Wireless channel characterisation over simulations for an indoors environment at 2.4GHz

Tafseer Akhtar, Ilias Politis, and Stavros Kotsopoulos

Wireless Telecommunications Lab.*, University of Patras, 26500 Rio Greece
{takhtar,ipolits,kotsop}@ece.upatras.gr

Abstract. Mobile communication is on the brink of another transformation as fifth generation networks and their architectures are already mature for deployment. As the volume and intensity of data flow drastically increases, the technologies that fuel such changes need to be evolved. Mobile small cells are going to play a key role in the deployment of these new communication infrastructures, extending the reach of wireless access. In this paper a number of path loss models for and indoors office environment are simulated using Mininet-WiFi. The channel characterization is based on a set of parameters including RSSI, SINR, latency, throughput, etc. The preliminary results indicate that ITU and multi walls multi floors models are accurate enough to be used as a basis for an intelligent, cloud based radio resource management of heterogeneous wireless mobile small cells.

Keywords: path loss· SINR· Transmit power· Mininet-WiFi

1 Introduction

It is already clear that fifth generation (5G) networks and services are defined through a set of strict requirements such as throughput gain and consumed energy. The driving force for such dramatic evolution towards a mobile networking paradigm of higher data rates and capacity, ultra-low latency and increased resilience, is the immersive, high quality of experience and ubiquitous smart mobile applications. 5G is also rotating around the notion of multitudes of connected devices over small areas resulting in ultra-dense device-to-device communication networks that will generate and consume huge data volumes [1],[2]. The 5G paradigm as it emerges in recent studies [3] and early pilots [4], adopts a number of technological solutions to form the building blocks of the next generation wireless mobile network architecture and address all these challenges [5].

Specifically, the future networking environment will be characterized by highly dense heterogeneous cells. This heterogeneity is extended not only to the diverse

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radio access technologies that 5G networks will incorporate (i.e., 3G, 4G, 5G, etc.) but also to the different type of cells that future wireless networks will consider, including macro, pico and small cells [6]. Cloud is already anticipated to be the cornerstone of 5G deployments and as such, Cloud-RAN is considered as a key enabler for efficient base band processing in the cloud [7]. As the future networking environment begins to materialize, it seems that the concept of cooperated small cells may provide a basis for the mobile cell architecture. SECRET project [8] aims to narrow the gap between current networking technologies and the foreseen requirements of 5G for higher networking capacity, ability to support more users, lower cost per bit, enhanced energy efficiency. SECRET project builds on current technology trends, widely accepted to form part of 5G, by aiming to a new deployment of small cells based on the notion of mobile small cells. Another dimension of innovation of SECRET is the provision of wireless fronthaul to provide high-speed reduced-cost energy-efficient connectivity to mobile small cells.

The research in the area of 5G wireless connectivity and communication follows in the steps of 4G and LTE. Evidently, the importance of channel modelling and particularly for indoors environments is still undimmed and offers opportunities for further investigation of the effect that environmental conditions (i.e., building materials, wall and floor surfaces, etc.) can have on the channel behaviour. One of the pillars of 5G networking paradigm is highly dense wireless networks, which may well be deployed indoors. Such communication system need to be developed with a specific focus on indoors propagation modelling, accounting for obstacles of various sizes, multiple walls and floors that intervene in the path of the propagated signals. Therefore, study of path loss models for indoors environments remain interesting. The recent research output has significantly contributed to novel wireless channel characterization through simulations and measurements. A keen interest has been aimed at the 2.4 GHz frequency, which concerns the 802.11b/g/n protocols. Many works have provided empirical data derived from measurements based on actual operating systems at 2.4 GHz [9, 10]. Another frequency of interest is the 3.5 GHz channel. Internationally acclaimed as a WiMax frequency, the 3.5 GHz channel has also been featured in scientific works [11], which investigate the variations of the signal amplitude and phase in both indoor and outdoor scenarios. There are, however, many open issues regarding the relation of the large scale fluctuations of the received signal to the intrinsic channel characteristics and site-specific irregularities.

This paper focuses on channel characterization of an office environment through simulations using the Mininet tool with wifi extensions [12]. The simulations aims to study the fluctuation of SINR (Signal to Interference Noise Ratio) over different distances from the transmitting nodes and also measure the required energy for achieving equal SINR for all receiving wireless nodes. The results and conclusions concerning validation of already known path loss models for 2.4 GHz frequency in an indoor environment will provide the basic setup for further studies and development of more intelligent radio resource management functionalities.

The rest of the paper is organised as follows.

2 Simulation scenario

2.1 Simulation setup

The experiment scenario contains small cells and nodes, where small cell are acting as access point and nodes (user interface) are connected with these small cells. All the nodes are having similar features (i.e., mode, channel, working frequency, antenna height, antenna gain, etc.) and the two small cells are also similar except the transmission power capability which is varying to observe and analyse the behaviour of nodes. The varying power is used for calculating RSSI (Received Signal Strength Indicator), SINR, path loss and throughput of the whole network.

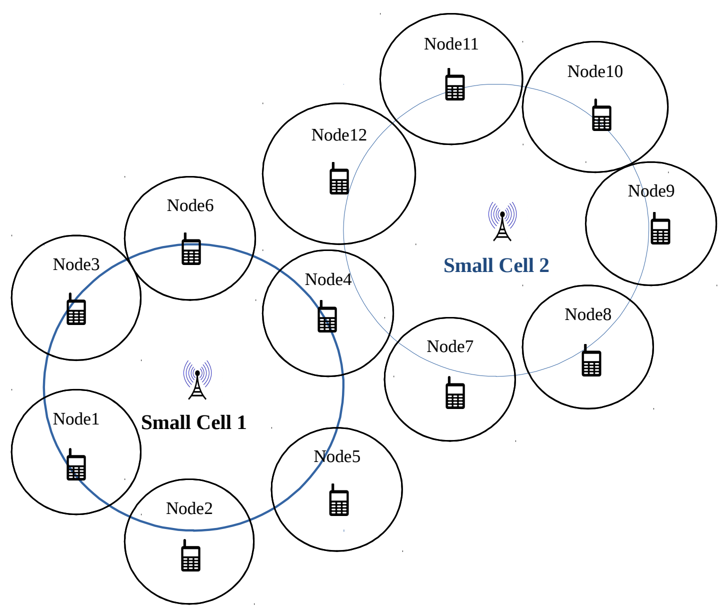

Fig. 1. Experimental network with nodes (UI) and small cells.

Mininet-WiFi tool is used for creating our experimental scenarios, in Fig. 1 the experimental network is described with all its components. There are twelve nodes and two small cells. Both the small cells are connected via a physical LAN (Local Area Network), all the nodes are only receiving the signal from small cells, and not transmitting any signal (downlink only). The distance between small cells is fixed and they are continuously transmitting the signal to the connected nodes. Every node is connected to only one small cell depending on the attributes of small cell in the range. There is no interference effect between any nodes as they are acting as receiver only. Mininet-WiFi is a SDN based emulator which uses mac80211_hwsim Linux kernel module for simulating the IEEE 802.11 radio device, which enables it for more accurate results and close real device behaviour.

2.2 Configurations of path loss models

In Mininet-WiFi there are several path loss models which can be used for analysing the behaviour of experimental network, some of them are for open space and few are for the indoor environment. These are the path loss model we have considered for analysing the behaviour of our experimental network.

Log distance path loss model Log distance path loss model is an extension of Frills free space path loss model and it is a generic model that can be used for outdoor environment. It can also be used in different kinds of environment where obstacles can also be a part of network structure. For far field region the transmitter distance $PL(d_0)$, where $d \geq d_f$, is path loss calculated in dB. At the distance (d_0) from transmitter, path loss (loss in the signal power is calculated in dB where movement happens from distance d_0 to d) at any given distance where $d > d_0$, is measured by equation(1(, where $PL(d_0)$ is Path Loss in dB at a distance d_0, $PL_{d_0 \to d}$ is Path Loss in dB at an arbitrary distance d and n is the Path Loss exponent.

$$PL_{d_0 \to d}(dB) = PL_{d_0} + 10n \log\left(\frac{d}{d_0}\right), \text{ where } d_f \leq d_0 \leq d \tag{1}$$

Table 1. Path loss exponent for various environments for Log distance path loss model.

Environment	Path Loss Exponent (n)
Free Space	2
Urban area cellular radio	2.7 to 3.5
Shadowed urban cellular radio	3 to 5
Inside a building-Line of Sight (LOS)	1.6 to 1.8
Obstructed in building	4 to 6
Obstructed in factory	2 to 3

Table 1 describes the values of path loss exponent that we can used for designing the network, in various kind of environment using Log distance path loss model. Path Loss Exponent (PLE) value depends upon the actual environment that we are modelling. PLE estimation needs empirical values which are collected over different time instants and the values provided here are for reference purpose.

Log normal shadowing model Log normal shadowing model is similar to the log distance model but in here we also consider the shadowing effect which makes it more practical and accurate compare to log distance model. It is an extension to log distance model where a new variable χ will come into play and added to the equation(1(of Log distance path loss calculation. In the real environment scenario the shadowing effect always exists, the path loss is calculated as in equation(2(.

$$PL_{d_0 \to d}(dB) = PL_{d_0} + 10n \log\left(\frac{d}{d_0}\right) + \chi, \text{ where } d_f \leq d_0 \leq d \tag{2}$$

In (2) χ is zero-mean Gaussian distributed random variable (in dB) with standard deviation (σ), the variable came into picture when shadowing effect exists. When there is no shadowing effect, the value of this variable is 0. The exponent and deviation of the random variable must be precisely known for modelling the network.

ITU indoor propagation model The International Telecommunication Union (ITU) path loss model is developed for the indoor environment. It is a radio propagation path loss model that estimates losses inside any closed area in a building surrounded by the walls, which is very appropriate for designing the appliances for indoor environment. The path loss depends upon many different parameters and it is calculated by using equation(3) in which L is the total path loss in dB, f is the frequency of transmission in MHz, d is the distance in meters, N is the distance power loss coefficient, n is the number of floors between the transmitter and receiver and $P_f(n)$ is the floor loss penetration factor.

$$PL_{d_0 \to d}(dB) = 20 \log(f) + N \log(d) + P_f(n) - 28 \tag{3}$$

The calculation of the distance power loss coefficient (N) is based on the frequeny range depicted in Table 2.

Table 2. Distance power loss coefficient (N) for ITU path loss model.

Frequency Band	Residential Area	Office Area	Commercial Area
900 MHz	N/A	33	20
1.2-1.3 GHz	N/A	32	22
1.8-2.0 GHz	28	30	22
4 GHz	N/A	28	22
5.2 GHz	30 (Apartment), 28 (House)	31	N/A
5.8 GHz	N/A	24	N/A
60 GHz	N/A	22	17

Floor loss penetration factor is also a crucial element for calculating the path loss the calculation of which is summarised in Table 3.

Table 3. Floor loss penetration factor (Pf) for ITU path loss model

Frequency Band	No of Floors	Residential Area	Office Area	Commercial Area
900 MHz	1	N/A	9	N/A
1.2-1.3 GHz	2	N/A	19	N/A
1.8-2.0 GHz	3	N/A	24	N/A
4 GHz	N	4n	$15 + 4(n-1)$	$6 + 3(n-1)$
5.2 GHz	1	N/A	16	N/A
5.8 GHz	1	N/A	22(1 floor), 28(2 floor)	N/A

ITU path loss model is used mostly for indoor environments. Appliances that use the lower bands (2.4 GHz) are preferred for this model, however it is applicable to a much wider frequency range.

Multi wall and floor propagation model For multi wall and multi floor environment the WINNER II channel model is used for calculating path loss. It is based on the stochastic geometry approach which has double direction radio channel model. It has both line of sight (LOS) and non LOS (NLOS) models parameters for various environments, in our experimental setup we are using NLOS model for calculating path loss. For calculating the path loss, the equation(4)is used. In ((4)), d is the distance between transmitter and receiver in meters, f is the channel frequency in GHz, A is the path-loss exponent, B is the intercept, C is the path loss frequency dependence, X is the environment-specific value (i.e., wall attenuation, etc.), FL is the floor loss, n_w is the number of walls between source and destination and n_f is the number of floors between source and destination.

$$\begin{aligned} PL(dB) = A\log(d) + B + C\log\left(\frac{f}{5}\right) + X + FL \\ X = 12n_w \\ FL = 17 + 4\left(n_f - 1\right) \\ n_f > 0 \end{aligned} \tag{4}$$

For the specific experiment scenario the values for various parameters are fixed and displayed in Table 4.

Table 4. Various fixed parameters for multi walls and floors propagation path loss model

Parameter	Value
Path Loss Exponent (A)	20
Intercept value (B)	46.4
Frequency Dependence (C)	20
Number of walls (nw)	2
Number of Floors (nf)	1

All these four path loss model are consider for the analysing the experimental network where our objective is to find the best path loss model which is suitable for small cell environment where the energy loss is minimum and the results closely emulate the real network environments.

3 Results and Discussion

In Mininet-WiFi for developing the experimental scenario, many parameters of nodes (UI) and small cell (Access point) are fixed and same values are used throughout the network. Table 5 showcases these parameters.

Table 5. Various fixed parameters of experimental setup

Simulation Parameter	Value
Total Small Cells	2
Total Nodes (UIs)	12
Working Frequency (GHz)	2.41
Channel Mode	a
Antenna Height (m)	1
Antenna Gain	5
Channel Used	36
Fading Coefficient	6
Path Loss Exponent	3.5
Noise Threshold (dB)	-91

3.1 Transmission power for achieving minimum acceptable SINR

In the experiment, all four path loss models are considered, where transmission power is changed from low to high with respect of distance between node and connected small cell to achieve minimum acceptable SINR (20 dB). The minimum acceptable SINR is needed between source and destination for efficient communication. As the distance between small cell (source) and destination (node) increases the need of transmission power also increase.

In Fig. 3, transmission power of small cell varies from low value to its highest value (which is 20 dBm) to achieve minimum SINR with respect to distance between small cell and connected node. In Log distance and Log normal shadowing the behaviour is almost similar with little variation where with the low value of transmission power, 10m distance or less is receiving minimum SINR value and they progress almost linearly. The maximum distance they can reach with the maximum transmission power (20 dBm) is around 40m in both the cases. ITU model shows different behaviour from Log distance and Log normal shadowing path loss model, which is designed for indoor environments, and is suitable for our experimental lab setup. ITU model requires very less power to cover the distance around 15m for minimum SINR but after that it moves very slowly to cover more distance for minimum SINR. For covering 20m distance it requires around 15 dBm and it barely reaches 30 m distance when maximum transmission power is applied to achieve minimum SINR. Multi walls and floors model from WINNER II model shows more acceptable behaviour and it is also suitable path loss model for indoor environment and effective for our experimental setup. Here for the coverage of 10m distance to achieve minimum SINR, it needs around 10 dBm and from that point, it varies almost linearly. The maximum distance coverage is just above 30m when maximum transmission power is applied. Evidently, after comparing and analysing these four path loss model, we can observe that Multi walls and floors model is most suitable for our experimental scenario as it closely emulated the real network environment.

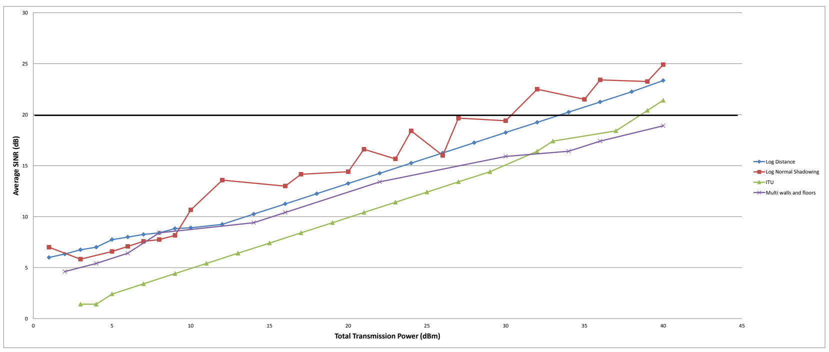

Fig. 2. Comparison of propagation models when combined power of small cell varies to change average SINR

3.2 Total transmission power and average SINR

All the path loss models are compared for analysing the average SINR when the nodes are stationary and only transmission power is varying to control the network. The result of various path loss model is shown in Fig. **??**, all four path loss models are compared on the basis of total transmission power and respective average SINR received by the network. The plot includes the total transmission power of both small cells, average SINRand the minimum acceptable SINR (20 dB).

It can be seen that the Log distance model varies linearly after the total power reaches the point around 15 dBm and it achieve maximum 23 dB average SINR when maximum power is applied (40 dBm). The behaviour of Log normal shadowing is irregular and it progresses with the increase in total power non-uniformly, although it achieve highest level of average SINR (25 dB) when maximum power is applied. The behaviour of the ITU model is uniform and it varies linearly from the start and barely reaches above acceptable SINR value when maximum transmission power is applied. Multi walls and floors model performs almost linearly with the increase of transmission power. Although the progress is very slow and it never achieves the average minimum SINR threshold even after applying the maximum transmission power. The comparison of these results leads to the conclusion that the ITU and Multi walls and floors models are more accurate than Log distance and Log normal shadowing models when used in the specific conditions. Hence, these results indicate that the ITU and Multi walls and floors models could be potentially be applied for realizing the network for further analysis and development of intelligent resource management techniques in an effort to maximise quality of experience for wireless users while minimising the energy consumption.

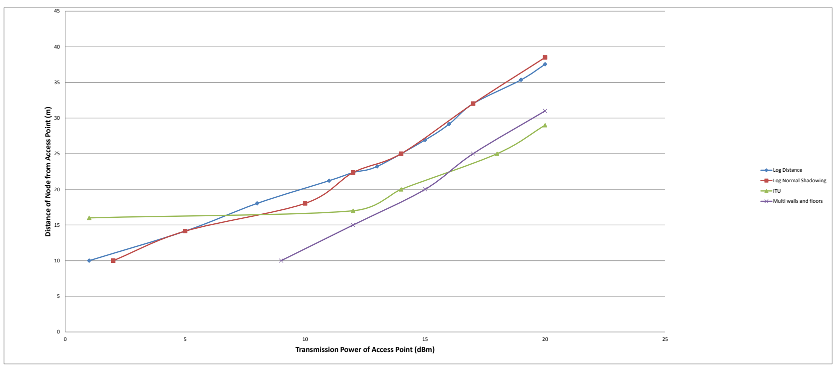

Fig. 3. Comparison of propagation models when combined power of small cell varies to change average SINR

4 Conclusions

The 5G era imposes a set of strict requirements for achieving ultra-low latency, high reliability and high throughputs across wireless mobile devices. Such requirements are more difficult to achieve in densely connected networks. The research studies of path loss models in indoors environments will need to be revisited in an effort to produce more accurate models. Accurate channel characterisation models would pave the road for precise and efficient resource management. Towards this end SECRET project aims to develop efficient radio resource management schemes based on accurate channel characterization in indoors and outdoors environments for provind mobile small cells with maximum quality of experience levels with the minimum energy consumption. This paper proposed Mininet-WiFi as a tool for simulating channel conditions and to this end, it compares a number of native to Mininet-WiFi and newly configured path loss models. The comparison indicates that both the ITU and the Multi walls and multi floors models are accurate enough to form the basis for the future developments.

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