD technology, this amount will be divided into two, each at 45 MHz for downlink and uplink purposes. Reviewing the data shown in Figure 12, the allocation of frequency spectrum at 45 MHz is not sufficient for the implementation of LTE in Java until 2021. Lack of frequency spectrum occurs at the end of the period, precisely between 2020 and 2021 Related to the lack of available frequency spectrum, there are some things that can be considered as a solution.

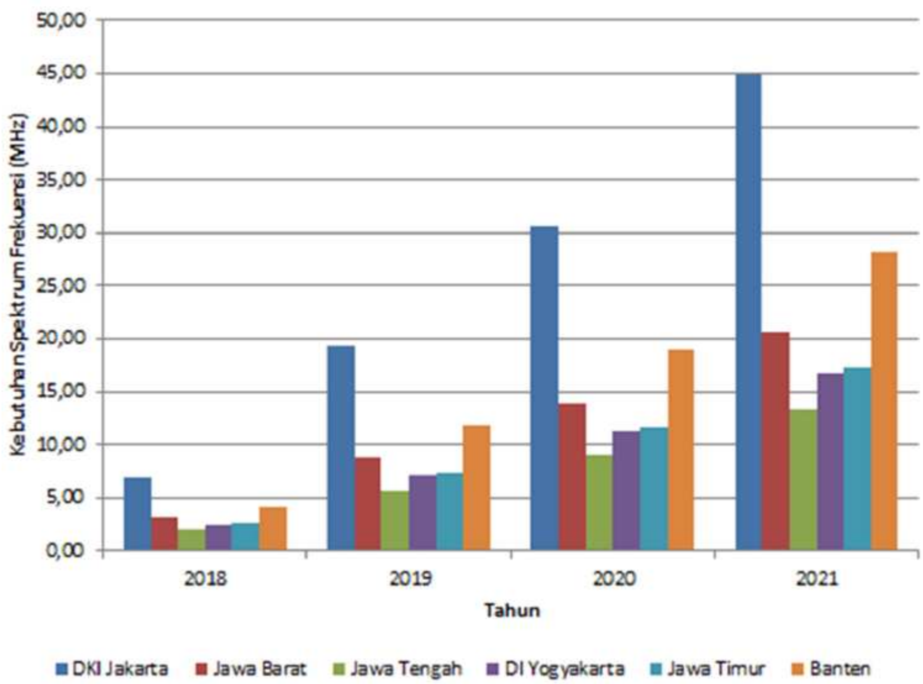

Fig. 13. Maximum Spectrum Needs in Various Regions

The first is the concept of heterogeneous networks. Spectrum shortage occurs because of the disproportionality between the growing numbers of customers with available capacity. In this study, the infrastructure considered is the only macro base station, which is fixed in number throughout the calculation period. In some areas with high population density, the numbers of macro base stations are no longer able to accommodate the growth of the service user. In such circumstances, heterogeneous networks can be used. HetNet (heterogeneous networks) is a combination of different types of mobile network infrastructure, including macro cell, small cell, and Distributed Antenna Systems (DAS).

The second solution is to do sectorization. Adding another infrastructure sometimes isn't optimal in terms of cost. In addition, the use of additional infrastructure increases the risk of interference from the newly added antenna. Thus, an increase in the number of sectors can be considered. At baseline, the number of sectors used is three for each eNodeB. This amount can be increased to six, which has implication for the capacity building of local networks. Theoretically, utilizing six sectors, it can significantly reduce the occurrence of overlap in the internal sector antennas compared to three ones. This reduction will decrease overlap and increase the soft handoff area additional capacity gain.

Although able to increase capacity up to 70-80%, the use of six sectors also raises new problems. Increased capacity and performance obtained from sectorization with higher order is often overshadowed by the cost of implementation. Changes in the design from three sectors into six sectors double the number of antennas to be purchased. It indirectly increases other costs such as transportation and installation. In addition, to make a narrower beam-width, the 33 degrees antenna should be physically larger than the 65 degrees antenna. In many cases, the surface area of the two six-sector antenna is bigger than the three-sector antenna. This can be a problem if the transmitter tower is using lighter materials to reduce the cost of manufacture and delivery.

One of few solutions to this problem is using the Twin Beam antenna. Quantitatively, the antenna used is still three, but the resulting radiation pattern is that of six. Two rays generated by Twin Beam antennas provide a wider range on the side of the sector, able to roll-off more quickly, and increase the ratio of front-to-back. There is an increased gain of 2-3 dB at bore-site produced by Twin Beam antenna compared to the 65 degree antenna. In HSDPA and LTE technologies, the increase in gain is pushing 16 and 64 QAM capacity further in the sector. The increase in throughput is directly proportional to the increase in quality of service to customers. It also allows the user to operate on less power, which contributed to a decrease in the level of interference.

The third is to use other frequency. 700 MHz spectrum is not the only frequency spectrum available for LTE service. Before the digital switchover process is complete, there is another potential frequency spectrum to be utilized. It is based on the plan of arrangement of the 1800 MHz frequency spectrum that has already begun and is scheduled to have been completed at the end of 2014.

Currently, most of the 1800 MHz frequency spectrum is used for 2G services. Of the total 75 MHz bandwidth available at 1800 MHz, Telkomsel for example, has three separate blocks of spectrum (respectively 7.5, 5, and 10 MHz). Indosat has two blocks, 5 MHz and 15 MHz. By structuring (re-farming) the frequency, the operator's spectrum which was separated bya few blocks, can be incorporated to improve the efficiency. Furthermore, it opens the opportunity to implement LTE 1800 MHz services.

In addition to LTE 1800 MHz, there is 2300 MHz frequency spectrum. This spectrum is used for neutral technology. One of the service providers that have a license to operate in this spectrum is Internux. Internux bagged BWA service provider license to use 15 MHz bandwidth for LTE services which is called BOLT. BOLT is the first TD-LTE services in Indonesia, but only to the data service.

In addition to the above two frequencies, there are other several candidates frequency spectrum that can be used, but with the characteristics and problems of its own. For spectrum below 1 GHz, there is a bandwidth of 25 MHz in 800 MHz frequency spectrum which is used for CDMA services today. 900 MHz spectrum also has a bandwidth of 25 MHz, but is still used for GSM services. Another frequency spectrum, the 1900 MHz and 2100 MHz, respectively 26 and 60 MHz wide, is still used for WCDMA technology and the utilization is still very high. 2600 MHz spectrum can also be used as an alternative, given the spectrum is widely used for the provision of LTE services in some other European and Asian countries. This frequency spectrum has a bandwidth up to 70 MHz. However, further studies need to be done for this frequency spectrum because it is still used for satellite services to date.

4. Conlusion

We have studied and proposed the spectrum requirement estimation for the cellular network. In the above study there are two frequency spectrum candidates which can be used, but with its own characteristics and problems. For spectrums below 1 GHz, there is a bandwidth of 25 MHz in the range 800 MHz frequency spectrum that is still used for CDMA services to date. The 900 MHz spectrum also has a bandwidth of 25 MHz, but still used for GSM service. Another frequency spectrum, 1900 MHz and 2100 MHz, each of the width of 26 and 60 MHz, is still used for WCDMA technology and its utilization is still very high. Spectrum 2600 MHz canal so be used as an alternative, given that the spectrum is plentiful used for the provision of LTE services in several European countries and Other Asia. The 2600 MHz frequency spectrum has a bandwidth of up to 70

MHz. However, further studies are needed for the frequency spectrum because it is still used for satellite services to date.

Based on the density, highest spectrum needs in 2021 are: dense urban 56.49 MHz, urban 31.32 MHz, and suburban 42.10 MHz. By province, the highest spectrum needs in 2021, namely: Jakarta 56.49 MHz, West Java 43.97 MHz, Central Java 37.34 MHz, DI Yogyakarta 32.52 MHz, East Java 39.23 MHz, and Banten 42, 10 MHz. Maximum spectrum needs for LTE implementation in Java is 56.49 MHz.

With the use of a macro base station only, 45 MHz bandwidth at 700 MHz frequency spectrum is not sufficient for the provision of LTE services in Java. Frequency spectrum shortage occurs in three administrative regions, namely East Jakarta, Central Jakarta and West Jakarta. Heterogeneous networks, sectorization, and other frequency spectrum utilization are solutions that can be considered related to the frequency spectrum shortage.

References

Ariyanti, S. (2013): Studi Pemanfaatan Digital Dividend Untuk Layanan Long Term Evolution (LTE), Journal, Buletin Pos dan Telekomunikasi Vol. 11 No.3, Kominfo.

Adhiarna, N. (2013) : Mobile Broadband Policy in Indonesia: Implementation Challenges, Presentation, Broadband Workshop Pretoria, Afrika Selatan.

Belhouchet, L. dan Ebdelli, H. (2010) : LTE Technology Performance Evaluation, Presentation, ITU/BDT Arab Regional Workshop on "4G Wireless Systems" LTE Technology.

Sokele, M. (2009) : Analytical Method for Forecasting of Telecommunication Service Life-Cycle Quantitative Factors, Dissertation, University of Zagreb.

Dubari, A. M. (2011): Analisis Skenario Optimalisasi Spektrum Digital Dividend dengan Parameter Valuasi Spektrum, Bachelor Degree Thesis, Institut Teknologi Bandung.

Holma, H. danToskala, A. (2009) : LTE for UMTS – OFDMA and SC-FDMA Based Radio Access, John Willey & Sons, 213-256.

Perdana, A.Y. (2009) :Perkiraan Kebutuhan Spektrum Frekuensi Untuk Implementasi Layanan Mobile Broadband di Indonesia, Bachelor Degree Thesis, Universitas Indonesia, 40-53.

Yonis, A. Z., Abdullah, M. F. L. danGhanim, M. F. (2012) : LTE-FDD and LTE-TDD for Cellular Communications, Proceeding, Progress in Electromagnetics Research Symposium, Malaysia.