Feasibility Study of LTE Network Implementation on Working Frequency 700 MHz, 2100 MHz, and 2300 MHz in Indonesia

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***Abstract*— The increasing density of data traffic leads to an increase in the demand for telecommunication services. Therefore, in this study, the LTE network expansion was carried out using a choice of frequencies of 700 MHz, 2100 MHz, and 2300 MHz. The analysis was carried out from the technical, economic, and sensitivity aspects. Sensitivity analysis was used to determine the minimum ARPU for each candidate frequency. This research was conducted using a case study of the city of Yogyakarta. Based on the simulation results, the average RSRP values for the three candidate frequencies are in the very good range. The SINR values for the three candidate frequencies are in the normal category and the throughput values are in the very good category. The techno-economic calculations of IRR, NPV and payback period for the frequencies of 2100 MHz and 2300 are included in a feasible business, while at a frequency of 700 MHz it is not feasible to do so. The results of the sensitivity analysis show that the frequency of 2300 MHz is a feasible frequency to be implemented for LTE networks with the minimum ARPU and the minimum number of users. This research can be used for the operator as a consideration for the implementation of other frequencies on LTE networks.**

***Keywords*— capacity planning, coverage planning, LTE, techno economy, sensitivity analysis**

I. INTRODUCTION (*HEADING 1*)

Based on information from the Ministry of Communication and Information, currently there has been a density of cellular networks or what is called congestion so that the quality of data services from the customer side has decreased. The government conducted an assessment of the physical condition of cellular mobile telecommunications networks in urban areas to evaluate network conditions in 10 major cities, that is Medan, Semarang, Yogyakarta, Surabaya, Bandung, Denpasar, Pontianak, Makassar and JABODETABEK [1].

One option to overcome the network traffic density is by expanding the LTE network. LTE network expansion can be carried out on other frequencies, that is several candidate frequencies that will be available in Indonesia to be used for LTE network implementation, including the 700 MHz frequency which was previously used for analog TV, the 2100 MHz frequency which has previously been used for 3G networks and the 2300 MHz frequency. for WiMax [2]. The frequencies of 1800 MHz and 2600 MHz are the frequencies commonly used for LTE operations and have been used by Singapore, Hong Kong, South Korea and several countries in Europe. Meanwhile, the operation of LTE networks in Japan and the United States uses a frequency of 700 MHz and 2100 MHz [3]

The proposed research is to compare the alternative candidate frequency bands of LTE that will be used for LTE network expansion, that is UHV (700 MHz), 3G (2100 MHz), and WiMax. (2300 MHz). The comparison is carried out in the perspective of sensitivity analysis of the influence of LTE carrier frequency and the effect of bandwidth on CAPEX and OPEX costs in the research area for urban, suburban, and rural areas in Yogyakarta City. This research will conduct technical analysis by calculating capacity planning and coverage planning as well as techno-economic analysis. The results of this study will later be considered for the operator in terms of the cost difference in implementing each candidate frequency in the implementation of LTE network expansion to overcome traffic congestion by producing a study of the difference in the cost of implementing each candidate frequency for LTE networks.

II. RESEARCH METHODOLOGY

In this study, there are several stages that can be seen in Figure 1

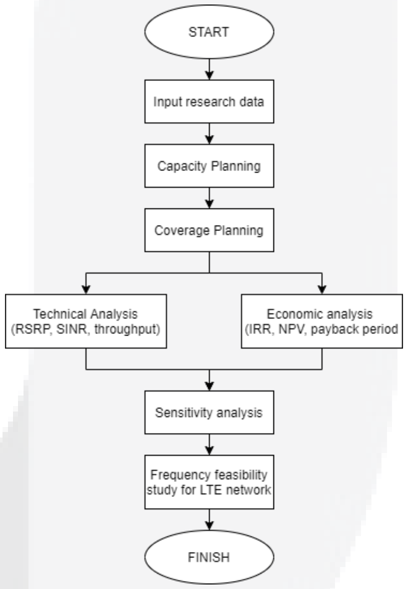


Fig. 1 Flow chart of the basic steps for LTE planning

The first stage is to calculate capacity planning and coverage planning to find the number of sites needed and then simulated on software to find the value of technical parameters, there are Reference Signal Receive Power (RSRP), Signal to Interference Noise Ratio (SINR), and throughput. The next stage is conducting a techno-economic analysis to find the value of the Internal Rate of Return (IRR), Net Present Value (NPV) and Payback Period (PBP) to see the feasibility of the business. The results of the previous research were analyzed using sensitivity analysis to see the feasibility of each candidate frequency in terms of technical and economic aspects as well as looking for the ARPU tolerance value and the minimum number of users for fixed revenue.

A. 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 equation [4]:

$$Pn = Po\ (1 + GF)^n \quad (1)$$

where Po is current population, GF is population growth and n is prediction year. After predicting the number of subscribers, the next step is to predict the number of LTE users by multiplying the productive age population by the market share value and LTE penetration of the provider used. Capacity planning also calculates the throughput value for each type of service and cell capacity to determine the number of sites.

B. Coverage Planning

Coverage planning is part of network planning to determine the number of sites needed based on the coverage area under study. In coverage planning, Maximum Allowed Pathloss (MAPL) is calculated using the equation:

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

$$EIRP = P_{TX} + G_{TX} - L_{TX} \quad (3)$$

$$RS = (K\ x\ T\ x\ B) + Noise\ Figure + SINR \quad (4)$$

where 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), dan L_TX is transmission losses (dB) [5]. Whereas, EIRP is Effective Isotropic Radiated Power (dBm) and RS is Receiver Sensitivity (dBm).

C. Reference Signal Receive Power (RSRP)

Reference Signal Received Power (RSRP) is an indicator that shows the signal strength received by User Equipment (UE) [6]. The range of RSRP quality values can be seen in Table 1

TABLE I RSRP QUALITY VALUE RANGE [7]

Values	Quality
≥ - 70 dBm	Very Good
-71 dBm to -81 dBm	Good
-81 dBm to -91 dBm	Normal
-91 dBm to -101 dBm	Bad
< -101 dBm	Very Bad

D. Signal to Interference Noise Ratio (SINR)

Signal to Interference Noise Ratio (SINR) is a comparison value of signal strength with signal interference from other cells. SINR indicates the minimum power level so that the user can still make a call [8]. The range of SINR quality values can be seen in Table 2.

TABLE II SINR QUALITY VALUE RANGE [7]

Values	Quality
$16\ dB - 30\ dB$	Good
$1\ dB - 15\ dB$	Normal
$-10\ dB - 0\ dB$	Bad

E. Throughput

Throughput is the amount of data access speed that can be done by the user. Total throughput is the average number of bits received for all terminals on a network [9]. The range of throughput quality values can be seen in Table 3

TABLE III THROUGHPUT QUALITY VALUE [10]

Values	Quality
> 1200 Kbps	Very Good
700 Kbps – 1200	Good
338 Kbps – 700 Kbps	Fair
0 Kbps – 338 Kbps	Poor

F. Internal Rate of Return (IRR)

Internal Rate of Return (IRR) is a method used to calculate the level of investment, IRR is an indicator of the level of efficiency of an investment. IRR calculation using equation (5) [11]:

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

where CF_t is cash flow per year in period t, i is the interest rate, C0 is the initial investment in year zero, n is the number of years, and t is year t.

G. Net Present Value (NPV)

Net Present Value or NPV is the difference between the present value of cash flows in and the present value of cash flows out in a certain period of time.. NPV calculation using equation (6) [5]:

$$NPV = \Sigma_{t=1}^{T} \frac{C_t}{(1 + r)^t} - C_o \quad (6)$$

where C_t is the cash flow per year in period t, C_0 is the initial investment value in 0th, and r is interest rate.

H. Payback Period (PBP)

The payback period of an investment is defined as the length of time it takes for the funds embedded in an investment to be fully recovered. PBP calculation using equation (7) [12]:

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

where PBP is payback period, C_0 is the required investment cost, C is annual cashflow.

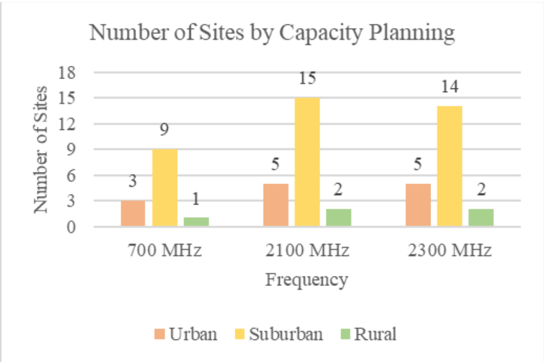
III. RESULTS AND ANALYSIS

A. Technical Analysis

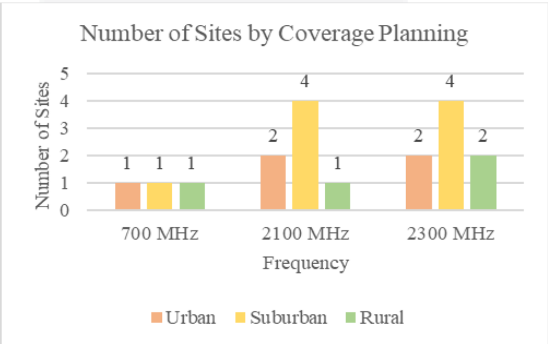
This research was conducted on a case study of the city of Yogyakarta which has a population of 373.535 people with a growth factor of 0,93% based on data from the Central

Statistic Indonesia of the City of Yogyakarta with an area of 32.5 km^2 which is divided into three regional characteristics, there are urban, suburban, and rural [13][14].

In this study, the provider assumption used is Telkomsel which has a market share value of 59.2% and LTE penetration of 82.36% [15]. Market share and LTE penetration values are used to forecast LTE subscribers in the next five years. After predicting the number of LTE subscribers, the number of sites needed is calculated based on customer needs. The results of the calculation of the number of capacity planning and coverage planning are then compared to see the largest number of sites to be implemented. In the results of this study, the number of sites from capacity planning is used because it has the largest number of sites compared to coverage planning. The frequency of 2300 MHz requires the highest number of sites compared to the other two candidate frequencies. After calculating the number of sites, simulation is carried out to determine the quality of technical services for each candidate frequency. The results of the prediction of the number of sites based on the calculation of capacity planning and coverage planning can be seen in Figure 2.



(a)



(b)

Fig. 2 Number of site, (a) capacity planning (b) coverage planning

The results of the software simulation for technical parameters, there are RSRP, SINR, and throughput values can be seen in Table 4

TABLE IV TECHNICAL PARAMETERS VALUE

Parameter	Frequency		
	700 MHz	2100 MHz	2300 MHz
RSRP	-55,62 dBm	-64,35dBm	-64.3 dBm
SINR	5,16 dB	3.17 dB	3.5 dB
Throughput	15,419 Kbps	9,145 Kbps	9,703 Kbps

The map for Yogyakarta City in the simulation and diagram of the RSRP, SINR, and throughput values based on the simulation results for the 700 MHz frequency can be seen in Figure 3. The results of the RSRP value are in the very good category, the SINR value is normal and the throughput is in the very good category.

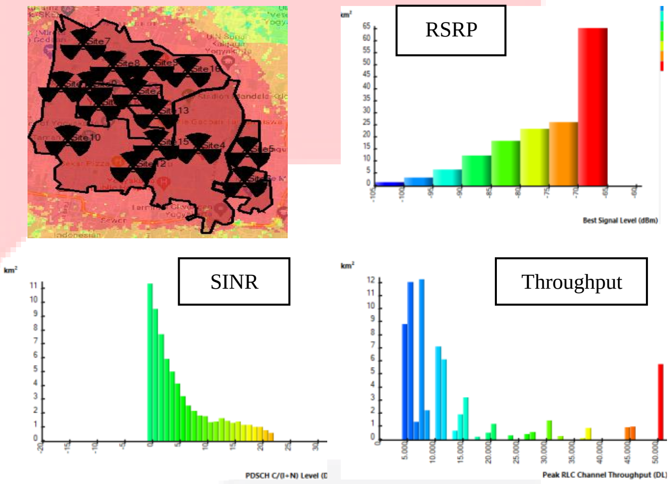


Fig. 3 700 MHz technical parameters simulation

The simulation results for the frequency of 2100 MHz for the RSRP value are in the very good category, the SINR value is normal and the throughput is in the very good category. Map for Yogyakarta City and diagram of RSRP, SINR, and throughput values in simulation results. The simulation results for the 2100 MHz frequency can be seen in Figure 4

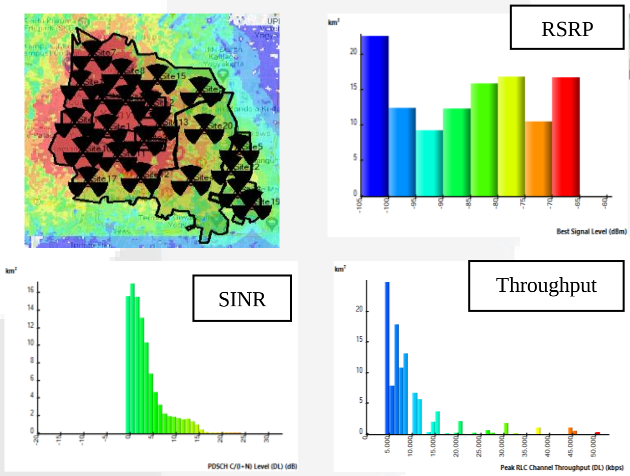


Fig. 4 2100 MHz technical parameters simulation

The simulation results for the frequency of 2300 MHz for the RSRP value are in the very good category, the SINR value is normal and the throughput is in the very good category. The map for the City of Yogyakarta in the simulation and diagram of the RSRP, SINR, and throughput values based on the simulation results for the 2300 MHz frequency can be seen in Figure 5

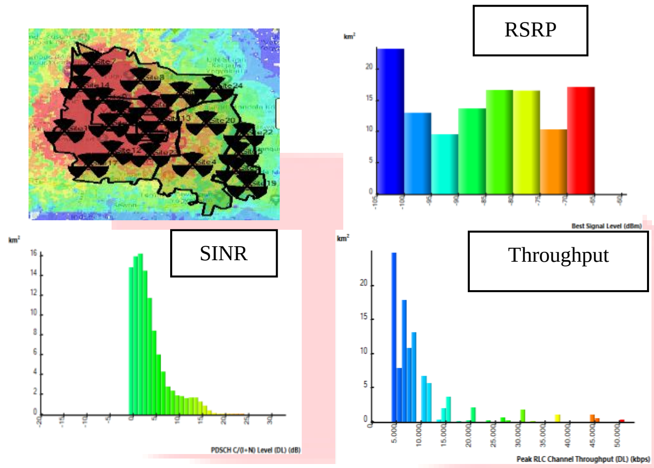
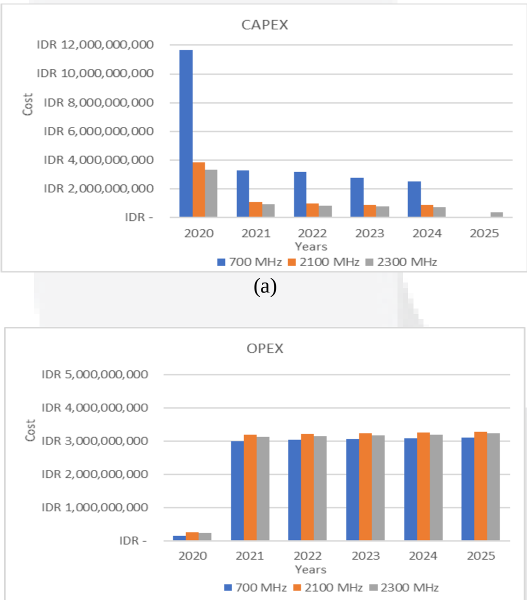


Fig. 5 2300 MHz technical parameters simulation

B. Economic Analysis

In the economic calculation, predictions of the CAPEX and OPEX costs of each candidate frequency for LTE networks are made. In CAPEX there are costs for eNodeB, license, pre-installation, and supporting equipment. OPEX costs include operational and maintenance costs, tower rental, employee salary, and telecommunications fees [16][17]. Inflation fee usage is 1.68% according to Bank Indonesia data in 2020, interest rate is 8% according to Bank Mandiri data in 2020, ARPU (Average Revenue per Usage) value from Telkomsel provider is IDR 44,000 in 2020 [18][19][20]. The graphs for CAPEX and OPEX costs can be seen in Figure 6



(b)

Fig. 6 Economic value, (a) CAPEX (b) OPEX

The 700 MHz frequency has the largest CAPEX value because the LTE network for the 700 MHz frequency is not yet available. While the most extensive OPEX costs are at the frequency of 2100 MHz. based on the CAPEX and OPEX values, it can be predicted that the business feasibility for each frequency can be seen in the IRR, NPV, and PBP values. The results for the IRR, NPV, and PBP values for each frequency can be seen in Table 5

TABLE V RESULTS OF IRR, NPV, AND PAYBACK PERIOD

Frequency	IRR	NPV		PBP
700 MHz	-25.49%	-IDR	10,483,056,336	6 Years
2100 MHz	31.33%	IDR	3,155,437,914	3 Years
2300 MHZ	43.45%	IDR	4,131,404,555	3 Years

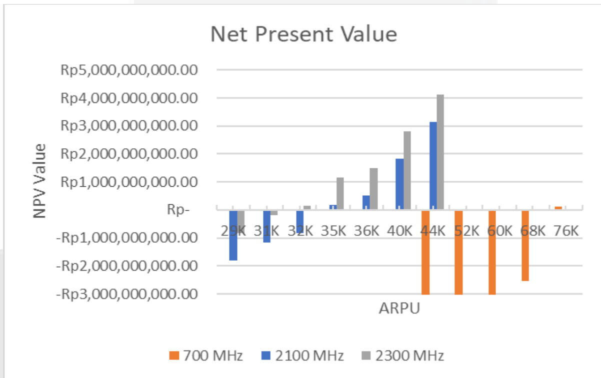
C. Sensitivity Analysis

Based on the results of the data that has been obtained, then a sensitivity analysis will be carried out for the technical side and the economic side. From the technical side, comparisons are made for the parameters of NPV, IRR and Payback Period in the form of percentages to see how many areas have appropriate RSRP, SINR, and throughput parameters and how many areas have less feasible technical parameter values. The table for comparison of feasible and less feasible areas is shown in Table 6

TABLE VI COMPARISON OF TECHNICAL PARAMETERS

Parameter	700 MHz		2100 MHz		2300 MHz	
	Eligible	Not Eligible	Eligible	Not Eligible	Eligible	Not Eligible
RSRP	97.16%	2.85%	69.95%	30.04%	69.81%	30.19%
SINR	83.54%	16.47%	84.39%	15.61%	86.33%	13.67%
Throughput	100%	0%	100%	0%	100%	0%

Furthermore is an analysis of the sensitivity of the NPV to the ARPU cost to obtain the minimum ARPU value and the sensitivity of the NPV to the number of users so that the NPV value can reach a positive value or which means that it is feasible to implement for each frequency of 700 MHz, 2100 MHz, and 2300 MHz. The results of the sensitivity analysis for ARPU and the number of users on the NPV value are shown in Figure 7



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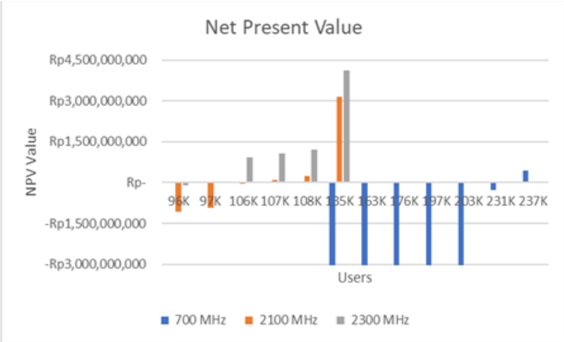

(b)

Fig. 7 Sensitivity of NPV, (a) ARPU (b) Users (2025)

The summary results for the sensitivity analysis with the first option, that is the change in the ARPU value with the assumption that the number of users is 135,978 people in 2025, the minimum number of ARPU can be seen which can be seen in Table 7

TABLE VII THE RESULTS OF THE SENSITIVITY ANALYSIS TO CHANGES IN THE ARPU VALUE

Option 1: Change in ARPU Value			
Frequency	Percentage of eligible area to total area (%)		ARPU Minimum
700 MHz	RSRP	97.16%	IDR 76,000
	SINR	83.54%	
	Throughput	100%	
2100 MHz	RSRP	69.95%	IDR 35,000
	SINR	84.39%	
	Throughput	100%	
2300 MHz	RSRP	69.81%	IDR 32,000
	SINR	86.33%	
	Throughput	100%	

The frequency of 2300 MHz has the minimum ARPU value of IDR 32,000 while the frequency of 700 MHz has the highest ARPU value because currently the 700 MHz frequency does not yet have the infrastructure for the LTE network thus causing it to have a large CAPEX cost. Furthermore, the summary results for the second sensitivity analysis with the option of changing the number of users with the assumption that the ARPU value in 2020 is IDR 44,000 people, the minimum number of users can be seen in Table 8

TABLE VIII RESULTS OF SENSITIVITY ANALYSIS TO CHANGES IN THE NUMBER OF USERS

Option 2: Changes in the number of users				
Frequency	Percentage of eligible area to total area (%)		Users (2020)	Users (2025)
700 MHz	RSRP	97.16%	227,199	237,961
	SINR	83.54%		
	Throughput	100%		
2100 MHz	RSRP	69.95%	102,564	107,423
	SINR	84.39%		
	Throughput	100%		
2300 MHz	RSRP	69.81%	93,476	97,904
	SINR	86.33%		
	Throughput	100%		

Based on the results of the NPV sensitivity analysis on the number of users, it is shown that the 2300 MHz frequency has the minimum number of users compared to the other two candidate frequencies, that is the frequency of 2100 MHz and 700 MHz which has a large number of users so that the LTE network is feasible to implement. Then the frequency of 2300 MHz can be the frequency that has the most potential to build an LTE network. With the analysis using option 1, the minimum ARPU value is IDR 32,000, while if using option 2, the frequency of 2300 MHz has the least number of users when using the ARPU of IDR 44,000. Technical parameters at the frequency of 2300 MHz are also included in the feasible category. Meanwhile, the 700 MHz frequency has better technical parameters compared to the other two candidate frequencies but has the highest ARPU value of IDR 76,000 using analysis option 1 and if analyzed using an ARPU of IDR 44,000, the number of users is 237,961 users so that it is feasible to implement. The three frequencies have the same PBP value, which is 5 years to get the capital back.

IV. CONCLUSIONS

This study concludes that the implementation of an LTE network using a frequency of 700 MHz, 2100 MHz, and 2300 MHz has different feasibility potentials from a technical and economic point of view. Based on the sensitivity analysis results results of sensitivity analysis, the 700 MHz frequency has the best technical feasibility, but the ARPU is quite high and the target number of users is high. This is because the 700 MHz frequency does not yet have a network. Meanwhile, the frequency of 2300 MHz has the minimum ARPU and the minimum target number of users in order to benefit operators as well as good service and signal quality. Therefore with sensitivity analysis it can be recommended that the 2300 MHz frequency band has the best potential for LTE networks both from the technical side and from the economic side.

ACKNOWLEDGMENT

The authors granted a high appreciation to the Postgraduate Program in Regulation & Management of Telecommunication, School of Electrical Engineering, Telkom University and colleague for the support given to complete this research.

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