Characterization of Multi-Link Channel for Wireless Channel

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Abstract: In this paper we present the results of a statistical analysis of the wireless radio channel in indoor home scenarios at 2.4 GHz frequency. This study focuses on developing an empirical path loss model for 802.11n network. The work is based on an extensive set of received signal strength (RSS) measurements collected within different typical indoor spaces scenarios. A frequency domain based experiment is performed for line-of-sight (LOS) and obstruction propagation conditions. A measurement of signal level within indoor environment is done without presence of people movement. The characterization of the path loss exponent and the reference path loss are provided. The measurement aims was to find empirical parameters to wireless channel models. Results are compared with corresponding values from the log-distance model, which is most widely used in wireless networks. The analysis reveals interesting regularities within the measured data and expected we observe a highly non stationary behaviour of the RSS.

Keywords: 802.11, Path loss, Indoor home scenarios, Received signal strength, Multi-Link channel.

Introduction

Channel path loss modeling plays a key role in many wireless applications. Existing models provide a reasonable approximation for applications in which a simplified physical layer representation does not severely compromise the overall outcome. This is a problem, in particular, for indoor environments, where random factors, such as multipath propagation may affect the signal path loss.

The purpose of this work is twofold. First, we perform a statistical study of the 2.4 GHz wireless channel in indoor home environments in order to see if the log-distance model provides accurate results.

Now a days, a multitude of emerging technologies are based on signals of opportunity as Wireless Local Area Network (WLAN), Ultra Wide-Band (UWB), Zigbee, and other used for indoor localization and tracking. In terms of cost and ability, Wireless based indoor location is widely used due to the already deployment of Anchor Points (AP) in urban and indoor areas.

Our study is based on a huge measurement campaign of collecting the RSS data in different realistic indoor spaces. We have selected several indoor spaces, which are typically for home environments (i.e., room, wall). In particular, we compare the empirical data and model parameters derived from it with analytical values [1].

The first step for indoor location is the distance estimation between the user and the AP. Several positioning techniques are found in literature for this task. Most of the network-based location estimations use RSS measurements because almost all mobile/PC devices are afforded to use this type of measurements. Theoretical and empirical models are used to translate the difference between the transmitted and Received Signal Strength into an estimated range [1]-[5].

A propagation model could built the radio map and also report changes in the environment [14]. There are several models in the literature to characterize this channel. This work considers the IEEE 802.11n channel model.

The remainder of this paper is organized as follows. In the next section we briefly review the channel models commonly used in wireless networks as well as existing statistical study of wireless channels. In section III we describe our measurement methodology and experimental setup. Section IV provides the flow of statistical processing of the measured data and the results. Finally, in section V we propose several improvements for the wireless channel model and conclude.

Related Work or Literature Studies

Literature Review

Puji Handayani, Lina Mubarokah et.al have presented loss and shadowing in the indoor atmosphere using frequency of 2.4 GHz. They achieved loss value of 51 dB over 10m distance using loss exponent of 4.2 and signal strength of -62 dBm over 14m distance [2].
Goes A. A. et.al have presented received signal strength or power over increased distance in the frequency range of 902-928 MHz using two ray ground model. Loss in the path is dependent on the signal strength for various values of distance .They achieved signal strength of -77 dBm with distance of 5m in indoor radio channel. The indoor channel has characterized using LOS and NLOS environment [6].
Christopher R. Anderson et.al have presented log-normal loss model using 2.5 GHz frequency. The measurement have done in the building environment and they achieved loss of 60 dB over 100m distance using path loss exponent value is equal to 2 which derive free environment and 65 dB over same distance using n = 2.4 [10].
P. F. M. Smulders et.al have presented signal strength and loss in the path using LOS path and also using obstructed path with bandwidth of 2 GHz. They achieved received power of -82 dBm in the obstructed path and -81 dBm in the direct path using 2GHz bandwidth [12].

Motivation

Today MIMO technology is used for many reason. For example, in broadband wireless connection we use Wi-Fi router to send data to one or more mobile terminal but the signal quality is not same for every path between router and mobile terminal because of the clutters or objects such as walls between them. Also environment which we transmit signal affect the signal strength. If we measure received signal strength at home at day light and again calculate it for the same distance but in the night then there is different in the signal level because of the clutters. Today many types of router with single and double antennas are available in the market. They use multi-link propagation channel for transmission and reception.
We measure signal strength and quality by using commercial tools at various locations in the indoor model. Signal level is measured using various methods such as RSS (received signal strength) and angle of the signal arrival. In all of these RSS has most used method because of it uses less requirements of the hardware. If there are large number of mobile terminals then quality of signal is decrease but also clutters between path degrades signal badly. In this project we use one channel router with one transmitter and two mobile receiver with 2.4GHz frequency. Signal level is dependent on how much transmit power and antenna gain we use. The problem using channel model with 2.4GHz frequency reduce signal strength because obstructions such as walls and frames decrease range than using with 5GHz.
Speed and directionality of the signal correlates with more number of antennas in the channel. We use multiple antennas which produce streams on radio channels for transmission of data. Which increase bandwidth of the system. Power and other atmosphere characteristics plays important role which limit range of the system. For various atmosphere, propagation delays are different. For example, indoor office environment has higher delay then than the residual environment where direct LOS not available.

Solution Methodologies

Techniques for channel modelling

Several wireless channel models with different levels of accuracy, complexity and flexibility are used in wireless systems simulators. Several works focus on the performance of 2.4 GHz radio links for wireless network in home environments. The free space model [15] assumes ideal propagation conditions with clear line-of-sight path between transmitter (TX) and receiver (RX) antennas and also the far-field conditions. The most used channel model in wireless network is the log-distance path loss model [15]. It accounts both for propagation path loss, logarithmically decreasing, and for shadow fading effects using a probabilistic model:

$$\overline{PL}(\text{dB}) = \overline{PL}(d_0) + 10\text{nlog}\left(\frac{d}{d_0}\right) + \text{WAF} \qquad (1)$$

Where d is the distance between transmitter and receiver antennas, $\overline{PL}(d_0)$ is the path loss at a reference distance d_0, which is typically one meter for indoor environments, n is the path loss exponent (PLE), which is determined either empirically or from the literature and WAF is wall attenuation factor for NLOS environment.
Overall, results reported in the literature agree that the standard normal distribution is not the best description for random signal propagation effects. Therefore, the log-normal shadowing used in most wireless channel simulators might be an oversimplification. However for such applications as localization, which uses RSS-based techniques, accurate channel modeling is of extreme importance. Naturally, absolute accuracy cannot be achieved with simulations in this case, because the measured RSS values are also sensitive to various other parameters (e.g., gain type of indoor space).

Experimental Setup

In all of the following experiments, wireless networks operating in the ISM band (2.4 GHz) were considered. The measurements were performed in several realistic indoor spaces such as in room environments where there is direct line-of-sight path available between transmitter and receiver. Second is wall between transmitter and receiver which is NLOS path for which we use wall attenuation factor value of 6.9 dB for heavy wall made of bricks. Reference distance for room environment is one meter. We added offset values in different environment for close approximation of empirical and analytical data. Layout of indoor home scenario is shown in figure 1.

We used Inssider home and wifiinfoview software to measure RSS empirically and distance equation using java code to measure RSS analytically. Then we used log-distance path loss model to measure path loss. We used the RSS from the minimum distance as the $\overline{PL}(d_0)$ in calculations. TX and RX antennas were in omnidirectional condition.

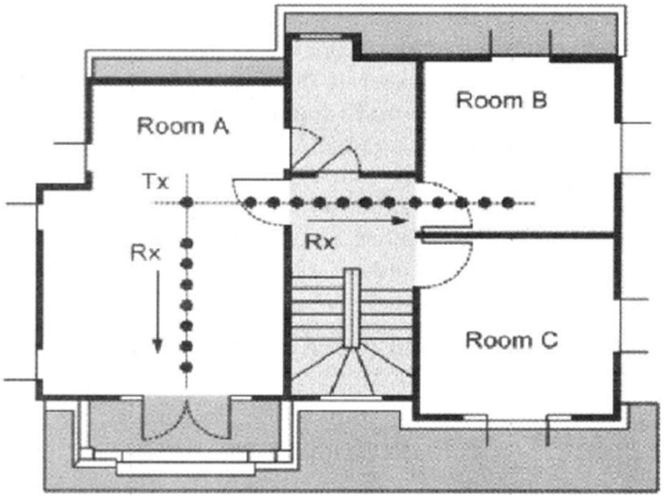

Fig.1. Layout of indoor home environment

Results and Sensitivity Analysis

Our results come from analyzing different groups of data. Transmitter and receiver antennas were placed with the same polarization and their gain effects are removed from the data.

Comparison of Results

As part of the analysis, we compare the analytical results from different scenarios with corresponding analytical values, which could be provided by a log-distance model. The channel parameters are configured with limited knowledge of the real channel under study. Because channel characterization for deriving them empirically could be complex and time-consuming. Different values of the PLE result in considerable difference in the curves, which entails incorrect results provided by the channel model.

For each comparison we use two curves calculated with formula (1): analytical and empirical. For the former one we select the values of the path loss exponent from the literature.typical values of PLE for indoor free space is 2, while it can be smaller for corridors (down to 1.5) and higher for furnished rooms (up to 3) when LOS condition is assumed.

Our primary goal instead is to explore the differences between the curve drawn from the data and the one typically provided by a channel model within a particular scenario.

Modelling of the RSS distribution

This part of the analysis is related to fitting our datasets to several different statistical models and comparing the results in order to determine the best fit for each group. We plot RSS vs. distance graph for two different scenarios. It is shown below. Received signal strength and path loss are reciprocal to each other. We also plot path loss vs. distance graph for two different environments. It is shown below. Different parameters values are shown in table 1. Wall Attenuation Factor value is shown in table 2. Offset values are shown for different home environment in table 3 [15]. RSS readings in morning and noon session for different days are shown below.

Table 1.

Standards	IEEE 802.11n
Frequency	2.4 GHz
Wireless transmit power	20dBm
Fade Margin	22dB
TX antenna gain	3dBi x 2
RX antenna gain	3dBi
Antenna type	Omnidirectional fixed antenna
Channel Spacing	40MHz
Software tool	inSSIDer home
Path loss exponent	2.8

- **Reading 2 :**

	Morning		Noon	
	LOS	NLOS	LOS	NLOS
Distance(meter)	RSS(dBm)	RSS(dBm)	RSS(dBm)	RSS(dBm)
1	-33	-33	-33	-33
1.7	-34	-48	-35	-49
2.9	-37	-51	-36	-53
3.74	-39	-54	-37	-59
4.77	-41	-60	-40	-61
6.03	-42	-63	-41	-64
6.8	-44	-65	-42	-65
7.65	-47	-66	-45	-66
8.6	-51	-68	-50	-67
9.65	-54	-70	-53	-69

- **Reading 3 :**

	Morning		Noon	
	LOS	NLOS	LOS	NLOS
Distance(meter)	RSS(dBm)	RSS(dBm)	RSS(dBm)	RSS(dBm)
1	-33	-33	-33	-33
1.7	-35	-51	-36	-55
2.9	-38	-53	-43	-56
3.74	-41	-54	-44	-58
4.77	-43	-59	-48	-59
6.03	-45	-62	-49	-61
6.8	-47	-64	-50	-65
7.65	-48	-66	-53	-66
8.6	-53	-69	-54	-69
9.65	-55	-71	-55	-70

- **Reading 4 :**

	Morning		Noon	
	LOS	NLOS	LOS	NLOS
Distance(meter)	RSS(dBm)	RSS(dBm)	RSS(dBm)	RSS(dBm)
1	-33	-33	-33	-33
1.7	-36	-52	-36	-50
2.9	-39	-53	-37	-53
3.74	-41	-54	-39	-58
4.77	-44	-59	-41	-60
6.03	-45	-62	-43	-62
6.8	-47	-65	-45	-65
7.65	-51	-66	-47	-66
8.6	-53	-68	-50	-67
9.65	-55	-70	-53	-69

- **Reading 5 :**

	Morning		Noon	
	LOS	NLOS	LOS	NLOS
Distance(meter)	RSS(dBm)	RSS(dBm)	RSS(dBm)	RSS(dBm)
1	-33	-33	-33	-33
1.7	-36	-52	-36	-50
2.9	-39	-53	-37	-53
3.74	-41	-54	-39	-56
4.77	-44	-59	-41	-59
6.03	-45	-62	-43	-61
6.8	-47	-65	-46	-65
7.65	-51	-66	-47	-66
8.6	-53	-68	-50	-67
9.65	-55	-70	-53	-69

Effect of RSS with distance in room environment

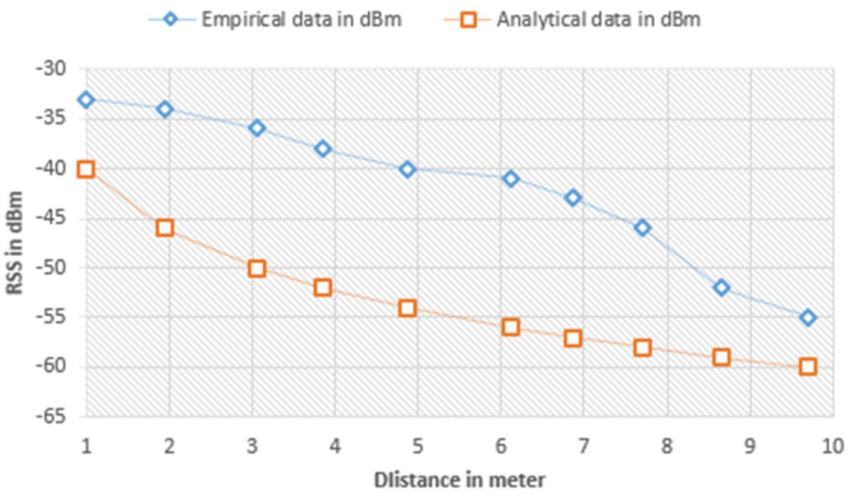

Fig 2. RSS vs. Distance graph for LOS path

Effect of RSS in wall between TX & RX

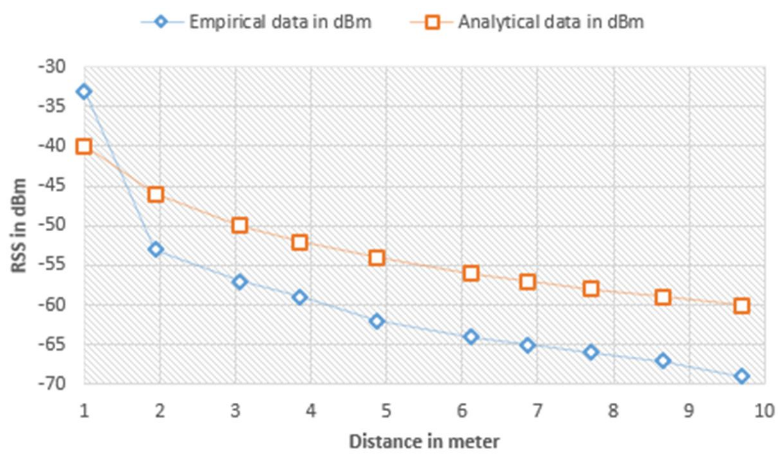

Fig 3. RSS vs. Distance graph for NLOS path

Effect of path loss in room environment

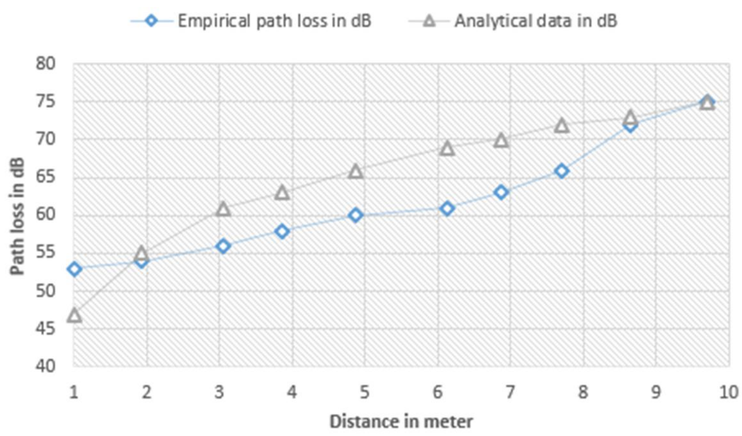

Fig 4. Path loss vs. Distance grath for LOS path

Effect of path loss in wall between TX & RX

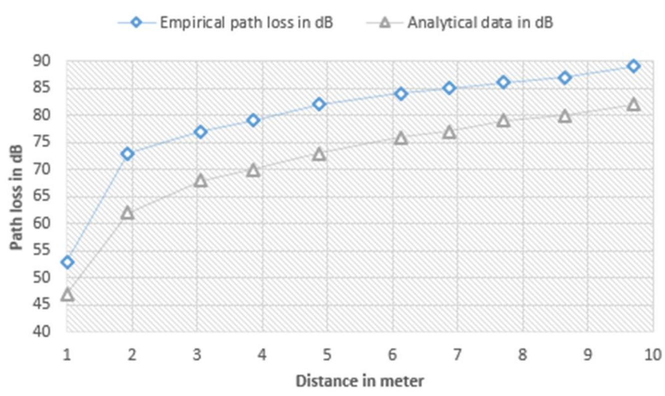

Fig. 5 Path loss vs. Distance graph for NLOS path

Table 2.

No.	Wall Attenuation factor value		
	Wall type	***Material used***	***Value in dB***
1	Heavy wall (> 10cm)	Bricks, concrete	6.9

Table 3.

Environment	Offset (dB)
Room (LOS path)	__
Wall between TX & RX (NLOS path)	6

Effect of path loss in wall between TX & RX with Offset

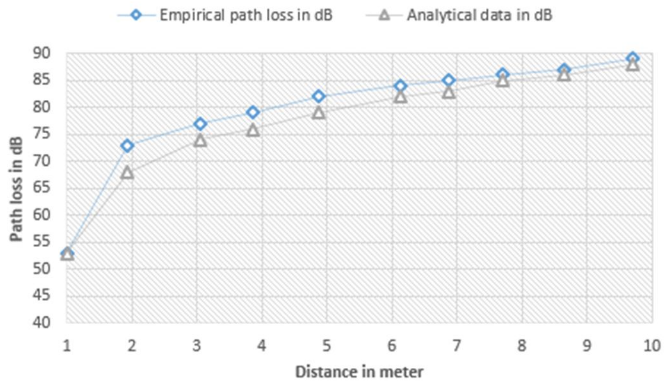

Fig. 6 Path loss vs. Distance graph for NLOS path with Offset

Figure 2 shows effect of received signal strength with distance for direct line-of-sight (LOS) which is unobstructed path. Figure 3 shows effect of RSS with distance for no line-of-sight (NLOS) which is obstructed path. Received signal strength and path loss are reciprocal to each other. When RSS decreases then path loss increases. Figure 4 shows effect of path loss with distance for room environment which is LOS path and figure 5 shows effect of path loss where there is wall between TX and RX which is NLOS path. We added wall attenuation factor value for NLOS environment. Offset added for close approximation between analytical and empirical data which is shown in figure 6.

Conclusion

In this paper we analyzed the 2.4 GHz wireless MISO channel based on experimental measurement performed in several indoor home scenarios. The measurements were performed in the 2.4 GHz band for antenna configurations, namely omnidirection-omnidirection propagation. The path loss increases as the T-R separation distance increases. We measured received signal strength for direct line-of-sight (LOS) and no line-of-sight (NLOS) path. For NLOS environment we added wall attenuation factor which depends on the type of wall and material used. As the empirical models the path loss exponent can be changed depending on the antenna directivity. Our observations allowed us to conclude that the behavior of RSS is very non-stationary across different scenarios as expected.

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