4G LTE Network Design Around Budi Luhur University Campus And Its Neighborhood Area

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***Abstract*—The need for high speed data and voice is essential nowadays. Long Term Evolution (LTE) is one technology that supports user's need of high speed data and voice. LTE development is still centered in the big cities, it is possible for LTE to start developing in educational area such as middle schools to universities. Budi Luhur University is one potential place for LTE development. The high number of lectures and student activities make students spend most of their time at the campus by accessing social media through their mobile phones, causing the need for high speed data communication is increasing. LTE planning is considered to be developed at and around Budi Luhur University to get reliable high speed access data communication for the students. Planning method and scenario used in this LTE planning is in 900 MHz frequency coverage, the Government assigned frequency for cellular operators. This planning will be simulated using Atoll software. The result of this planning will shows the best area to locate the site according to the need in Budi Luhur University and its surrounding area.**

Keywords-network design, mobile network, telecommunication, Long Term Evolution, network capacity, network coverage

I. Introduction

The need for high-speed data and voice are now starting to rise. One of the technologies that can meet the demands of data and voice communications is the Long Term Evolution (LTE). LTE is a technology that is standardized by 3rdGeneration Partnership Project (3GPP). LTE is designed to provide cheaper spectrum efficiency for the operator, as well as mobile broadband services with high quality to users. LTE technology itself was developed from the Global System for Mobile (GSM) and Universal Mobile Telecommunications System (UMTS), with this technology that delivered more data rate speed increases. To support LTE good facilities, it is also required good planning LTE network to be able meet potential customers demand on high-speed mobile data connection.

Currently, LTE network planning and installation is still centered on certain places such as business centers. The only LTE network planning of public places that have been done are the *Gambir* Railway Station in Central Jakarta [1], this is because the station is a place that is never empty of visitors and the need for fast and adequate data access services. In the future, the University is a place that becomes part of the development of this LTE technology. In addition to the expected high user-level Mobile Station (MS) usage, students also tend to be up to date on the development of gadgets that exist today.

In this study will be conducted to determine the site with some planning method that is based on capacity and based coverage. Scenario planning is to use 900 MHz frequency and bandwidth of 5 MHz. Atoll software simulations is used to provide the best possible result of the planning. With the LTE network planning at the Budi Luhur University, is expected to help mobile operators implement LTE network.

II. The Long Term Evolution Network

Long Term Evolution is a radio access network developed by 3rd Generation Partnership Project (3GPP). LTE is a continuation from WCDMA-UMTS of the Third Generation Network (3G). 3GPP standardized the Long Term Evolution with the aim to develop a system capable of accommodating low-latency high speed data requirement. LTE is designed to be capable of 100 Mbps downlink speed and 50 Mbps uplink speed. It provides cellular and broadband operators with better spectrum efficiency and capacity to support high capacity voice and data access on low latency and operating cost for the forthcoming decade. LTE also covers high speed data for multimedia *unicast* and broadband services [2].

A. LTE Capacity Planning

LTE Capacity Planning aims to design a network with longer usable lifetime based on current and projected future needs. Capacity Planning also aims to define the number of needed cells based on traffic demand in a particular area. Steps for capacity-based network design include:

1. Calculating the number of subscribers a few years into the future.

The designed network should be able to fulfill the traffic growth for the next few years. Therefore, the predicted number of users for the forthcoming years is calculated with:

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

with

P_0 = initial number of residents
Pn = number of residents in the n-th year
GF = growth factor

and the total target user:

$$\Sigma TU = Pn \times A \times B \times C \quad (2)$$

with

ΣTU = Total target user
Pn = number of residents in the n-th year
A = productive age residents
B = Network Operator market share
C = Network Operator LTE users target

2. Calculating the throughput for each services

In LTE data usage, there are various services such as VoIP, video conference, chats, etc. with each service has its own different throughput characteristics. Throughput for each service can be obtained from the following equation:

$$Tmin = ST \times SDR \times BR \times \left[\frac{1}{(1 - BLER)}\right] \quad (3)$$

where

Tmin = Minimum throughput should be provided by the network to maintain service quality (Kbit)
ST = Average duration of each service (s)
SDR = Session Duty Ratio, ratio of transmitted data for each session
BR = Bearer Rate, data rate must be provided by a service application layer (Kbps)
BLER = Block error rate permitted in one session

3. Calculating single user throughput to get the average value

Single User Throughput (SUT) is observed from the LTE user perspective, individual users' habit on using LTE services is very diverse. Throughput per user calculated during rush hour condition is from the following equation:

$$SUT = \frac{(\sum Tmin \times BHSA \times PR \times (1 + PAR))}{3600} \quad (4)$$

where

SUT = Single User Throughput (kbps)
BHSA = Busy Hour Service Initiation
PR = Penetration Rate of the services usage in the area
PAR = Peak to Average Ratio, percentage surge in traffic at rush hour
3600 = time frame of 1 hour (3600 seconds)

4. Calculating network throughput and cell capacity

Network throughput is the overall user traffic demand in the area of interest. Network throughput can be obtained by multiplying the total target user that has been predicted by the value of a single user throughput. The calculation for Netwotk Throughput (NT) is:

$$NT = \Sigma TU \times SUT \quad (5)$$

5. Determining the number of cells needed based on capacity requirement

The capacity of each cell depends on the bandwidth being used, uplink and downlink directions capacities are provided by the following equations:

$$DL\ cap. + CRC = (168 - 36 - 12) \times (Cb) \times (Cr) \times Nrb \times C \times 1000$$
$$UL\ cap. + CRC = (168 - 24 - 12) \times (Cb) \times (Cr) \times Nrb \times C \times 1000 \quad (6)$$

6. Cell Dimensioning

Cell dimensioning determines the number of cells that will be needed to accommodate the traffic in the area of interest. Capacity planning based on the calculation for cell number (Cn) is from the following equation:

$$Cn = \frac{NT\ (bps)}{Cell\ Capacity\ (bps)} \quad (7)$$

While the throughput density (Td) and cell area (Ac) are:

$$Td = \frac{NT\ (bps)}{Area\ (km^2)} \quad (8)$$

$$Ac = \frac{Cell\ Capacity\ (bps/cell)}{Td\ (bps/km^2)} \quad (9)$$

For cells with omni directional antennas, the extent of coverage by each cell can be derived from hexagonal radius:

$$Rc\ (km) = \sqrt{\frac{Ac\ (km^2)}{2.6}} \quad (10)$$

B. LTE Coverage Planning

Radio Link Budget (RLB) is the most important element of coverage based network planning. Coverage based planning will result in maximum allowable loss or attenuation value, also called Maximum Allowable Path Loss (MAPL). MAPL value then compared to the path loss value from the capacity planning by inserting the cell radius into the propagation model. MAPL value can be derived from [3]:

$$EIRP = P_{Tx} - Lc - Ga \quad (11)$$

$$MAPL = EIRP + Ga_{Rx} - Lb - S_{Rx} - M_F \quad (12)$$

where, all in dB:

EIRP = Enthropic
P_{Tx} = Transmitter Power Output
Lc = Cable Loss
Ga = Antenna Gain
Ga_{Rx} = Receiver Antenna Gain
Lb = Body Loss
S_{Rx} = Receiver Sensitivity
M_F = Fade Margin

C. Okumura-Hata Propagation Model

This propagation model is considered the best in terms of accuracy to predict the path loss for early cellular systems [4]. This model is shown by the following equation:

$$Lp(urban) = 69.55 + 26.16\log(fc) + [44.9 - 6.55\log(hBS)]Log(d) - 13.82\log(hBS) - a(hUE)(dB) \quad (13)$$

with

Lp = damping track (dB)
fc = frequency (MHz)
h_{BS} = BTS antenna height (meters)
h_{EU} = user antenna height (meters)
a (Hue) = user antenna height correction factor

For f_c above 400 MHz, then $a(h_{UE})$ or antenna height correction factor of the EU is formulated as follows:

$$a(h_{UE})= 3.2[\log(11.75h_{UE})]^2- 4.97 \quad (14)$$

for dense urban area, and

$$a(h_{UE})=[1.1\log(fc)-0.7]h_{UE}-[1.56\log(fc)-0.8] \quad (15)$$

for urban area.

III. System Planning

The first step in network planning is to collect the condition data of the area. The resulting parameter analysis is then used as input data for the LTE Dimensioning, which consists of capacity-based and coverage-based planning. Both methods have the same objective but from different angles.

A. Capacity Planning

Parameters required in designing networks based on capacity, among others, the population of the next few years, the rate of population growth, the population of productive age, the market share of the operator, as well as the target LTE network user who served in the area shown in Table 1.

TABLE I. Parameter estimation of the number of users

Parameter	Value	Description
The population of campus and surrounding	12400	2015 records
Productive Age Population	9300	75% of the citizens of the campus and surrounding areas (2013)
Population Growth Rate	6%	Forecast for 5 years
Market Share	21%	Network Operator
LTE user coverage target	70%	Assumptions

The parameters used for the calculation of a single user throughput as shown in Tables 2 and 3. Peak to average ratio (PAR) for urban area is 20% [5]. The parameters used to calculate the network throughput is obtained from the value of a single user throughput (SUT) multiplied by the number of the target user at each location.

The parameters used to calculate the capacity of the cells are:

- Frequency: 900 MHz with 5MHz Bandwidth
- Modulation: 64 QAM (code bits = 6)
- Code Rate: 11/12
- Nrb: 25 resource block for 5 MHz bandwidth
- C (MIMO): 2

To determine the extent of coverage and the radius of the cell, the parameters used include:

- Antenna Type: Sectoral
- BS antenna height: 15 meters
- High-antenna UE: 1 .5 meter
- Frequency: 900 MHz

TABLE II. Uplink and downlink models for urban traffic

Traffic Parameters	Uplink				Downlink			
	Bearer Rate (kbps)	***Session Time (s)***	***Session Duty Ratio***	***BLER***	***Bearer Rate (kbps)***	***Session Time (s)***	***Session Duty Ratio***	***BLER***
VoIP	26.9	80	0.4	1%	26.9	80	0.4	1%
Video Phone	62.53	70	0.2	1%	62.53	70	0.2	1%
Video Conference	62.53	500	0.1	1%	62.53	500	0.1	1%
Gaming	31.26	1800	0.5	1%	125.06	1800	0.8	1%
Streaming Media	31.26	1800	0.1	1%	250.11	1800	0.9	1%
Signaling	15.63	7	0.2	1%	15.63	7	0.2	1%
Browsing	62.53	1800	0:05	1%	250.11	1800	0:05	1%
FTP	140.69	600	1	1%	750.34	600	0.5	1%
E-mail	140.69	50	0.5	1%	750.34	50	0.5	1%
P2P file sharing	250.11	60	0.1	1%	750.34	60	0.1	1%

TABLE III. Penetration Ratio models for urban traffic

Traffic Parameters	Urban	
	Penetration Ratio	***BHSA***
VoIP	2%	0.1
Video Phone	2%	0.1
Video Conference	2%	0.1
Gaming	15%	1.2
Streaming Media	13%	1
Signaling	20%	4
Browsing	15%	2
FTP	1%	0.2
E-mail	3%	1
P2P file sharing	1%	0.4

TABLE IV. Parameter calculation of network throughput

Location	SUT (UL)	SUT (DL)	Target User
BLU campus population	2.62Kbps	31.27Kbps	1420
Population around BLU campus			409
Total			1829

B. Coverage Planning

Coverage Planning determine the value of the maximum allowed path attenuation between transmitter and receiver by reviewing the Traffic devices to be used in the network [3]. Specifications for link budget parameters were used in this study are shown in Table 5.

TABLE V. BUDGET LINK CALCULATION PARAMETER

Equipment	Downlink Budget		
	Parameter	*Value*	*Unit*
	Bandwidth	5	MHz
ENB (Tx)	Tx Power	43	dBm
	Feeder Loss	2	dB
	Antenna Gain	11	dBi
	EIRP	52	dBm
UE (Rx)	Antenna Gain	0	dBi
	Body Loss	3	dB
	EU Noise Figure	7	dB
Equipment	**Uplink Budget**		
	Parameter	*Value*	*Unit*
	Bandwidth	5	MHz
UE (Tx)	Tx Power	25	dBm
	Body Loss	1	dB
	Antenna Gain	0	dBi
	EIRP	24	dBm
ENB (Rx)	Antenna Gain	8	dBi
	Feeder Loss	1	dB
	ENB Noise Figure	4	dB

IV. SIMULATION AND ANALYSIS

This part discusses the Capacity Planning and Coverage Planning for Budi Luhur University campus and its surrounding area. It is calculated the LTE network demand from the target prediction of user, traffic demand, and cell capacity needed to accommodate them.

A. Capacity Planning

Single User Throughput calculation based on the parameters in Table 2 yields the result shown in Table 6 for uplink and Table 7 for downlink.

TABLE VI. UPLINK THROUGHPUT PER SERVICE

Traffic Parameters	Bearer Rate (Kbps)	Session Time (s)	Session Duty Ratio	BLER	Throughput (kbit)
VoIP	26.9	80	0.4	1%	869
Video Phone	62.53	70	0.2	1%	884
Video Conference	62.53	500	0.1	1%	3158
Gaming	31.26	1800	0.5	1%	28 418
Streaming Media	31.26	1800	0.1	1%	5684
Signaling	15.63	7	0.2	1%	22
Browsing	62.53	1800	0:05	1%	5685
FTP	140.69	600	1	1%	85 267
E-mail	140.69	50	0.5	1%	3553
P2P file sharing	250.11	60	0.1	1%	1516

TABLE VII. DOWNLINK THROUGHPUT PER SERVICE

Traffic Parameters	Bearer Rate (Kbps)	Session Time (s)	Session Duty Ratio	BLER	Throughput (kbit)
VoIP	26.9	80	0.4	1%	869
Video Phone	62.53	70	0.2	1%	884
Video Conference	62.53	500	0.1	1%	3158
Gaming	125.06	1800	0.8	1%	181 905
Streaming Media	250.11	1800	0.9	1%	409 271
Signaling	15.63	7	0.2	1%	22
Browsing	250.11	1800	0:05	1%	22 737
FTP	750.34	600	0.5	1%	227 376
E-mail	750.34	50	0.5	1%	18 948
P2P file sharing	750.34	60	0.1	1%	4548

While the resulting throughput for urban area from Table 3 is shown in Table 8.

TABLE VIII. SINGLE USER THROUGHPUT

User Behavior	UL	DL	Data Rate	
	Throughput (kbit)	*Throughput (kbit)*	*UL (kbps)*	*DL (kbps)*
VoIP	869	869	2:09	2:09
Video Phone	884	884	2:12	2:12
Video Conference	3158	3158	7:58	7:58
Gaming	28 418	181 905	6138.33	39291.58
Streaming Media	5684	409 271	886.65	63846.26
Signaling	22	22	21:22	21:22
Browsing	5685	22 737	2046.44	8185.42
FTP	85 267	227 376	204.64	545.70
E-mail	3553	18 948	127.90	682.13
P2P file sharing	1516	4548	7:28	21.83
Total			**9444.23**	**112605.9**
Single User Throughput (Total / 3600)			**2.62**	**31.28**

Network throughput for Budi Luhur University and surrounding area can be derived by multiplying total value from Table 8 with the values from Table 4 and is shown in Table 9.

TABLE IX. TOTAL NETWORK THROUGHPUT

Location	UL-SUT	DL-SUT	Target User	Network Throughput(UL) (Kbps)	Network Throughput (DL) (Kbps)
UBL campus residents	2.62Kbps	31.27Kbps	1420	3720.4	44403.4
Residents around campus UBL			409	1071.58	12789.4
Total			**1829**	**4799**	**57225**

Capacity calculation for 5 Mhz bandwidth on the downlink and uplink and required number of cells is as follows:

DL Cap + 24 = (168 – 36 – 12)×6×0.92×25×2×100

DL Cap = 32975976 bps = 33 Mbps

UL Cap + 24 = (168 – 24 – 12)×4×0.6×25×2×100

UL Cap = 15839976 bps = 15.8 Mbps

From (7), the number of cells needed by the network for 1829 users at 900 Mhz frequency with 5 MHz bandwidth is calculated at 0.3 for uplink and 1.7 for downlink. Cell radius is calculated from (8), (9), and (10):

$$Td = \frac{57225000\ bps}{3.05\ km^2} = 1876\ \text{bps/km}^2$$

$$Ac = \frac{32971976\ bps/sel}{18762404\ bps/km^2} = 1.75\ \text{km}^2\text{/cell}$$

$$Rc = \sqrt{\frac{1.75}{2.6}} = 0.82\ \text{km}$$

Path loss for the cell is calculated from (13)-(15) as:

$$a(hUE) = [1.1\log(900\ MHz) - 0.7]1.5 - [1.56\log(900\ MHz) - 0.8]$$

$a(h_{UE})$=0.016

$$Lp(urban) = 69.55 + 77.28 + [44.9 - 7.7](-0.07) - 16.25 - [0.016]\ (dB)$$

Lp(urban) = 127.9 dB

B. *Coverage Planning*

Coverage planning aims to review whether the installed equipment will able to meet the required radius obtained from capacity planning. Path loss Value between capacity planning and coverage planning should be similar So that the network can operate as desired. the value of the Maximum Allowed Path Loss (MAPL) must be greater than the path loss from the capacity planning calculation. The result is shown in Table 10.

TABLE X. BUDGET LINK CALCULATION RESULT

Equipment	Downlink Budget		
	Parameter	***Value***	***Unit***
	Bandwidth	5	MHz
ENB (Tx)	Tx Power	40	dBm
	Feeder Loss	5	dB
	Antenna Gain	10	dBi
	EIRP	45	dBm
UE (Rx)	Antenna Gain	0	dBi
	Body Loss	3	dB
	EU Noise Figure	7	dB
Equipment	**Uplink Budget**		
	Parameter	***Value***	***Unit***
	Bandwidth	5	MHz
UE (Tx)	Tx Power	25	dBm
	Body Loss	1	dB
	Antenna Gain	0	dBi
	EIRP	24	dBm
ENB (Rx)	Antenna Gain	8	dBi
	Feeder Loss	1	dB
	ENB Noise Figure	4	dB

with uplink MAPL of 131 dB, which is higher than calculated path loss of 127.9 dB.

C. *Simulation Result*

Plotting of the coverage is centered on Budi Luhur University's main administration building, with pre-existing operator's tower equipment already located there as the most logical site. The resulting simulation is shown in Fig. 1 and Fig. 2. In which, green denotes signal level 0 ~ 80 dBm categorized as strong up to 600 meters from the tower site, with fully strong coverage of 300 meters

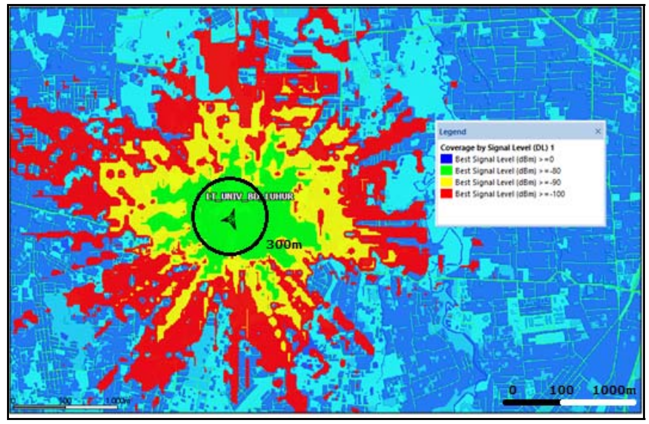

Figure 1. Simulated LTE coverage, BLU campus is in the circle

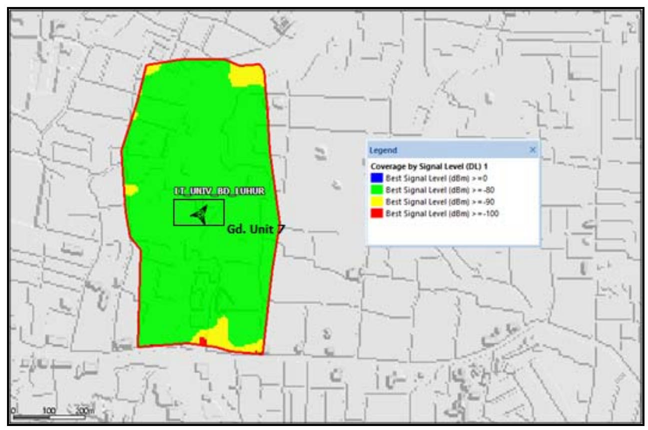

Figure 2. Budi Luhur University campus simulated LTE coverage

From the simulation, it can be determined that Budi Luhur University and the surrounding areas can be covered by LTE service, even exceeding the scope of the planned target location. So that people who are up to 3km away from campus can still receive LTE signal.

V. CONCLUSION

Based on the calculations, simulations and analysis on the design, it can be concluded that:

1. By using the government assigned frequency of 900 Mhz and bandwidth of 5 MHz, the capacity of the cell is only 33 Mbps.
2. To accommodate traffic capacity at Budi Luhur University campus and its surrounding area, more than a single cell is needed when 5 MHz bandwidth is used
3. To meet the demand, the LTE operation should be at the new but currently un-allocated 1800 Mhz frequency, which is capable of 20 Mhz bandwidth.

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