Frequency recommendation for long term evolution network implementation using simple multi attribute rating technique

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Article Info

Article history:

Received Jul 31, 2021
Revised Oct 12, 2021
Accepted Dec 29, 2021

Keywords:

Capacity planning
Coverage planning
LTE
Simple multi attribute rating technique
Techno-economy

ABSTRACT

The increasing demand for telecommunication services causes data traffic density. Therefore, in this research, the long-term evolution (LTE) network expansion was carried out using a choice of frequency bands of 700 MHz, 2100 MHz, and 2300 MHz. The analysis was carried out from the technical and economic aspects. Frequency band recommendations were obtained using the simple multi-attribute rating technique (SMART) method. This research was conducted using a case study of Semarang City. Based on the simulation results, the average of reference signal receive power (RSRP) values for frequency 700 MHz and 2300 MHz is in the very good range, while the frequency of 2100 MHz is in the good range. The signal to interference noise ratio (SINR) values for the three frequencies are in the normal category and the throughput values are in the very good category. The techno-economic calculations of the three frequencies, namely the value of internal rate of return (IRR), net present value (NPV), and payback period are included in the business category that is feasible to do. Based on the ranking results, the 700 MHz frequency is the most superior, both in terms of technical and economic aspects.

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1. INTRODUCTION

The increasing demand for services that require high bandwidth and the need for data traffic services on a massive scale makes the network capacity full. Based on data or information from cellular operators, the current condition has occurred in a situation of cellular network density or called congestion so that throughput on the customer side has decreased. According to data from Cisco, by 2023 the population in global will have mobile connectivity over 70%. The mobile subscribers will be increase from 66% of the population in 2018 to 71% of the population in 2023. By 2023, 4G networks will increase by 4% from 42% in 2018 to 46% of total cellular connections. Mobile 4G connections on a global scale from 3.7 billion in 2018 will be increase to 6.0 billion in 2023 [1]–[7]. An example, what happened in Indonesia, the government assessed that there had been network congestion in several big cities in Indonesia such as Medan, Semarang, Yogyakarta, Surabaya, Denpasar, Pontianak, Makassar, Jakarta, Bogor, Depok, Tangerang, and Bekasi, which resulted in a decrease in network quality. These problems make telecommunications networks facing new challenges but also have new opportunities for development. One way to solve this problem is to expand the long-term evolution (LTE) network. However, to expand the network, additional frequencies are needed, there are several frequency options that can be used for the implementation of LTE networks, such as 700 MHz, 2100 MHz, and 2300 MHz [8], [9]. Network expansion needs to be reviewed both from a technical and economic perspective so that the quality of service provided to customers is good and from a business perspective it can generate profits so that it can be a solution to these problems.

2. METHOD

This research was conducted in several stages, the initial stage is calculating capacity planning and coverage planning to determine the number of sites to be simulated to find the value of technical parameters, namely reference signal receive power (RSRP), signal to interference noise ratio (SINR), and throughput. The next stage is to conduct an economic analysis with techno-economic calculations to find the value of internal rate of return (IRR), net present value (NPV), and payback period to find out whether the business is feasible or not. The decision-making method to recommend the best frequency band is done by using a simple multi-attribute rating technique (SMART).

2.1. Capacity planning

Capacity planning serves to determine the number of sites based on customer needs. In capacity planning, predictions of the population for the next few years are carried out using as (1) [10]. Where Po is the current population, GF is the growth factor, and n is the number of estimated years. In addition, it also predicts the number of LTE subscribers by multiplying the number of productive ages with the market share value and LTE penetration from the provider used. Capacity planning also considers the throughput value for each service and cell capacity to determine the number of sites needed.

$$Pn = Po\ (1 + GF)^{n} \tag{1}$$

2.2. Coverage planning

Coverage planning serves to determine the number of sites needed based on the coverage area in the case study. In coverage planning, maximum allowed pathloss (MAPL) is calculated using as (2). Where $EIRP$ is effective isotropic radiated power (dBm) which can be calculated using as (3), RS is receiver sensitivity (dBm) which can be calculated using as (4), IM is interference margin (dB), L_{RX} is reception losses (dB), G_{RX} is reception gain (dB), FM is fading margin (dB), P_{TX} is transmission power (dBm), G_{TX} is antenna gain (dB), and L_{TX} is transmission losses (dB). The coverage planning uses okumura hatta for frequency 700 MHz and Cost-231 propagation models for 2100 MHz and 2300 MHz [11]–[14].

$$MAPL = EIRP - RS - IM - L_{RX} + G_{RX} - FM \tag{2}$$

$$EIRP = P_{TX} + G_{TX} - L_{TX} \tag{3}$$

$$RS = (K\ x\ T\ x\ B) + Noise\ Figure + SINR \tag{4}$$

2.3. Signal to interference noise ratio

Signal to interference noise ratio (SINR) is the ratio of the main signal strength to the resulting interference signal (noise) [15], [16]. The SINR parameter indicates the minimum power level at which the user can still make a call. If the SINR value is below 0 dB it means the received signal strength is bad. Table 1 shown the range of SINR quality values [17].

Table 1. SINR quality value range

SINR values (dB)	Quality
16 to 30	Good
1 to 15	Normal
-10 to 0	Poor

2.4. Throughput

Throughput is a parameter value that shows the speed of service received by the user [18]. The throughput parameter is measured in a certain time unit with the network conditions used to transfer data. Throughput quality can be said to be good if it has a value above 700 kbps and poor quality if it is below 338 kbps. Table 2 shown the range of throughput quality values.

Table 2. Throughput quality value range

Throughput (kbps)	Quality
> 1200	Very Good
700 – 1200	Good
338 – 700	Fair
0 – 338	Poor

2.5. Reference signal receive power

Reference signal received power (RSRP) is an indicator that shows the signal strength of the eNodeB received by user equipment (UE) [18]. The RSRP value is used to show the quality of network coverage in an area, the greater the RSRP value, the better the quality of the signal emitted by the transmitter. Table 3 shown the range of RSRP quality values [17].

Table 3. RSRP quality value range

RSRP values (dBm)	Quality
RSRP ≥ - 70	Excellent
-71 > RSRP > -81	Good
-81 > RSRP > -91	Normal
-91 > RSRP > -101	Poor
RSRP < -101	Very Poor

2.6. Internal rate of return

Internal rate of return (IRR) is a method used to calculate the level of investment. The IRR calculation can be used as a reference to see whether the business to be run will be more profitable or not. IRR also an indicator of the level of efficiency of an investment that serves to clearly determine the rate of return of a business. IRR calculation using as (5). where CF_t is the cash flow per year in period t, C_0 is the initial investment in year zero, n is the number of years, and t is year t.

$$C_0 = \sum_{t=1}^{n} \frac{CF_t}{(1+IRR)^t} \quad (5)$$

2.7. Net present value

Net present value (NPV) is the difference value between expenses and income in a certain period. In general, the NPV calculation is used to project the potential profit that will be generated on an investment or business that will be run. If NPV>0, then the project is feasible, NPV=0, it means the company has neither profit nor loss, NPV<0, then the company is not feasible [19]. NPV calculation can be calculated using as (6). Where CF_t is the cash flow per year in period t, i is the value of interest rate, the initial investment in year 0 is C_0, n is the total of years, and t is year t.

$$NPV = \sum_{t=1}^{n} \frac{CF_t}{(1+i)^t} - C_0 \quad (6)$$

2.8. Payback period

Payback period (PBP) is a period that shows how long the capital issued can be returned. The faster the payback period is generated, the more attractive the business is to run. Payback periods that are too long usually make the business is not feasible to run. PBP can be formulated in as (7). Where PBP is the payback period, C_0 is the required investment cost, and C is the annual cash flow.

$$PBP = \frac{C_0}{C} \quad (7)$$

2.9. Simple multi attribute rating technique

Recommendation decisions are made by comparing each research result from both a technical and economic perspective. The results of the comparison will be ranked for the three frequencies, there are 700 MHz, 2100 MHz, and 2300 MHz. The weighting and decision-making methods are carried out using the simple multi-attribute rating technique (SMART) [20]–[24]. The steps for the SMART method are:

– Determine eligibility parameters.
– Give weight to each parameter using a priority scale from 1-100 (lowest priority to highest priority).
– Calculate the normalization of each weighted parameter using as (8):

$$W_j = \frac{w_j}{\sum_{j=1}^{m} w_j} \quad (8)$$

where W_j is the normalized weight of the criteria to j, w_j is the weight value of the criteria to j, m is the number of criteria, and w_m is the weight of the criteria to m.

- Provide parameter values for each data, parameter values for each of these data can be in the form of quantitative or qualitative.
- Specifies the utility value for each parameter. There are 2 categories of utility values, the first category is "the greater value is more desirable" which is calculated as (9) and the second category is "smaller value is more desirable" with (10):

$$u_i(a_i) = \frac{C_{max} - C_{out}}{C_{max} - C_{min}} x\ 100\% \quad (9)$$

$$u_i(a_i) = \frac{C_{out} - C_{min}}{C_{max} - C_{min}} x\ 100\% \quad (10)$$

where $u_i(a_i)$ is the utility value for the i parameter, C_{max} is the maximum parameter value, C_{min} is the minimum parameter value, and C_{out} is the i parameter.

- Determine the final value, by multiplying the utility value result with the weight normalization result and then adding up the values of all parameters.

3. RESULTS AND DISCUSSION

3.1. Technical analysis

This research used a case study of Semarang City which has a population of 1,653,524 people based on data from statistics Indonesia with an area of 373.3 km^2 [25] which is divided into three types of areas, namely urban, suburban, and rural. The distribution of the population in urban areas is around 51.10%, suburban areas are around 38.08%, and rural areas are around 10.82% of the total population. In this research, the bandwidth used is 15 MHz with the assumption that the provider used is Telkomsel which has a market share value of 59.2% and LTE penetration of 82.36%. The site height in the urban area is 30 m, the suburban area is 50 m, and the rural area is 80 m. After predicting the number of LTE subscribers in the next five years, it is possible to predict the number of sites required based on customer needs. The number of sites required based on the calculation of capacity planning is more than the calculation of coverage planning. The 2300 MHz frequency requires the greatest number of sites compared to other frequencies because the service coverage that can be found by the 2300 MHz frequency is smaller. After knowing the number of sites, a simulation is carried out to determine the quality of service. Figure 1(a) shown the site's prediction based on capacity planning. Figure 1(b) shown the site's prediction based on coverage planning.

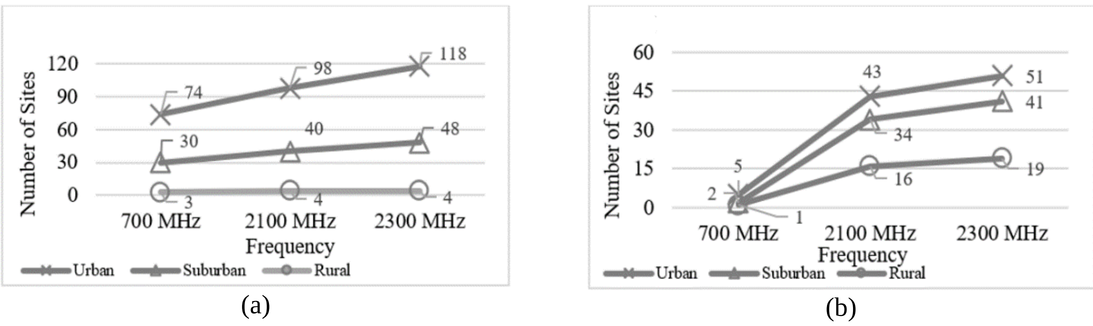
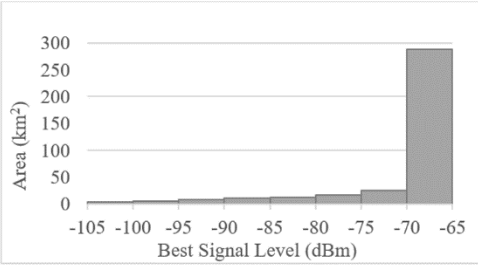


Figure 1. Number of sites by (a) capacity planning and (b) coverage planning

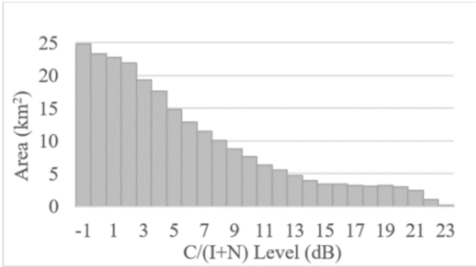
Table 4 shown the RSRP, SINR, and throughput values for the three frequencies. Figure 2 shown the simulation results of the 700 MHz frequency. Figure 2(a) shown the RSRP value. Figure 2(b) shown the SINR value. Figure 2(c) shown the throughput value. The results of the RSRP frequency of 700 MHz are in the very good category, the SINR value is included in the normal category, and the throughput value is in the very good category based on the range value table.

Table 4. Technical parameters value

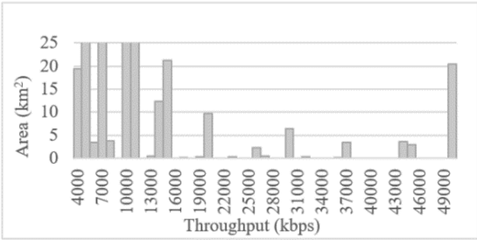
Parameter	RSRP (dBm)	SINR (dB)	Throughput (kbps)
700 MHz	-53.05	6.58	18,656.81
2100 MHz	-72.28	4.53	10,503.56
2300 MHz	-68.08	4.43	10,428.21



(a)



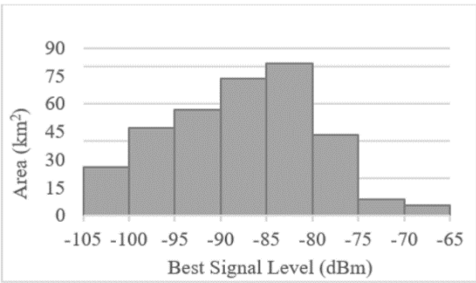
(b)



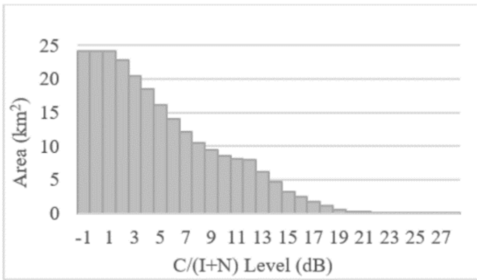
(c)

Figure 2. 700 MHz simulation, (a) RSRP, (b) SINR, and (c) throughput

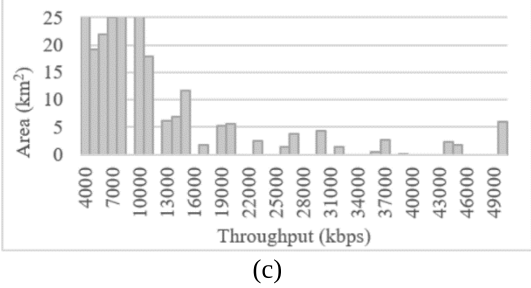
Figure 3 shown the simulation results of the 2100 MHz frequency. Figure 3(a) shown the RSRP value. Figure 3(b) shown the SINR value. Figure 3(c) shown the throughput value. The results of the RSRP frequency of 2100 MHz are in a good category, the results are lower than the frequencies of 700 MHz and 2300 MHz The SINR value is included in the normal category and the throughput value is included in the very good category based on the range value table.



(a)



(b)



(c)

Figure 3. 2100 MHz simulation, (a) RSRP, (b) SINR, and (c) throughput

Figure 4 shown the simulation results of the 2300 MHz frequency. Figure 4(a) shown the RSRP value. Figure 4(b) shown the SINR value. Figure 4(c) shown the throughput value. The results of the RSRP frequency of 2300 MHz are included in the very good category. The SINR value is included in the normal category, which means that the noise is not too disturbing, and the throughput value is included in the very good category based on the range value table.

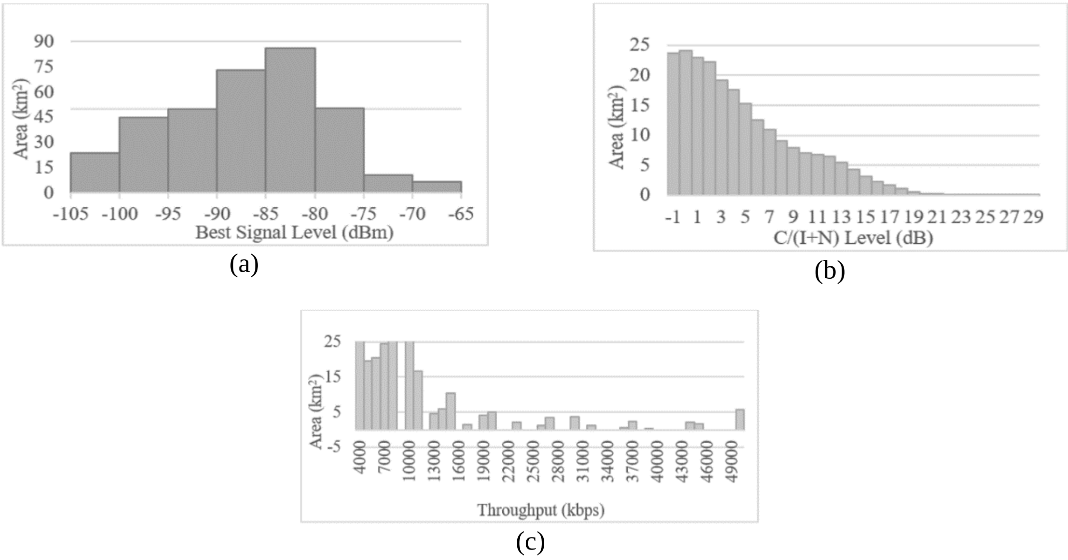


Figure 4. 2300 MHz simulation, (a) RSRP, (b) SINR, and (c) throughput

3.2. Economic analysis

In the economic calculation, it is necessary to predict the capital expenditures (CAPEX) and operational expenditures (OPEX) costs of each frequency for the implementation of the LTE network. The CAPEX value includes the cost of eNodeB, license, pre-installation, and supporting equipment. The OPEX value includes operational and maintenance costs, tower rental, employee costs, and telecommunication usage fees. Figure 5(a) shown the graph of the CAPEX value. Figure 5(b) shown the graph of OPEX value.

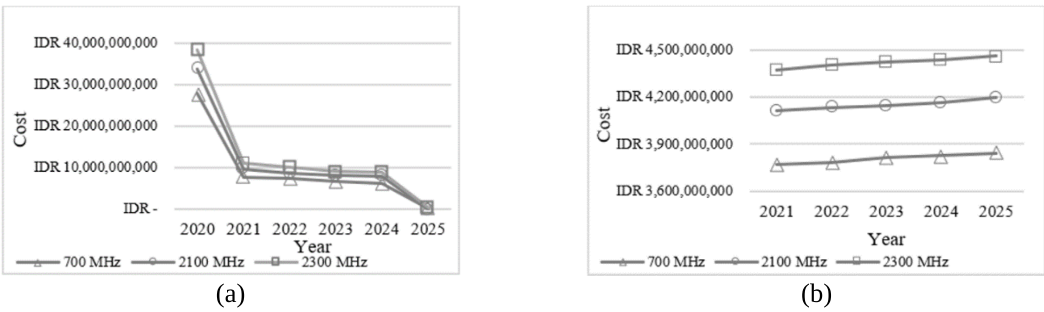


Figure 5. Economic values (a) CAPEX and (b) OPEX

The frequency of 2300 MHz requires the highest cost from both CAPEX and OPEX. The 700 MHz frequency requires the lowest cost compared to the other two frequencies. Based on the projected CAPEX and OPEX values in the next five years, it can be predicted that the business feasibility for each frequency can be seen from the IRR, NPV, and PBP values contained in the Table 5.

Table 5. Economic parameters value

Parameter	IRR	NPV	PBP
700 MHz	49.37%	IDR 38,911,752,567	2nd year
2100 MHz	30.23%	IDR 23,956,362,641	3rd year
2300 MHz	18.19%	IDR 11,956,978,575	4th year

3.3. Technical analysis

The results obtained from the research will be compared by giving a weighting for each frequency. The weighting method is carried out using SMART. The weighting for each parameter is assumed to be equally important so that the weight given is 100 for each parameter. The result of the normalized value of the weighting using as (8) is 0.17. Table 6 shown the utility value of each parameter using as (9) and as (10) and the final value of each parameter.

Table 6. Utility value and final value of each parameter based on smart method

Parameter	Category	Utility values			Final value		
		700 MHz	2100 MHz	2300 MHz	700 MHz	2100 MHz	2300 MHz
RSRP	First category	1.00	0.00	0.22	0.167	0.000	0.036
SINR	First category	1.00	0.05	0.00	0.167	0.008	0.000
Throughput	First category	1.00	0.01	0.00	0.167	0.002	0.000
NPV	First category	1.00	0.45	0.00	0.167	0.074	0.000
IRR	First category	1.00	0.39	0.00	0.167	0.064	0.000
PBP	Second category	1.00	0.50	0.00	0.167	0.083	0.000
Total Final Value					1.000	0.231	0.036

4. CONCLUSION

In conclusion, network congestion can be overcome by expanding or adding LTE networks using additional frequencies. The implementation of the LTE network using the frequencies of 700 MHz, 2100 MHz, and 2300 MHz has different potential feasibility, both from technical and economic perspectives. Based on the final value obtained from the calculation using the SMART method, the 700 MHz frequency has the superior potential both in terms of technical and economic feasibility. The implementation of an LTE network using a frequency of 700 MHz can provide benefits for operators because it has the potential to have greater benefits from economic aspects and benefits for customers because they get better service and signal quality compared to the other two frequencies. So, with the SMART method as a support for decision making, it can be recommended that the 700 MHz frequency band is the most superior for LTE network implementation.

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