A Fuzzy-Logic Based Signal Loss Model At 2.6ghz For Wireless Networks

Stephen Ojo, Victor Ojong Etta

Abstract: The article presents an optimal signal loss propagation model developed at 2.6GHz with the use of fuzzy-logic which is used to primarily represent all measure of uncertainties and uncertain data spectrum thereby producing accurate results. Experimental data were collected across Cyprus at 2.6GHz and compared with three existing signal loss models. The fuzzy-logic signal loss prediction model was then developed and compared with the experimental data and with each of the theoretical empirical models, the newly developed model predicted signal loss with the greatest accuracy as it gives the lowest root-mean square error. The newly developed model is very efficient for signal propagation.

Keywords: signal loss, fuzzy-logic, experimental, propagation, accuracy, empirical

1. INTRODUCTION

Wireless networks have brought a great uniqueness to the world of mobile communication because of the capacity to provide adequate coverage with the use of effective propagation models [1]-[4]. The wireless mobile networks employs high frequency radio waves to establish communication between a base transceiver station and a mobile receiver in a way without any wired connection between them [5]-[6]. There are many growing issues when it comes to wireless communication and the sustainability of such a system in which some of them are channel capacity, noise, interference, losses in signals, frequency reuse and security of wireless system. The major goal and objective in signal transmission is to have a minimal attenuation as signals transmit from the transmitter to the receiver. Signal Propagation models are essential parameters employed in wireless network planning and optimization. They are very effective in interference analysis and cell parameter evaluation. Planning for a network entails using the right signal propagation model so optimization can be achieved. These models are developed principally to ensure high accuracy in signal transmission. Signal loss are developed by network engineers and professionals to estimate the path loss of the received signal as they travel from the base station to the receiver. The problem with many of these models is that they only function effectively in the environment where the field measurement was carried out and performed woefully when deployed to the other areas. For this reason, the signal propagation models faces a huge difficulty when it comes to generalizing and extension for use in multiple environments. Signal Propagation measurements must therefore be carried out before any analytical model of high accuracy can be achieved. The experimental measurements is important so there can be proper channel characterization and to provide signal parameters that will generate efficient performance and optimization. Measured signal loss will be compared with existing analytical signal loss models to determine which of the models predicts signal loss with the greatest level of accuracy and lowest coefficient of error. The validation will be done with root-mean square error (RMSE. The world of wireless telecommunication is growing at a fast rate and the need for an optimized model is coming more to the forefront because of an increased appetite for an advanced and improved service as in the case of bandwidth by mobile subscribers; as a result, there is a high need for proper network coverage prediction [2]. In wireless radio networks obstacles in the signal path as it travels from the transmitter to the receiver causes attenuation in signal strength which is the signal loss that must be accurately characterized for effective transmission to take place. Signal loss is the attenuation of radio signal. The models play a very prominent role role in radio frequency coverage optimization, interference analysis and also for an optimized usage of the available network resources [3]. The accuracy of the propagation model cannot be overemphasized because it plays a major role in the overall system design and implementation. For network service providers to accurately determine the exact value of signal loss, there is need for extensive field measurements, site survey analysis and a careful parameter evaluation to represent what is best for the environment where the model is to be deployed. Many propagation models have been developed and they fall into different categories such as empirical, stochastic and deterministic with each of them not performing optimally when deployed to other areas outside of the original place where the propagation measurement was taken. It is for this reason that this study will employ the concept of fuzzy logic because it can solve the problem of uncertainties that has existed in the other propagation models. The introduction of fuzzy logic to the subject of signal loss is to ensure greater accuracy in the network prediction model so that good quality of service will be enjoyed by mobile subscribers. The probability of call blocking, call dropping will also reduce drastically when a fuzzy-logic designed signal loss model is developed as the case in this paper. A network planner who cannot accurately determine the signal loss will ultimately produce a very much expensive network or a network of low quality [5].

2. MATERIALS AND METHODOLOGY

The fuzzy- logic designed signal loss model articulated in this article will follow a systematic approach. Field measurements was collected across 6 base stations in Cyprus. Measured signal loss will be compared with existing analytical propagation models and validation will be done with the root—mean square error (RMSE). The performance of the developed fuzzy-logic based signal will also be compared with the performances of the existing signal loss propagation model and results will be shown in section three of the paper.

2.1 Experimental Study
The signal losses measured were obtained from the experimental study carried out at 6 base stations in Cyprus with the aid of a drive test. The field measurements was done in conjunction with Vodafone Telecommunication company in Cyprus with measurements collected across rural, ,suburban and urban areas so as to ensure a wide class of representation. The areas in the cities are categorized as urban (metropolitan), while some others less congested are classified as sub-urban and the areas closer to what is obtainable in free space where a dominant line of sight exists were classified as flat/ open (rural) areas because of the network congestion in the place, cell size and other technical factors. Field measurements were collected at a distance of 100m-2.0km with the intervals of 100m. The field experiments were conducted with Test Mobile System (Tems) 16.3 investigation tool coupled with other equipment all housed in a vehicle during the drive test. A portable Lenovo laptop computer, a fix GPS was used to ascertain the exact location at a particular point as signals travel from the transmitter to the receiver. A mobile phone of height 1.5m serves as the mobile receiving station. Also a USB connector to connect device to the Laptop, serial cables, a vehicle. All the drive test equipment and devices were connected to the Lenovo Laptop inside the vehicle and signal strength was measured at 2600MHz at an interval of 100m starting from 1km-2.0km. Signal strength was measured across 6 base stations in Cyprus at an operating frequency of 2.6GHz. Two base stations in Kyrenia, two in Lefkosia and two in Magusa representing urban, suburban and rural areas respectively. The signal strength measured is subtracted from the effective isotropic radiated power (EIRP) to determine the exact signal loss at each measuring distance.

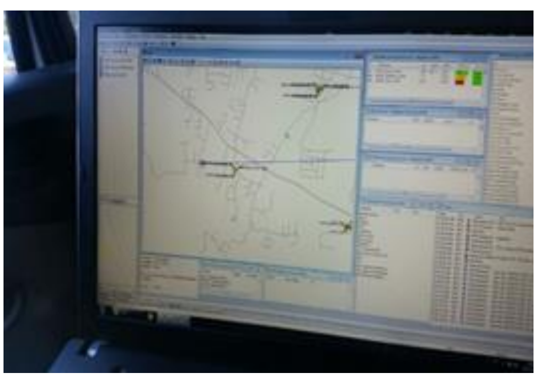

***Figure1: Drive** test at 2.6GHz*

2.2 Selected Signal Loss Models
Some existing signal loss models were selected and compared with the measured data so as to check which of them agreed well with the field measurements with little or no error. There are so many of these models but the few prominent ones will be examined and used in this article.

2.2.1 Stanford University Interim Model
The Stanford university interim model is applicable for signal propagation below 11GHz and used for both fixed and wireless mobile system

$$\text{Signal loss} = B + 10\gamma \log_{10}\left(\frac{d}{d_0}\right) + K_f + K_h + S_f \quad for\ d \succ d_0 \qquad (1)$$

$$A = 20\log_{10}\left(\frac{4\pi d_0}{\lambda}\right) \qquad (2)$$

$$\gamma = a - bh_b + \frac{c}{h_b} \qquad (3)$$

$$K_f = 6.0\log_{10}\left(\frac{f}{2000}\right) \qquad (4)$$

$$K_h = -10.8\log_{10}\left(\frac{h_r}{2000}\right) \quad for\ terrain\ A\ and\ B \qquad (5)$$

$$K_h = -20.0\log_{10}\left(\frac{h_r}{2000}\right) \quad for\ terrain\ C$$

B in the equation is given as the free space signal loss while d represent distance in km from transmitter to the receiver a,b,c represents terrain parameters for urban, suburban and rural areas respectively.

2.2.2 ECC-33 Model

This signal loss propagation came into existence as an improvement of the Okumura model. All the inadequacies of the initial model were reviewed in the development of the ECC-33 model [10].

$$S_L(dB) = A_{FS} + A_{BM} - G_B - G_R \qquad (6)$$

$$A_{FS} = 92.4 + 20\log_{10}(d) + 20\log_{10}(f) \qquad (7)$$

$$A_{BM} = 20.41 + 9.83\log_{10}(d) + 7.894\log_{10}(f) + 9.56(\log_{10}(f))^2 \qquad (8)$$

$$G_B = \left(\log_{10}\left(\frac{h_b}{200}\right)\right)\left(13.958 + 5.8(\log_{10}(d))^2\right) \qquad (9)$$

$$G_R = [42.57 + 13.7\log_{10}(f)][\log_{10}(h_r) - 0.585] \qquad (10)$$

Where A_{FS} represents the free space attenuation, is the median signal loss, is the base station height gain factor, is the mobile station antenna gain factor, f is the frequency in GHz, d is the distance of separation between the transmitting station and the mobile station in km.

2.3 Fuzzy-Logic Signal Loss Model
Fuzzy-logic is all about precision and accuracy because some parts of the system cannot be analyzed critically if we go by the existing analytical signal loss models. Fuzzy logic is all about the need to reflect all parts of the system in a very accurate way. The fuzzy-logic designed signal loss model designed in this article employs fuzzy set theory in which two variables like frequency are members of a set with some degree of membership. It is very useful in the design of signal loss models because it can effectively represent non-linear systems which is what is obtained in a typical urban environment where it is very difficult to have a line of sight. The type 2 fuzzy logic will be adopted in developing our signal loss model because the IF-THEN rules will be very useful in achieving efficient system

design. All the details of the propagation environment that will step up the accuracy of the model are converted into type-2 fuzzy set by the fuzzifur and later inference by the IF-THEN depending on the input and output of the signal loss model [6-8] The fuzzy interference system is such that the behavior of the system that controls the input and the output variable is controlled by a set of rules A which provide a strong correlation to the development of an accurate signal loss model than the existing ones. The rule used in the development of our signal loss model is specified as follows

$$if\ y = B, then\ z = C$$

$$100 \leq f \leq 2600GHz$$

$$1.5 \leq h_r \leq 8m$$

$$100 \leq d \leq 2km$$

$if\ y = B, then\ z = C$ When a set of input variables are read then each of the rule that has any degree of truth is added to the membership function as the fuzzy logic system (FLS) approximately represents both the input and the output variable.

The input variables in the signal loss model are received signal strength and the distance while the output is the signal loss. We adopted a Gaussian membership function for the two input variables and a triangular membership function for the output variable. The deffuzification process is very important because the fuzzy quantity needs to be converted back to the crisp entity. The fuzzy-logic toolbox in MATLAB 2016RB was used for the simulation and a 16 – based rule system was adopted because of simplicity.

3. RESULTS AND DISCUSSION.

The signal loss of the received signal at any point from the transmitter to the receiver is given as follows

$$signal\ loss = EIRP - signal\ strenght \quad (11)$$

The effective Isotropic Radiated Power (EIRP) is 57.6dBm and the signal loss becomes

Signal loss = 53.5 – Received power,

The two inputs to the fuzzy-logic are distance and the received signal strength. From the fuzzy-logic design, the rule view of the model is shown

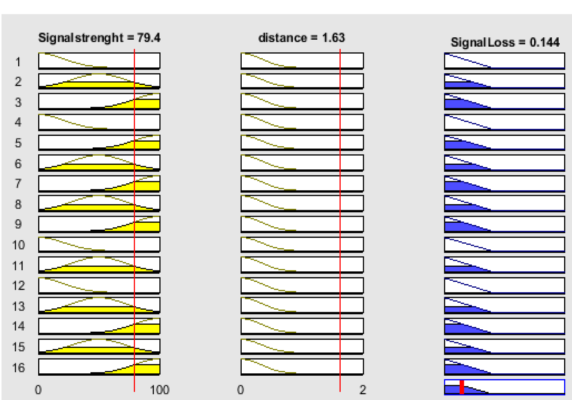

Figure2: *Rule view of Fuzzy based signal loss model*

The signal loss is largely dependent on the two parameters which is a function of distance and the received signal strength. To model an accurate and effective signal loss, the network providers must do it as a function of the two parameters.

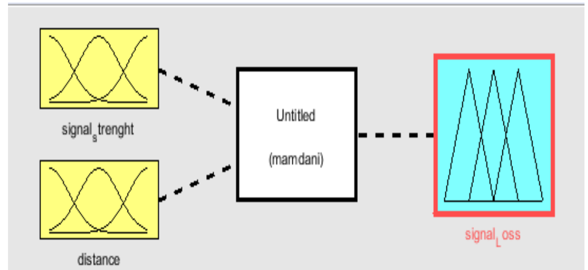

Figure3: *inputs and output parameter of the design*

The surface view of the model in each of the areas considered will be shown in the next section and it reflects large signal loss in urban areas because of the non-existent of dominant line of sight.

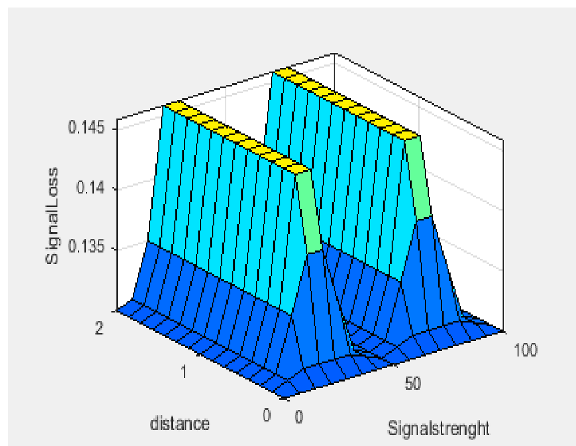

Figure 4: *Surface view of the signal loss in rural area*

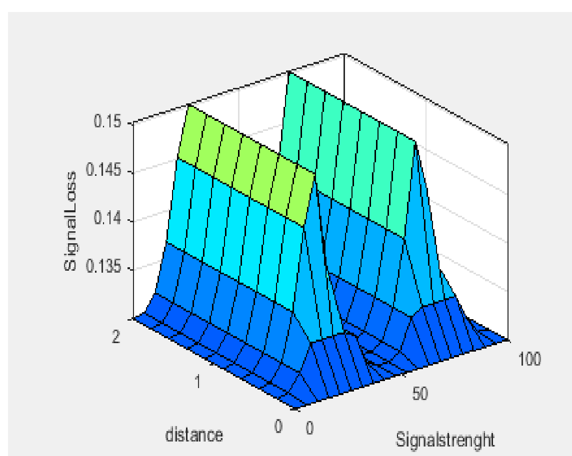

Figure 5: *Surface view of the signal loss in urban area*

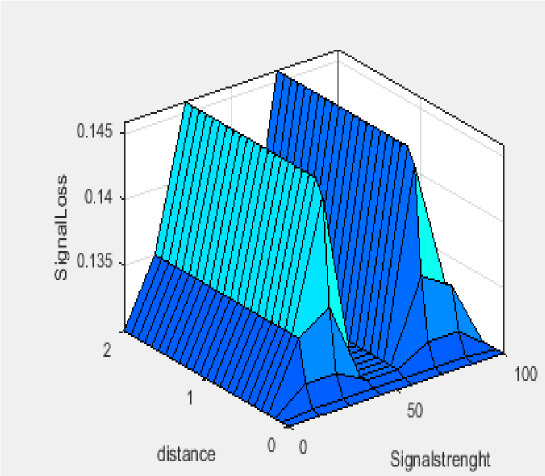

Figure 6: *Surface view of the signal loss in suburban area*

Figures 4,5 and 6 shown gives the surface plots of the fuzzy-logic signal loss model and it is evident from the plots that the signal loss is largely dependent on the distance and the signal strength. The signal loss is smallest in the rural areas where there is little obstruction in signal path from the transmitter to the receiver and where a clear dominant line of sight exists. The performance of the fuzzy-logic signal loss model was compared with the experimental study and existing propagation models in rural, suburban and urban areas as shown in figures 7,8 and 9. The newly developed fuzzy-logic signal loss model predicts signal loss in Cyprus very accurately as it gave signal loss very close to experimental data. The performance of the new model was far better than the existing models because of the ability of fuzzy-logic to accurately model any form of uncertainties. That is why the new model gave the signal loss accurately like the field measured data.

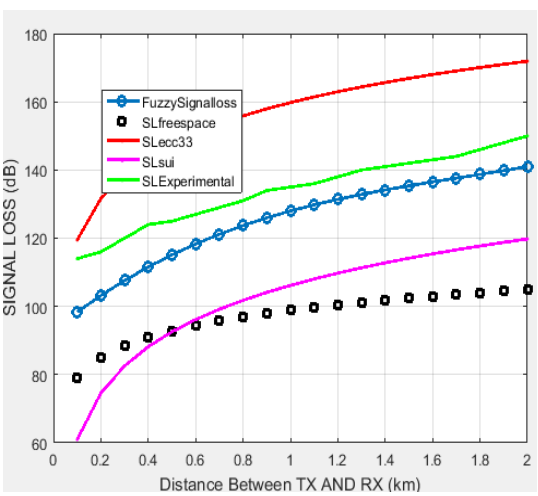

Figure 7: *Signal loss of experimental data, the newly developed fuzzy-model and the existing models in urban areas.*

Figure 7 shows that the new fuzzy-logic model predicts signal loss accurately than the other existing models examined. The graph of the fuzzy-logic model is the closest to the experimental data. Signal loss is highest in the urban areas because of the many obstructions in signal path from the transmitter to the receiver.

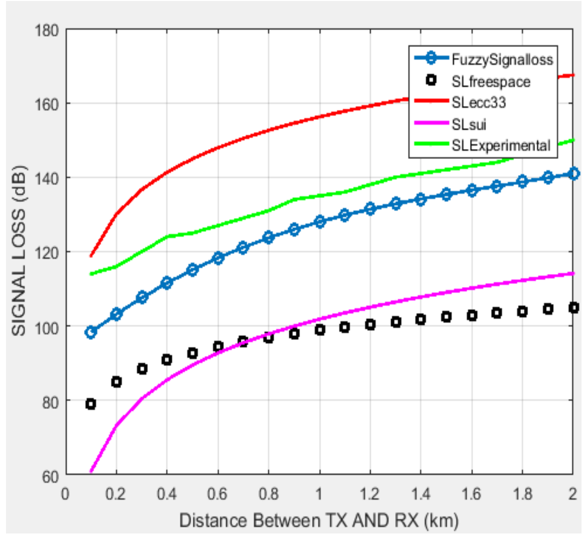

Figure 8: *Signal loss of experimental data, the newly developed fuzzy-model and the existing models in suburban areas.*

Figure 8 shows that the new fuzzy-logic model predicts signal loss accurately than the other existing models in suburban areas in locations examined. The graph of the fuzzy-logic model is the closest to the experimental data

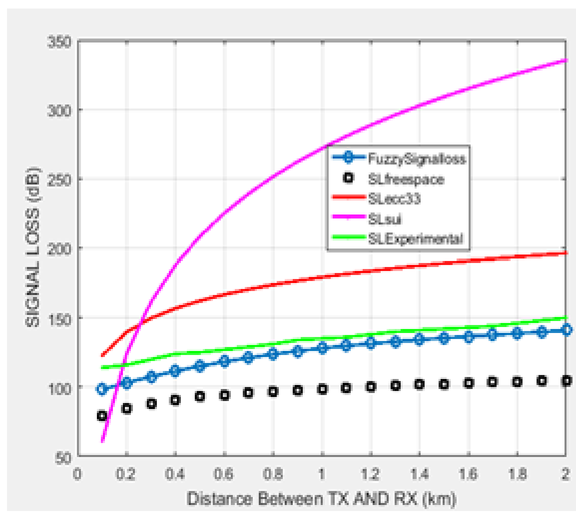

Figure 9: *Signal loss of experimental data, the newly developed fuzzy-model and the existing models in rural areas.*

Figure 9 shows that the new fuzzy-logic model predicts signal loss accurately than the other existing models in rural areas in all locations examined. The graph of the fuzzy-logic model is the closest to the experimental data. Signal loss is highly reduced in all base stations in rural areas because there is a dominant line of sight.

Table 1. *The RMSE values for the different signal loss models*

Signal loss Model	Rural	Suburban	Urban
ECC-33	8.59	9.44	8.02
Free space	7.89	8.96	5.92
Fuzzyy-logic model	2.96	3.84	4.78
SUI	22.62	16.94	14.65

4. CONCLUSION

A newly developed fuzzy-logic based signal loss model was developed in the article at an operating frequency of 2.6GHz. The developed model was compared with the other existing models and it predicted signal loss with the lowest root-mean square error. The new model has an RMSE values of 2.96dB, 3.84dB and 4.78dB in rural, suburban and urban areas respectively. The other existing models over predicted signal loss. The new models perform best when compared with the experimental signal loss in Cyprus and can therefore be used for signal loss prediction and data analysis. The concept of fuzzy-logic used in the development of the model made it more efficient accurate than the other existing empirical models.

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