Jurnal Ilmiah KURSOR
Menuju Solusi Teknologi Informasi
Vol. 10, No. 4, Desember 2020

ISSN 0216 – 0544
e-ISSN 2301– 6914

PLANNING OF 5G NETWORK PATH LOSS IN GEOMETRY BASED STOCHASTIC CONCEPT BY USING LINEAR REGRESSION METHODS

[a]Achmad Ubaidillah, [b]S. Ida Kholida

[a] Electrical Engineering, University of Trunojoyo Madura 1 Telang, Kamal, Bangkalan
[b] Physics Education, University of Islamic Madura 2 Bettet, Pamekasan
E-mail: ubaidillah.ms@trunojoyo.ac.id, idakholida@uim.ac.id

Abstract

This research is a continuation of several previous studies that made 5G network planning using the Free Space Reference Path Loss model. In this study, a 5G network path loss planning was made using the Geometry Based Stochastic model. A forecasting system is created that connects the path loss with the distance between the transmitter and the receiver antenna using the linear regression method. It is important to look at 5G network planning on a different side. The result shows that the path loss value in the light of sight condition is better than the non-light of sight condition with the lowest value of 94.4271 dB at the frequency of 28 GHz and 99.5856 dB at the 73 GHz frequency. Linear Regression analysis shows that the best path loss calculation is the frequency 28 GHz of LOS conditions with MSE is 0.001 and the standard deviation error is 0.0319.

Key words: 5G, Path loss, Geometry Based Stochastic, Linear Regression..

INTRODUCTION

The 5G telecommunication network is a development of the previous generation network (4G) which works in the 700 MHz - 2.6 GHz frequency spectrum [1]. The 5G network is presented to answer the needs of improving data transmission speed, delay, reliability and user access anywhere and anytime [2] [3]. Another advantage of the 5G network is in terms of energy efficiency, affordability and much better Bit Error Rate (BER) [4] [5].

The 5G network has the potential to be further developed from various aspects, such as in terms of power control, speed, channel capacity, transmission control, traffic and even optimization aspects [6]. This is because the 5G network works in the frequency range 30-300 GHz and can provide a wide frequency band [7]. Other aspects that can be developed in optimizing the performance of the 5G network are antennas, multiple access and large scale propagation planning [8]. And one of the most important problems in planning large scale propagation is path loss. Path loss is the power losses as the distance between transmitter and receiver increases [9] [10].

There are two methods of modeling large scale propagation, namely Free-Space Reference Path Loss and Geometry-Based Stochastic. The path loss value is then used to plan the power link budget of the applied telecommunication system [11]. Linear regression is used in planning and forecasting that links the path loss to the distance between the transmitter and receiver. Regression was chosen because it can simply know the tendency of relationship between two parameters.

The next chapter discusses a brief theory about 5G telecommunication network, Geometry Based Stochastic and Linear Regression. The chapter Result and Discussion discusses the result of the research accompanied by discussion and analysis of the result of the research. Chapter Conclusion closes this research paper by providing conclusions about the research result.

MATERIAL AND METHODS

5G Telecommunication Network

Digital telecommunication technology must continue to be developed in various innovations, so that it can always provide quality service (QoS), easy access and other benefits. Hence, the 5G network emerged. This 5G network is a development of the previous network technology (4G) which can provide greater bandwidth [12].

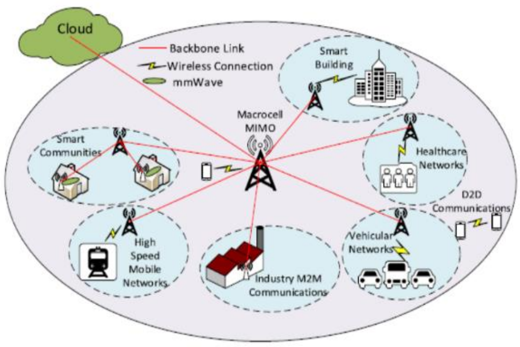

Fig 1. Application area and Technologies of 5G [13]

The presence of the 5G network brings various positive and significant impacts from the previous generation of 4G, such as improving QoS, security and lowering transmission costs. By considering and improving these various aspects, 5G network technology is capable of broadcasting large amounts of data in Gbps, enabling multimedia newspapers and High Definition (HD) TV programs, increasing call speed and clarity of audio and video, and supporting multimedia interactive.

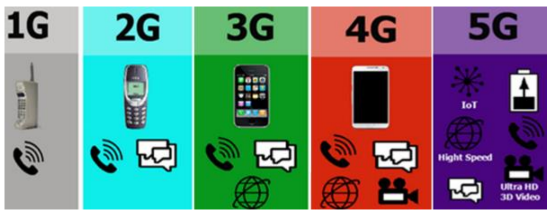

Fig 2. The development of generation of mobile wireless networks [14]

Geometry Based Stochastic

There are two mmWave signal propagation models, namely the Free-Space Reference Path Loss Model and Geometry Based Stochastic. And the propagation model used in this research is Geometry Based Stochastic.

In this signal propagation model, it has dependence on the value of distance parameters fitting, frequency fitting and frequency and distance intercept values. For parameter fitting values with the distance between the transmitter and receiver as follows [15]:

$$W = (\sum D \sum P - NP) \quad (1)$$

$$X = (\sum D \sum F - N \sum DF)(\sum F \sum P - N \sum FP) \quad (2)$$

$$Y = ((\sum D)^2 - N \sum D^2)((\sum F)^2 - N \sum F^2) \quad (3)$$

$$Z = (\sum D \sum F - N \sum DF)^2 \quad (4)$$

$$A = \frac{W - X}{Y - Z} \quad (5)$$

Where,
A : Parameter Fitting with Distance
D : 10 log 10 (d), where D is distance reference between the transmitter and the receiver
F : Frequency usage (GHz)
N : Number of samples or data
P : Transmission path loss

The intercept of the optimization of offset value path coefficient parameter based on the distance of the transmitting and receiving antenna and frequency, according to the following equation :

$$R = (\sum D \sum FP - \sum P \sum DF)(\sum F \sum D^2 - \sum D \sum DF) \quad (6)$$

$$S = (\sum B \sum D^2 - \sum D \sum DP)(\sum D \sum F^2 - \sum F \sum DF) \quad (7)$$

$$T = ((\sum D)^2 - N \sum D^2)(\sum D \sum F^2 - \sum F \sum DF) \quad (8)$$

$$U = (\sum D \sum F - N \sum DF)(\sum F \sum D^2 - \sum D \sum DF) \quad (9)$$

$$B = \frac{R - S}{T + U} \quad (10)$$

Where :

B : Intercept

The fitting value of frequency parameter is as follows :

$$H = (\sum F \sum P - N \sum FP)((\sum D)^2 - N \sum D^2) \quad (11)$$

$$I = (\sum D \sum F - N \sum DF)(\sum D \sum P - N \sum DP) \quad (12)$$

$$J = ((\sum F)^2 - N \sum F^2)((\sum D)^2 - N \sum D^2) \quad (13)$$

$$K = (\sum D \sum F - N \sum DF)^2 \quad (14)$$

$$C = \frac{H - I}{J - K} \quad (15)$$

Where :
C : Parameter Fittings with Frequency

So that the path loss equation is obtained as follows :

$$G = 10.\log_{10}\left(\frac{d}{1m}\right) \quad (16)$$

$$L = 10.\log_{10}\left(\frac{f}{1GHz}\right) \quad (17)$$

$$P = A.G + B + C.L + X_\sigma \quad (18)$$

Where :
P : Signal propagation path loss of Geometry Based Stochastic Channel (dB)
d : Distance between transmitter and receiver (meter)
A : Parameter Fitting with Distance (dB)
B : Intercept
C : Parameter Fittings with Frequency (dB)
X_σ : Shadow Fading
f : Frequency usage (GHz)

Linear Regression

This method is used to determine the relationship between the independent variable and the dependent variable, in order to obtain a prediction system for the value of the dependent variable on changes in the independent variable. The linear regression follows the following equation :

$$Y' = a + bX \quad (19)$$

Where :
Y ' : Dependent variable (predicted value)
X : Independent variable
a : Constant (Y' value if X = 0)
b : Regression coefficient

The methodology in this study follows the following steps :

1. Determine the value of several 5G network parameters such as frequency, oxygen attenuation, rain attenuation, Free Space Path, transmitter and receiver antenna distances.
2. Calculating path losses in a Stochastic-based Geometry model.
3. Analyze mathematically the relationship between path loss and distance using linear regression method.
4. Make conclusions.

RESULT AND DISCUSSION

In this study, the calculated path loss value is compared with the path loss value from direct measurement [16]. Then a planning system was formed using the linear regression method to analyze the relationship between the path loss and the distance between the transmitter and receiver.

Table 1. Comparison of Parameters of the Geometry-Based Stochastic Method of LOS Conditions

Parameters	**Measurement**			**Calculation**		
	A	**B**	**C**	**A**	**B**	**C**
28 GHz	1,1	46,8	2,1	1,2	46,86	2,23
73 GHz	1,1	46,8	2,1	1,204	46,8	2,11

Table 2. Parameters Comparison off the Geometry-Based Stochastic Condition of NLOS Conditions

Parameters	**Measurement**			**Calculation**		
	A	**B**	**C**	**A**	**B**	**C**
28 GHz	2,8	31,4	2,7	2,79	31,89	2,68
73 GHz	2,8	31,4	2,7	2,706	31,71	2,6

From table 1 and table 2, and based on calculation result, it can be analyzed that the higher the frequency causes the signal propagation model parameter value to be smaller, while the distance calculation parameter (A) gets bigger even though it is a little.

In NLOS conditions, the distance and frequency parameters (A and C) are greater than the LOS conditions. However, the intercept parameter (B) in LOS conditions is greater than NLOS. So that obstruction in NLOS conditions makes the distance and frequency fitting parameters (A and C) bigger, while the intercept parameter (B) gets smaller.

According to the calculation of conditions, almost all parameters of the signal propagation model are greater than the measurement results except the parameter (B) at the frequency of 73 GHz with the same result. This is different from the results of the calculation of parameters (A and C) that are smaller than the measurement results. Exceptions to the parameter (B) for NLOS conditions, where the calculation results are smaller than the measurement results.

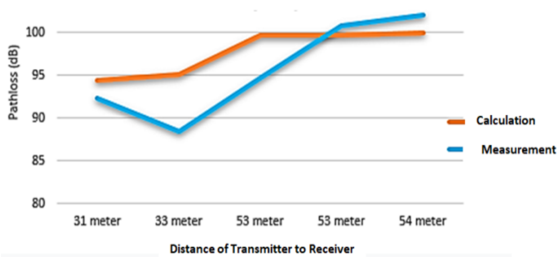

Fig 3. LOS Transmission Path loss Value Against Distance at Frequency 28 GHz

Based on Figure 3, the measurement and calculation results have the same tendency, namely the farther the distance between the transmitter and receiver, the greater the loss path. However, the linearity is more visible in the calculation results than in the measurement results. At a distance of 31 meters and 54 meters, the path loss values were 92.3 dB and 102.1 dB, respectively. Meanwhile, calculations at the same distance have path loss values of 96, 806 dB and 99,554 dB, respectively.

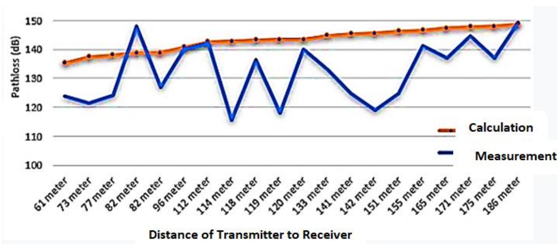

Fig 4. NLOS Transmission Path Loss Value Against Distance at Frequency 28 GHz

The path loss value at a frequency of 28 GHs with NLOS conditions is greater than LOS. This can be seen for example from the path loss value with NLOS conditions at a distance of 61 meters, namely 123.8 dB for measurements and 155, 2509 dB for calculations. This value is greater than the LOS condition at a distance of 54 meters. So that the NLOS condition causes a path loss greater than the LOS condition.

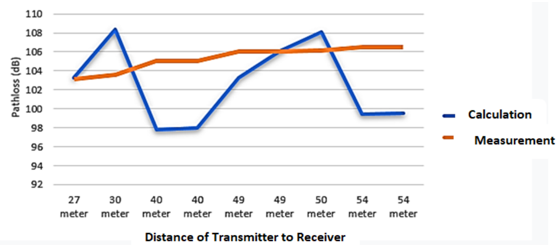

Fig 5. LOS Transmission Path Loss Value Against Distance at Frequency 73 GHz

LOS condition is a condition where the transmitter and receiver have no resistance at all. Based on Figure 5, the calculation results produce a path loss with a more linear increase than the measurement results with the lowest path loss value of 103.09 dB at a distance of 27 meters and the largest is 106,5218 dB at a distance of 54 meters. Whereas in the measurement results, the lowest path loss value is at a distance of 40 meters and the highest is at a distance of 50 meters with a path loss value of 97.8 dB and 108.1 dB respectively.

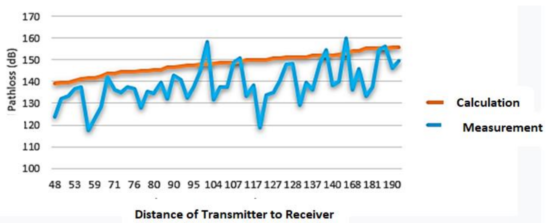

Fig 6. NLOS Transmission Path loss Value Against Distance at Frequency 73 GHz

Based on the calculation results, the path loss value at a distance of 48 meters is 139.06235 dB. While the path loss value at a distance of 49 meters, the LOS condition at the same frequency is 106.0408287 dB. It can be concluded that the NLOS conditions at a frequency of 73 GHz also cause greater path loss.

The linearity of the calculated path loss value is better than the measurement result. Because in its measurement, the obstacle condition has different total attenuation even though it is the same distance. The use of frequency also affects the path loss value. The higher the frequency, the smaller the path loss. Based on the calculation results, the path loss value at a frequency of 73 GHz with a distance of 118 meters is 132.5449 dB, while at a frequency of 28 GHz it is 136.4 dB.

The next analysis is to use linear regression. Based on the path loss data and the distance from the transmitter to the receiver, several conditions are obtained.

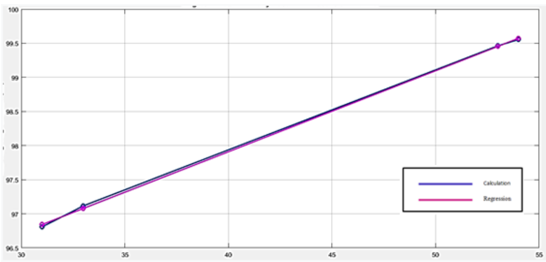

Fig 7. Graph of Calculation and Prediction of path loss to distance on frequency 28 GHz in LOS condition

At a frequency of 28 GHz and LOS conditions, the resulting intercept value is 87.1688; the value of the slope of the independent variable is 0.2364; the error is 0.9998 and the MSE value is 0.001 and the standard deviation is 0.0636, as shown in Figure 7.

At the frequency of 28 NLOS conditions, the intercept value was 125,179; the value of the slope of the independent variable is 0.1259; error is 0.9989; the MSE value is 1.0763 and the standard deviation error is 1.0375, as shown in Figure 8.

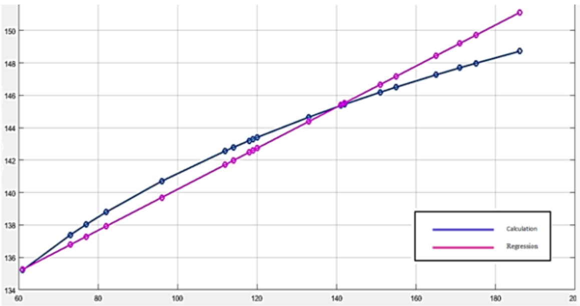

Fig 8. Graph of Calculation and Prediction of path loss to distance on frequency 28 GHz in NLOS condition

At a frequency of 73 GHz, LOS conditions, the intercept value is 93.7424; the slope value of the independent variable is 0.2038; the error value is 0.9165; the MSE value is 0.0146 and the standard deviation error is 0.1209, as shown in figure 9.

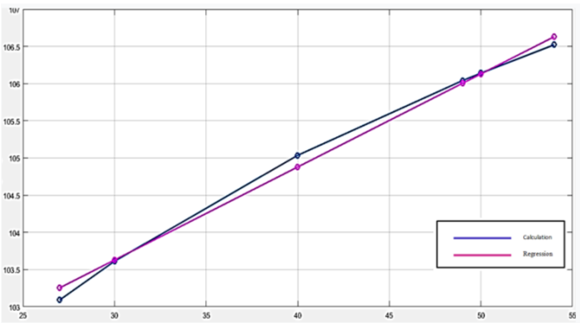

Fig 9. Graph of Calculation and Prediction of path loss to distance on frequency 73 GHz and LOS condition

Meanwhile, at the 73 GHz frequency and NLOS conditions, the intercept value was 124.6771; the value of the slope of the independent variable is 0.0629; the error value is 0.9809; with an MSE value of 0.8366 and a standard deviation of 0.9147, as shown in Figure 10.

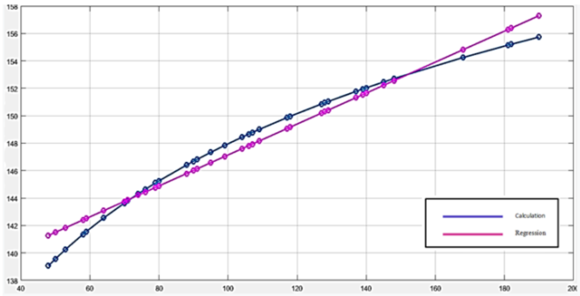

Fig 10. Graph of Calculation and Prediction of path loss to distance on frequency 73 GHz and NLOS conditions

Based on the analysis using linear regression, the result of the best path loss calculation is the frequency 28 GHz of LOS conditions with MSE is 0.001 and the standard deviation error is 0.0319.

CONCLUSION

Based on the analysis of the research results, some conclusions that can be drawn are as follows: Based on calculations on all signal propagation models, it shows that the path loss value in the light of sight condition is better than the non-light of sight condition with the lowest value of 94.4271 dB at the frequency of 28 GHz and 99.5856 dB at the 73 GHz frequency. Based on the analysis using linear regression, the result of the best path loss calculation is the frequency 28 GHz of LOS conditions with MSE is 0.001 and the standard deviation error is 0.0319. Suggestions for further research are to add some influential parameters in the communication channel such as noise.

REFERENCES

[1] A. Ubaidillah, M. Ulum and S. Pramono, "Planning of Path Loss in Large Scale Signal Propagation Model at 5G Network by Using Linear Regression Methods," *Journal of Physics: Conference Series* , 2019.

[2] A. M. Ahmed, S. A. Hasan and S. A. Majeed, "5G Mobile Systems, Challenges and Technologies : A Survey," *Journal of Theoritical and Applied Information Technology,* vol. 97, no. 11, pp. 3214-3226, 2019.

[3] T. S. Rappaport, G. R. MacCartney, Jr., M. K. Samimi and S. Sun, "Wideband Millimeter-Wave Propagation Measurements and Channel Models for Future Wireless Communication System Design," *IEEE Transaction on Communications* , vol. 63, no. 9, September 2015.

[4] A. Barreto, B. Faria, P. L. d. A. Erika, R. L. Ignacio, L. Mads, R. M. d. Amorim and V. Robson, "5G-Wireless Communications for 2020," *Journal of Communication and Information Systems,* vol. 31, no. 1, 2016.

[5] D. D. Pai, "A Survey on Millimeter of Wave Mobile Communications for 5G Cellular Networks," *International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering,* vol. 5, no. 6, June 2017.

[6] S. Buzzi, C. Lin I, T. E. Klein, H. V. Poor, C. Yang and A. Zappone, "A Survey of Energy-Efficient Techniques for 5G Networks and Challenges Ahead," *IEEE Journal on Selected Areas in Communications,* vol. 34, no. 4, April 2016.

[7] S. Kumar, T. Agrawal and P. Singh, "A Future Communication Technology: 5G," *International Journal of Future Generation Communication and Networking,* vol. 9, no. 1, pp. 303-310, 2016.

[8] R. . K. Saha, . P. Saengudomlert and C. Aswakul, "Evolution Toward 5G Mobile Networks - A Survey on Enabling Technologies," *Engineering Journal* , vol. 20, no. 1, January 2016.

[9] K. A. Garg and D. A. Mishra, "5G Network Advanced Techniques : A Literature Review," *International Journal of Engineering and Technical Research,* vol. 8, no. 5, pp. 52-57, 2018.

[10] M. B. Majed, T. A. Rahman, O. A. Aziz, M. N. Hindia and E. Hanafi, "Channel Characterization and Path Loss Modeling in Indoor Environment at 4.5, 28 and 38 GHz for 5G Cellular Networks," *International* .

[11] M. B. Majed, T. A. Rahman and O. A. Aziz, "Propagation Path Loss Modeling and Outdoor Coverage Measurements Review in Millimeter Wave Bands for 5G Cellular Communications," *International Journal of Electrical and Computer Engineering,* vol. 8, no. 4, pp. 2254-2260, 2018.

[12] Z. M. Temesvari, D. Maros and P. Kadar, "Review of Mobile Communication and The 5G in Manufacturing," *ScienceDirect Procedia Manufacturing : The 12th International Conference Interdisciplinarity in Engineering,* vol. 32, pp. 600-612, 2019.

[13] A. K. Tripathi, A. Rajak and A. K. Shrivastava, "Role of 5G Networks : Issues, Challenges and Applilcations," *International Journal of Engineering and Advanced Technology,* vol. 8, no. 8, pp. 3172-3178, 2019.

[14] H. T. S. AlRikabi and A. H. M. Alaidi, "Analysis of Efficient Energy Prediction for 5G Wireless Communication Technologies," *International Journal of Emerging Technologies in Learning,* vol. 14, no. 8, pp. 23-37, 2019.

[15] S. Sun, T. S. Rappaport, T. A. Thomas, A. Ghosh, H. C. Nguyen, I. Z. Kovács, I. Rodriguez, O. Koymen and A. Partyka, "Investigation of Prediction Accuracy, Sensitivity, and Parameters Stability of Large-Scale Propagation Path loss Models for 5G Wireless Communications," *IEEE Transactions on Vehicular Technology,* vol. 65, no. 5, May 2016.

[16] T. S. Rappaport, S. Sun, R. Mayzus, H. Zhao, Y. Azar, K. Wang, G. N. Wong, J. K. Schulz, M. Samimi and F. Gutierrez, "Millimeter Wave Mobile Communications for 5G Cellular: It Will Work!," *IEEE Access*, vol. 1, no. 10, pp. 335-349, 2013.

.