An Academic Study of Roadmap of 5G Implementation in Indonesia

Bambang Supriadi
School of Electrical Engineering and Informatics
Bandung Institute of Technology
Bandung, Indonesia
Email: 13.supriadi@gmail.com

Sigit Haryadi
School of Electrical Engineering and Informatics
Bandung Institute of Technology
Bandung, Indonesia
Email: sigit@stei.ib.ac.id
sigitharyadi59@gmail.com

***Abstract*—Based on the roadmap of the International Telecommunication Union (ITU), 5G mobile technology standard will be published in 2020. In this paper the timeline of 5G implementation in Indonesia has been designed by using technological forecasting that is Gompertz model. The roadmap of 5G implementation consist of three milestones for mobile technology implementation which are: 4G start in 2015, 4.5G start in 2020 and 5G start in 2025. The 5G technology will reach the inflection point in 2027 and 98% of penetration in 2035. The 5G mobile spectrum demand has been calculated, which are: in 2025 the demand is 83 MHz using macro-cell configuration and 17 MHz using small-cell configuration, in 2026 the demand is 380 MHz (using macro-cell) and 80 MHz (using small-cell), in 2027 the demand is 1.027 MHz (using macro-cell) and 216 MHz (using small-cell), in 2028 the demand is 2.024 MHz MHz (using macro-cell) and 426 MHz (using small-cell), and in 2029 the demand is 3.298 MHz (using macro-cell) and 693 MHz (using small-cell). The amount of IMT band used in Indonesia is 490,75 MHz. Using the assumption that all IMT band are assigned for 5G technology, then there will be a deficit of radio frequency spectrum that is needed by 5G technology. It start in 2026 for macro-cell and in 2029 for small-cell. To meet the spectrum demand the short term, middle term and long term solution is urgently needed.**

Keywords- 5G, forecasting, Gompertz, spectrum

I. Introduction

Mobile broadband technology continues to evolve from early generation (1G) that carry only analog voice traffic, until current advanced generation of 4G which is an ip-based mobile broadband technology. 4G is known as "The Future of Mobile Broadband", it provides faster data rate access up to 1000 Mbps.

Third Partnership Project (3GPP) defined Long Term Evolution (LTE) in 3GPP release 8. LTE as one of basis technology for 4G (besides WiMAX) is established in 2008. The commercial launch of LTE in Indonesia was started in 2015. International Telecommunications Union-Radio communications sector (ITU-R) specified a set of requirements for 4G standards, named the International Mobile Telecommunications Advanced (IMT-Advanced) [1].

The peak data rate required by 4G is 100 Mbps for high mobility communication (such as from trains and cars) and 1000 Mbps for low mobility communication (such as pedestrians and stationary users). LTE deployed in Indonesia has a peak data rate of 100 Mbps for low mobility. Although the data rate does not meet the requirement for 4G but the operator in Indonesia still use the term 4G for the commercial name of the technology.

A starting point for the use of 4G technology has just begun in Indonesia. Meanwhile the ITU has issued a roadmap to transform 4G into 5G. ITU name the 5G technology as International Mobile Telecommunications 2020 (IMT-2020).

The reasons for transformation of 4G into 5G are: 1) Based on cisco VNI report [2], Mobile data traffic will grow at a compound annual growth rate (CAGR) of 53 percent from 2015 to 2020, reaching 30.6 exabytes per month by 2020 and There will be 11.6 billion mobile-connected devices by 2020, exceeding the worlds projected population at that time (7.8 billion). This will force the cellular system to fulfill the rapid growth of data traffic and support the mass rapid growth of users; 2) The latency performance is needed to be upgraded. There are some new coming services like Machine-to-Machine (M2M) and Vehicle-to-Anything (V2X). These services may not need bigger capacity of data rate but they need smaller delay to be operated optimally.

The fact that by 2020 the 5G standard will be published by the ITU, then a roadmap of commercial launch of 5G in Indonesia is really needed. The rest of the paper is organized as follows: section II presents brief overview of 5G mobile broadband communication, section III is the methodology of the study, section IV is the roadmap of 5G implementation in Indonesia, section V is the analysis of the study and section VI is the conclusion.

II. 5G Mobile Broadband Communication

The experts expect that 5G will have a backward compatibility with previous cellular technology like 4G and 3G. The mobile communication of 5G will be developed on foundation of 4G LTE that is now becoming more mature [3]. The 5G will also has an interoperability with other wireless technology such as WiFi and other technologies. There will be step change in data speed and order of magnitude reduction in end-to-end latency.

TABLE I
4G AND 5G TECHNICAL COMPARISON

	4G	5G
High mobility peak data rate	100 Mbps (up to 360 km/h)	1000 Mbps
Low mobility peak data rate	1.000 Mbps	10.000 Mbps
Userplane latency	less than 10 ms	10 x reduced
Scalable bandwidth	up to 40 MHz, extendable to 100 MHz	As much as possible
Downlink peak spectral efficiency (SE)	15 bit/s/Hz	As much as possible
Uplink peak SE	6.75 bit/s/Hz	As much as possible
Connection density	$\sim$ 2.000 active users/km^2	>1,5X

Next Generation Mobile Networks (NGMN) has proposed the architecture of 5G, as shown in Fig. 1. The architecture of 5G system comprises three layers: 1) Infrastructure resource layer, consist of Virtualized Network Function (VNF), Radio Access Technology (RAT) and devices; 2) Business enablement layer, consist of library of modular network functions and value enabling capabilities; 3) Business application layer, consist of some applications run by the operator or third party application companies [4].

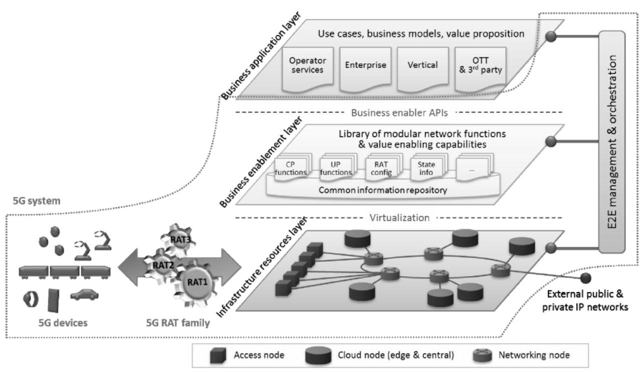

Fig. 1. Proposed 5G architecture by [4]

The incremental improvement of LTE data rate could not meet the requirement of 5G (see Table I). It is needed some key technologies to meet the requirements of 5G. Some key technologies are proposed in [3] and [5].

III. METHODOLOGY

In this paper, the 5G roadmap is designed using three milestones, which are 4G (LTE-A), 4.5G (LTE-B) and 5G. The main features of different LTE Releases (LTE, LTE-A and LTE-B) are described in [6]. The technological forecasting is used to estimate diffusion of the three technologies in Indonesia. Gompertz model as one among the technological forecasting is used in this study to design a 5G roadmap in Indonesia. The variable of Gompertz model for 4G is defined from the Mobile Network Operator (MNO)'s penetration data in 2015 dan penetration target in 2016. Meanwhile the 4.5G and 5G variable is set based on assumption. The penetration rate of each technology is multiplied by Indonesian population to get the number of subscribers. Based on the penetration data of the three milestones, the timeline of 5G implementation is designed.

The equation from [7] is used to calculate the radio frequency spectrum that is needed to implement 5G. To calculate the amount of radio frequency spectrums needed based on the equation is depend on other parameters. Those parameters are 1) spectral efficiency; 2) number of mobile station and 3) data traffic per-subscriber/month. Then the amount of radio frequency spectrum that is needed to implement 5G in Indonesia is obtained.

A. Gompertz Model

Technological forecasting model is used to study the mobile technology transition from 4G into 5G. Some forecasting models are usually using the $S-curved$ graphic to analyze the transition of technology. The mathematical models used to forecast the technology is called quantitative adoption model [8].

The forecasting model used in this study is the Gompertz model. This model is given by the equation 1.

$$Y = A.e^{B.e^{C.t}}, \tag{1}$$

where Y = Y(t) is the estimated diffusion level at time t. The parameters that determine the model are A, B, C. Parameter A is the saturation level, B is related to the year that diffusion reaches the point of inflection, and C measures the diffusion speed [9].

B. Calculation for Spectrum Demand

The amount of radio frequency spectrum is calculated using the equation 2, 3 and 4 [7].

$$cellcaps = subs \times \frac{8192Mbit/GB \times Usg[GB/subs/month]}{sites \times 3(str)x3600s/hr \times 30d/m} \times dist \tag{2}$$

$$dist = \frac{7\%(busyhourshare)}{50\%(maxload)} \times \frac{50\%}{15\%}(distribution) \tag{3}$$

$$BW[MHz] = \frac{cellcaps[Mbps]}{SE[bit/s/Hz]}, \tag{4}$$

where $cellcaps$ is cell capacity based on aggregate throughput in a period of time, $sites$ is number of mobile station and SE is cell spectral efficiency.

IV. ROADMAP OF 5G IMPLEMENTATION IN INDONESIA

A. Roadmap of 5G Technology Penetration

LTE has been deployed in Indonesia for one year. The penetration of the technology in Indonesia as long as that time is described in Table II. The data in Table II are collected from many source that are from [10]–[17].

Using assumption that 4G will saturate in magnitude of 80%, based on table II the parameters of Gompertz could be generated using equation 1. The parameters are: $A = 80$,

TABLE II
INDONESIA 4G LTE PENETRATION IN YEAR 2015-2016

Year	Type	Users	Indonesian Population	Penetration (%)
2015	History	7.600.000	255.461.700	3
2016	Target	28.800.000	258.705.000	11,1

$B = -3,3$ and $C = -0,51$. The forecasting model of 4G LTE implementation in Indonesia has been studied by [18]. In this paper the Gompertz variables for 4.5G and 5G is assumed to be the same as the variable of 4G. The parameters for all of the three technology milestones are described in Table III.

TABLE III
PARAMETERS FOR 4G, 4,5G AND 5G

	Technology		
Gompertz variable	4G	4,5G	5G
A	80	100	100
B	-3,3	-3,3	-3,3
C	-0,51	-0,51	-0,51
Initialization year	2015	2020	2025

Based on the table III, the penetration rate could be generated using equation 1. Using Indonesian population data that is derived from the Central Bureau of Statistics of Republic of Indonesia, the subscribers of each technologies is generated using equation 5

$$subscribers(t) = Y(t) \times country.populations \tag{5}$$

The penetration of 4G, 4.5G, 5G and also the total penetration are respectively displayed in figure 2.

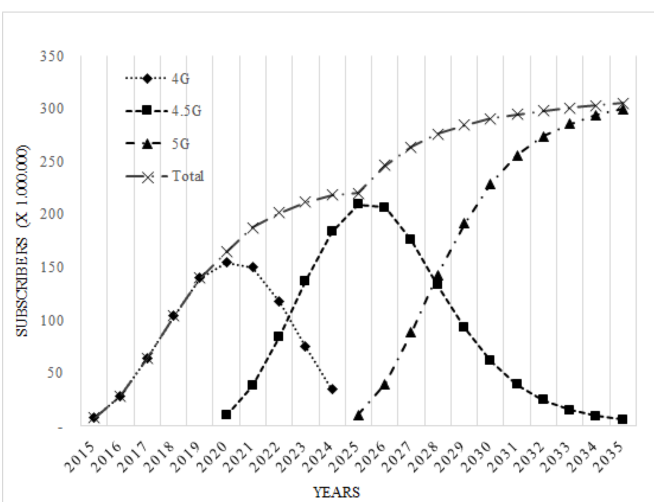

Fig. 2. Roadmap of 5G Technology Penetration

B. Roadmap of 5G Technology Implementation

Based on the forecasting model of 5G implementation in previous subsection then the timeline of 5G implementation in Indonesia could be made. The figure of roadmap in figure 3 is based on the figure that is created by [19].

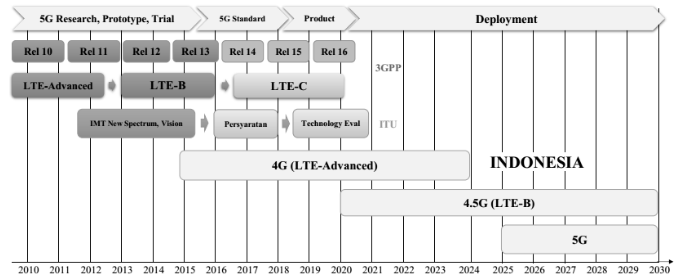

Fig. 3. Roadmap of 5G Technology Implementation in Indonesia

The timeline of all the three milestone is as follows: the 4G was initiated in 2015 then in 2020 there will be a transition of 4G into 4.5G. Meanwhile the 5G itself will start the commercial launch in 2025.

C. Roadmap of 5G Spectrum

In a mobile broadband technology roadmap, one of the important thing should be planned is the amount of frequency spectrum that is needed. The explosive growth of mobile data traffic resulted in an increasing demand for radio frequency spectrum. Total Mobile data traffic in Indonesia based on the Cisco VNI shown in table IV.

TABLE IV
MOBILE DATA TRAFFIC IN INDONESIA (CAGR=58%)

No	Year	Mobile Data Traffic (User/month in MB)
1	2015	388
2	2020	3.820
3	2025	37.619
4	2030	370.415
5	2035	3.647.317

It is assumed that the number of 5G mobile stations to be built in 2025 is equal to the number of 4G station in 2015 as many as 25.861 stations, as it is shown in table V. There will be an increase in the number of station as much as 30% every year as an assumption.

TABLE V
NUMBER OF 4G BASE STATIONS IN INDONESIA 2015

No	Operator Name	Number of eNB Station
1	MNO A	3.000
2	MNO B	3.134
3	MNO C	3.361
4	MNO D	9.025
5	MNO E	2.900
	TOTAL	21.420

The parameters for the spectral efficiency of 4G, 4.5G and 5G are displayed in table VI. The spectral efficiency that is shown in table is the downlink cell spectral efficiency (bits/s/Hz).

TABLE VI
SPECTRAL EFFICIENCY

MIMO Configuration	4G (LTE Rel. 8)	4.5G (LTE Rel. 10)	5G (assumption)
2x2	1,69	2,4	3,4
4x2	1,87	2,6	3,6
4x4	2,67	3,7	5,1

Based on the data in table IV and table V and by using the equation 2 and 3, the cell capacity from 2025 - 2035 is generated. Using the spectral efficiency parameters that is shown in table VI, the frequency spectrum demand is calculated and described in figure 4. The frequency spectrum for 5G could be reduced by applying small-cell with parameters of MU-MIMO 2x2, ISD = 100m, 3 sectors that will gain the spectral efficiency of 24.4 bits/s/Hz [5].

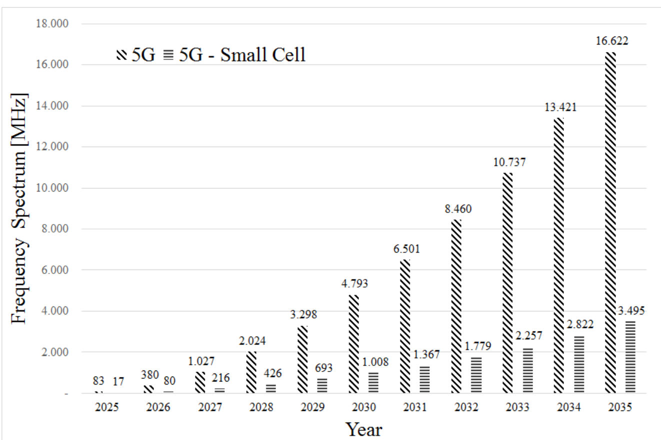

Fig. 4. Roadmap of 5G Spectrum in Indonesia

The International Mobile Telecommunication (IMT) band that is used in Indonesia is shown in table VII. Others bands of IMT is used by other services such as broadcasting satellite service (BSS), fixed service.

Assume that the IMT band in table VII is not occupied by other technology (i.e. 2G, 3G and 4G), so there will be a gap between the available and the demand spectrum to implement the 5G technology. The gap between 5G mobile spectrum demand vs the available IMT band in Indonesia is described in figure 5.

V. ANALYSIS

The roadmap of 5G technology penetration as describe in figure 2 has a starting point in 2015. 4G is projected to grow to 80% of maximum penetration. The initialization period of 4.5G will be happening in 2020, which will give 5 years for initialization phase of 4G. The termination phase of 4G will start in 2021 until the subscribers loss in 2025. The transition period for 4G into 4.5G is in 2020 and the termination period

TABLE VII
IMT BAND IN INDONESIA

Band (MHz)	Bandwidth (MHz)	Current Usage
450-457,5 / 460-467,5	2×7,5	CDMA
824-835 / 869-880 (Band 5 FDD)	2×11	CDMA dan LTE FDD (Neutral Technology)
880-915 / 925-960 (Band 8 FDD)	2×35	GSM dan LTE FDD
1710-1785 / 1805 - 1880 (Band 3 FDD)	2×75	GSM dan LTE FDD (Neutral Technology)
1903,125-1910 / 1983,125-1990	2×6,875	3G - 3GPP2 std (PCS 1900)
1920-1980 / 2110-2170 (Band 1 FDD)	2×60	3G - 3GPP std (UMTS)
2300 - 2400 (Band 40 TDD)	100	LTE TDD dan BWA (Neutral Technology)
TOTAL BW =	**490,75**	

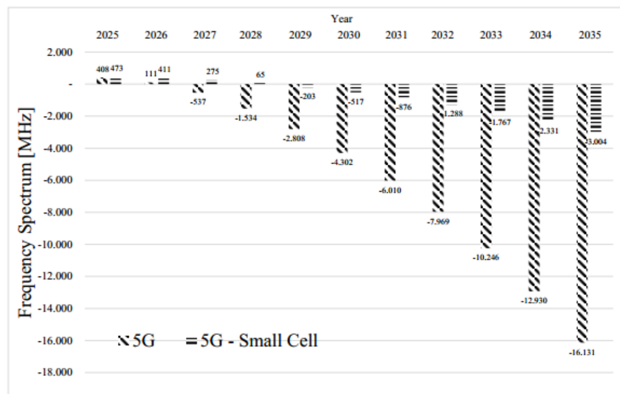

Fig. 5. Gap between 5G Spectrum Demand vs Total IMT bands in Indonesia

for 4.5G is in 2026. The 5G technology will initialize in 2025, which will give 5 years for 4.5G initialization phase. 4.5G and 5G will grow together until 2035.

The frequency released and reused mechanism of all the three technologies will be as follows: 1) 4G will need an extra frequency spectrum in 2018 and beyond, as 4G will reach the inflection point in 2018. The reduction of 2G and 3G spectrum should be considered in this year; 2) as the termination year of 4G start in 2021 and 4G will lose their subscribers in 2025, the radio frequency spectrum that is used by 4G could be released and used by the the advanced technologies (4.5G or 5G); 3) 4.5G will reach the inflection point in 2023, in this year an extra frequency spectrum is needed to meet the number of subscribers and the increase of mobile data traffic; 4) The reduction of 4.5G spectrum is possible after 2026.

The timeline of 5G technology implementation is shown in figure 3. 5G standards ,based on ITU's roadmap, will be published in 2020. In common, there is a time lag between a standard established and the commercial launch of mobile technology in Indonesia. The lag is about 5 years. Based on the forecasting that is done in this study, it shows the same way, that the commercial launch of 5G mobile technology in Indonesia will happening in 2025. The implementation of 5G in 2025 will not be a disruptive technology to both 4G and 4.5G. All of the three technologies could reach their mature state.

There will be a deficit of radio frequency spectrum to implement 5G technology. It could be seen in figure 5, the deficit is started in 2026 for macro-cell configuration and in 2029 for small-cell configuration. To meet the demand, refarming of radio frequency spectrum is an urgent need. It is proposed three steps to supply radio frequency spectrum for mobile service. The steps are divided in: 1) short term: band 700 MHz - digital dividend and band 2600 MHz. band 2600 MHz is currently used by broadcasting satellite service (BSS); 2) middle term: band 3400-3600 MHz, this band is used by fixed satellite service (FSS) and broadband wireless access (BWA); 3) long term: band above 6 GHz.

VI. Conclusion

In this paper, the roadmap of 5G implementation in Indonesia has been designed. The roadmap consist of three milestones for mobile technology implementation which are: 4G start in 2015, 4.5G start in 2020 and 5G start in 2025. 5G technology will reach the inflection point in 2027 and 98% of penetration in 2035. The 5G mobile spectrum demand has been calculated, which are: in 2025 the demand is 83 MHz using macro-cell configuration and 17 MHz using small-cell configuration, in 2026 the demand is 380 MHz (using macro-cell) and 80 MHz (using small-cell), in 2027 the demand is 1.027 MHz (using macro-cell) and 216 MHz (using small-cell), in 2028 the demand is 2.024 MHz MHz (using macro-cell) and 426 MHz (using small-cell), and in 2029 the demand is 3.298 MHz (using macro-cell) and 693 MHz (using small-cell). The amount of IMT band used in Indonesia is 490,75 MHz. Using the assumption that all IMT band are assigned for 5G technology, there will be a deficit of radio frequency spectrum that is needed by 5G technology. It start in 2026 for macro-cell and in 2029 for small-cell. To meet the spectrum demand the short term, middle term and long term solution is urgently needed.

References

[1] ITU, "Detailed specifications of the terrestrial radio interfaces of International Mobile," vol. 2, 2015.

[2] Cisco, "Cisco Visual Networking Index : Global Mobile Data Traffic Forecast Update," *Growth Lakeland*, vol. 2011, no. 4, 2011. [Online]. Available: http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white{_}paper{_}c11-520862.html

[3] J. J. G. Andrews, S. Buzzi, W. Choi, S. V. S. Hanly, A. Lozano, A. A. C. K. Soong, and J. J. C. Zhang, "What will 5G be?" *IEEE Journal on Selected Areas in Communications*, vol. 32, no. 6, pp. 1065–1082, 2014.

[4] NGMN and M. Iwamura, "NGMN View on 5G Architecture," *Vehicular Technology Conference (VTC Spring), 2015 IEEE 81st*, 2015.

[5] S. Vahid, R. Tafazolli, and M. Filo, "Small Cells for 5G Mobile Networks," in *Fundamentals of 5G Mobile Networks*, 1st ed., J. Rodriguez, Ed. West Sussex: John Wiley & Sons, 2015, vol. 1, ch. 3, p. 98.

[6] F. B. Saghezchi, J. Rodriguez, S. Mumtaz, A. Radwan, W. C. Y. Lee, B. Ai, M. T. Islam, S. Akl, and A.-E. M. Taha, "Drivers for 5G: The Pervasive Connected World'," in *Fundamentals of 5G Mobile Networks*, 1st ed., J. Rodriguez, Ed. John Wiley & Sons, 2015, ch. 1, p. 5.

[7] Nokia Siemens Networks, "Mobile broadband with HSPA and LTE capacity and cost aspects," no. June, p. 12, 2010.

[8] Tellabs, "Forecasting the Take-up of Mobile Broadband Services," 2010. [Online]. Available: http://www.tellabs.com/resources/papers/tlab{_}forecastmobbrdbnd.pdf

[9] S. Konstantinos and S. Vasilios, "A New Empirical Model for Short-Term Forecasting of the Broadband Penetration: A Short Research in Greece," *Modelling and Simulation in Engineering*, vol. 2011, pp. 1–10, 2011. [Online]. Available: http://www.hindawi.com/journals/mse/2011/798960/

[10] Admin, "Persaingan Operator Layanan 4g di 2015." [Online]. Available: http://www.mastel.id/persaingan-operator-layanan-4g-di-2015/

[11] Indotelko, "Ini Klasemen Operator untuk Layanan 4G di 2015." [Online]. Available: http://www.indotelko.com/kanal?c=id{\&}it=klasemen-operator-4g-2015

[12] Admin, "Smartfren Pasang Target Ambisius untuk 4G di 2016." [Online]. Available: http://www.indotelko.com/kanal?c=id{\&}it=smartfren-pasang-target-ambisius-4g-2016

[13] Kabarbisnis, "Indosat Ooredoo yakin pelanggan 4G bakal tembus 4 juta." [Online]. Available: http://www.kabarbisnis.com/read/2863872/indosat-ooredoo-yakin-pelanggan-4g-bakal-tembus-4-juta

[14] Khoirunnisa, "2016, XL Fokus Inovasi Digital Berbasis 4G LTE." [Online]. Available: http://selular.id/news/2016/02/2016-xl-fokus-inovasi-digital-berbasis-4g-lte

[15] A. Rouzni, "Psst.. Ini Bocoran Rencana 4G Telkomsel di 2016." [Online]. Available: http://inet.detik.com/read/2015/12/19/163349/3100228/328/psst-ini-bocoran-rencana-4g-telkomsel-di-2016

[16] Y. H. Widiartanto, "2016, Bolt Fokus Tingkatkan Jumlah Pelanggan." [Online]. Available: http://tekno.kompas.com/read/2016/02/04/09590097/2016.Bolt.Fokus.Tingkatkan.Jumlah.Pelanggan

[17] Yudhianto, "2016, 4G Smartfren Sambangi 85 Kota." [Online]. Available: http://inet.detik.com/read/2016/01/13/185120/3117918/328/2016-4g-smartfren-sambangi-85-kota.

[18] M. Suryanegara, A. Ramadhan, A. K. Akbar, and M. Asvial, "The forecasting model of 4G LTE implementation in Indonesia," *ICMIT 2014 - 2014 IEEE International Conference on Management of Innovation and Technology*, no. 1, pp. 461–466, 2014.

[19] Huawei, "5G : A Technology Vision," *Huawei, White paer*, pp. 1–16, 2014.