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Analysing of Indoor Radio Wave Propagation on Ad-hoc Network by Using TP-LINK Router

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Abstract**—**This paper presents results of measurements campaign carried out at a carrier frequency of 24GHz with the help of TP-LINK router in indoor line-of-sight (LOS) scenarios. Firstly, the radio wave propagation strategies are analyzed in some rooms with router of point to point Ad hoc network. Then floor attenuation is defined for 3 floors in experimental region. The free space model and dual slope models are modified by considering the influence of corridor conditions on each floor. Using these models, indoor signal attenuation can be estimated in modeling of indoor radio wave propagation. These results and modified models can also be used in planning the networks of future personal communications services.

Keywords**—**radio wave signal analyzing, LOS radio wave propagation, indoor radio wave propagation, free space model, two ray model and indoor attenuation.

I. Introduction

WIRELESS personal communications are intensely used in indoor environments. Some of the important applications of them are: WLANs, portable computers, wireless local loops and wireless access to the Internet. For the design and maintenance of indoor wireless services the knowledge of the signal propagation in different environment is demanded. To improve the performance of an indoor Wireless Local Area Network (WLAN), it is very important to analyze signal attenuation. Therefore, it is necessary to analyze the signal power distribution in the indoor environment of certain building. Signal attenuation in wireless network for indoor communication system depends on the influence of working frequency, antenna height, type of antenna, wall characteristics, floor partitions and the type of floor construction materials between antennas. It is important to characterize the indoor radio propagation channel to secure satisfactory performance of a wireless communication system. The mobile radio channel in indoor communication system is characterized by a multipath situation. The signal transmitted by the base station will propagate along different paths to the receiving antenna of the mobile.

In this case, attenuation is the most important thing for various wireless communication conditions. Signal propagation through a wireless channel usually arrives at the destination along a number of different paths. These paths arise from scattering, reflection, refraction or diffraction of the radiated energy off objects that lie in the environment. The received signal is much weaker than the transmitted signal due to phenomena such as mean propagation losses, slow fading, and fast fading. All experimental results including the various forms of signal attenuation types depend on all conditions of indoor obstacles and floor partitions between transmitter and receiver in indoor radio wave propagation system and the results of signal strength and pass loss measurements at various frequencies in complex building. This paper presents results of measurements campaign carried out at a carrier frequency of 24 GHz with the help of TP-Link router in indoor line-of-sight (LOS) scenarios.

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II. Propagation Loss Modelling

Radio Channel Models were suggested to aid in computation of signal strength in the place where the regions for wireless communications in indoor environments. Path loss calculation is taken from the power output point of the transmitter to the signal input of the receiver and includes everything between these points, like the antennas, cables, free space loss and any other losses encountered. In indoor environments the distance dependent attenuation is different than in free space, because of reflection, diffraction and scattering, even if the transmitter and receiver antennas are in line of sight. The close or open position of the doors, and the movement of persons also influences on the signal power distribution within the building. Because multipath disturbances are hard to estimate, there are necessary signal strength estimations in indoor wireless communication. There are many propagation models to estimate signal strength and to obtain the optimum signal strength between transmitter and receiver. These models are used to modify the existing models and adjust the experiment result to obtain the excellent signal strength. Moreover, these models are used when the transmitter and the receiver locations are at the same floor, in the LOS and NLOS indoor environment. [1], [2], [3], [4].

A. Free Space Model

The free space propagation model assumes the ideal propagation condition that there is only one clear line-of-sight path between the transmitter and receiver. H. T. Friis presented the following equation to calculate the received signal power in free space at distance *r* from the transmitter.

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 r^2} \quad (1)$$

$$L(d) = 32.44 + 20\log(f) + 20\log(r) \quad (2)$$

Where r is the distance between antennas, expressed in kilometers and f is the carrier frequency, expressed in MHz. [5], [6].

B. Dual Slope Model Based on Two Ray Model

An approach for predicting average signal level is the dual slope breakpoint approach. This model is derived from a two ray path model where there is a direct ray and a reflected ray. The angle of incidence of the reflected ray becomes almost grazing, which leads to a reflection coefficient of -1. Physically this corresponds to the incursion of the first Fresnel zone boundary into the propagation path.

Fig. 1 shows the dual slope model based on the two ray model of radio wave propagation and its relative formulae.

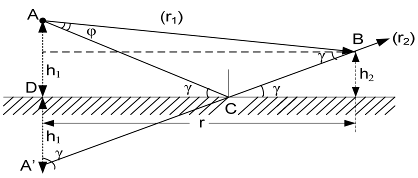

Fig. 1 The two ray model

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 r^2} \cdot \frac{p}{\left[1 + \frac{r}{R_0}\right]^{N_B - 2}} \quad (3)$$

$$L(d) = 10\log\left[\frac{P_t}{P_r}\right] \quad (4)$$

$$L(d) = 10\log\left(\frac{P_t}{P_r}\right) = 10\log\left[\frac{(4\pi)^2 r^2}{G_t G_r \lambda^2} \cdot \frac{\left(1 + \frac{r}{Ro}\right)^{N_B - 2}}{p}\right] \quad (5)$$

$$L(d) = 32.44 + 20\log(f) + 20\log(r) + (N_B - 2).10\log\left(1 + \frac{r}{Ro}\right) - 10\log(p) \quad (6)$$

$$R_0 = \frac{4h_t h_r}{\lambda} \quad (7)$$

Where,
λ = wavelength
P_r = received power
P_t = transmitted power
G_t = reader antenna gain
G_r = tag antenna gain
p = polarization mismatch
N = the variation power before the breakpoint
N_B = increased signal loss beyond the breakpoint
R_O = breakpoint distance (m) [7]. [8].

III. Experimental Procedures

The main goal of such experiments is a special test of the measured data compared to each suggested model and to obtain radio coverage for each experimental site, all the experiments have been carried out in different rooms of the Mandalay Technological University, Myanmar, comprising third floors, long hallways and contiguous enclosed classrooms with windows.

All measurements were carried out at both Line-of-Sight (LOS) and Non-Line-of-Sight (NLOS) in the area of complex building along all corridors.

In all measurements, wireless isotropic antenna is used to receive and transmit wireless data. Moreover, 8dBi antenna 1.3 meter heights of transmitter and receiver, and 10 dBm of transmitted power were used during measurement. Laptop with appropriate software called Netstumbler is used to survey received signal strength.

At first, all experimental points are marked as 1 meter from the left and right corners of the wall within the room. And then transmitter is located in a fixed centre position in a room, as shown on the reference building layout.

Then to get floor attention, the transmitter and receiver are placed at the different floors and then all the measurements are recorded. All experimental results are shown in table 1.

To conduct some experiments for examining LOS signal attenuation, the movement of receiver is 1 meter from the transmitter for each point and moves long the corridor to the end of it. Moreover to conduct some experiments for estimating of people influence in NLOS environment, the transmitter and receiver are placed at the constant distance of 12 meters, then some students are forced to walk between antennas. The maximum number of people in our experiment is up to 5. And then all the measurements were written out. All experiments are carried out more than 40 times on different days.

There are so many wireless equipments using this standard. But TP-LINK Wireless N Router of Wi-Fi – Ad-hoc is more reliable and is suitable for our experiments. So it has been chosen to use because of its significant characteristics. This provides up to 300 Mbps wireless connection with other 802.11n wireless clients. For our experiments, considering that the power of the transmitter is P_t *(dBm)* and the received signal power is given by the expression:

$$P_r = P_t(dBm) - L(d) \quad (8)$$

Where
P_r = received signal power
P_t= transmitted power
L(d) = path losses between antennas

IV. Building Layout

The building has reinforced concrete walls, and cellular concrete blocks or glass indoor walls. Small changes in position or direction of a receiver (relative to a transmitter) may result in wide variations in signal strength. All elements inside the building are also important to consider during measuring the signal strength.

Fig. 2 (a), (b), (c) and (d) show the layout design of main building of Mandalay Technological University (MTU) where all experiments were carried out. There are three floors in this building and each floor is constructed with four corridors. The thickness of each floor is 0.7m and its height is 4.2m. The widths of each corridor are 14m, 24m, 51m and 62m respectively, the distance between two floors is 11.8m and their designs are shown in Fig. 2 (a).

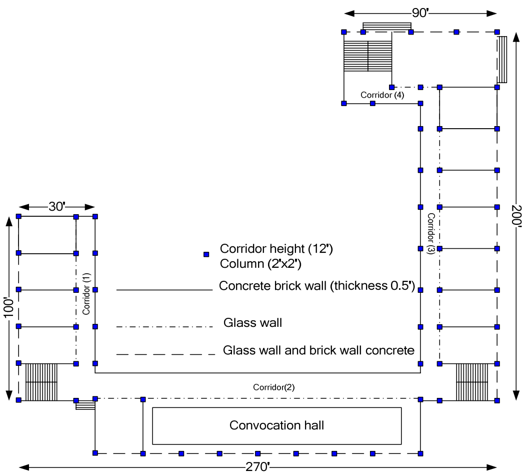

Fig. 2(a) Plan view of experimental building

Fig. 2(b) Building layout of MTU design

Fig. 2(c) Experimental region of building (4x9m^2) room

Fig. 2(d) Experimental region of building (9x13m^2) room

V. Experimental Results

The propagation of Wi-Fi signals, as for any electromagnetic wave, is governed by the properties of materials in the propagation medium. Although the high frequency used by Wi-Fi is able to penetrate obstacles such as walls and ceilings, these obstacles affect the signal propagation. For a wireless network in a home or office, obstructions such as walls, furniture, people etc. impede the propagation of signals.

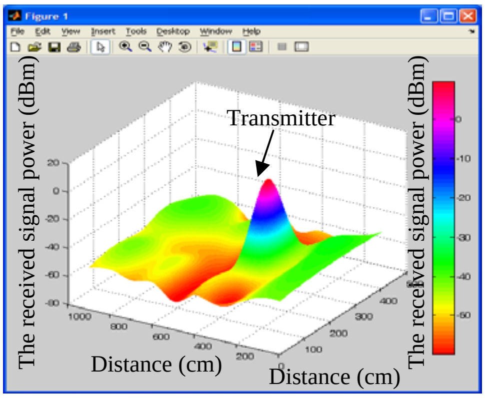

Fig. 3(a) The results of propagation for (4x9 m^2) room are shown as 3D

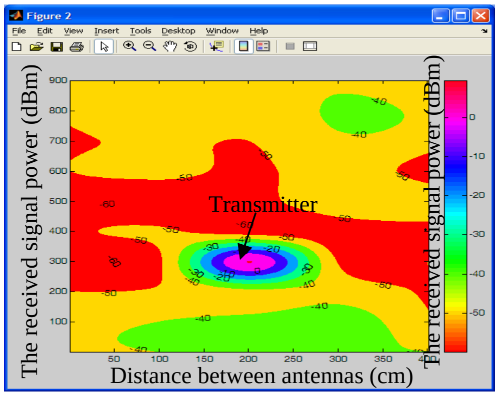

Fig. 3(b) The results of propagation for (4x9 m^2) room are shown as top view

After all measurements, all experimental data were used to draw received signal power with the help of MatLab programming language. In a multi-storey building, losses between floors are also introduced, depending on the building materials used.

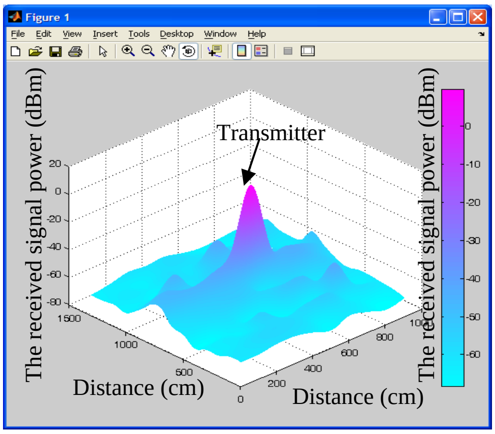

Fig. 4(a) The results of propagation for (9x13 m^2) room are shown as 3D

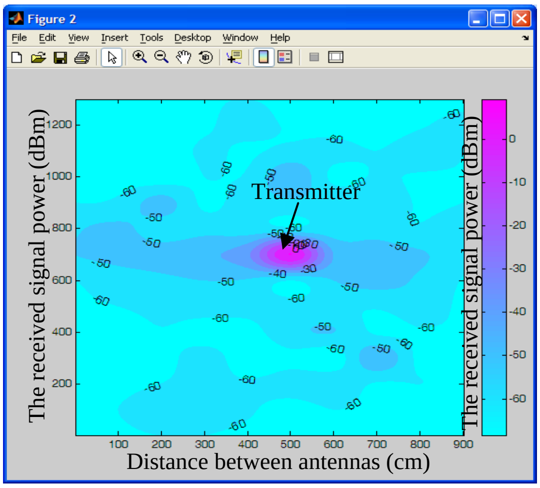

Fig. 4(b) The results of propagation for (9x13 m^2) are shown as top view

A loss of approximately 6dB is usually experienced between adjacent floors. The table below gives the approximate losses for different building materials.

TABLE I
FLOOR ATTENUATION DEPENDING ON NUMBER OF FLOORS

Number of separating floors	Path losses in dB	Remark
Through one floor	18	2400MHz
Through two floors	24	2400MHz
Through three floors	29	2400MHz

Fig. 5 shows the comparison of the experimental data and theoretical data curves based on free space model and two ray model. The horizontal increment values are used to describe the distance from the transmitter to the receiver, always 1 meter gradually increasing away from the transmitter and the vertical increment values are used to describe the received signal power lever in dBm at the received point.

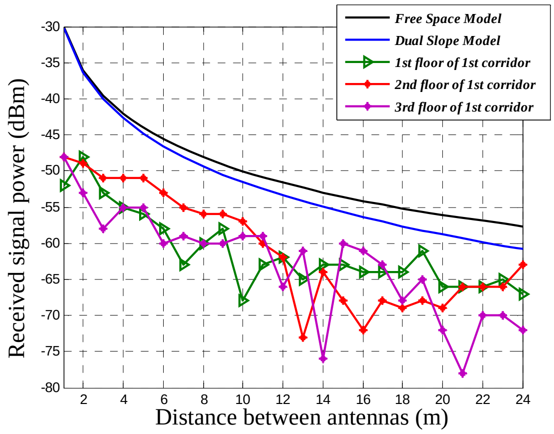

Fig. 5 Two models and experimental data

It is clear that the signal strength getting from our experiments attenuated about 10dB below the two given models. This attenuation is obvious of indoor constructed material types, parameters of building, propagating signal characteristic and so on. The free space and two ray model are well known models for radio wave propagation between antennas especially in Line-Of-Sight (LOS) environment. But those models can be used not only LOS environment but also in free space such as outdoor condition. In this paper submitted all possible ways to use those models in order to be useful in indoor environments using parameters of experimental region.

VI. ADJUSTING EXISTING MODELS

The mentioned two models can well be used in indoor environment after some adjusting to them depending on parameters of the experimental building, the size of Fresnel zone and the characteristics of propagation between antennas.

At first, the possible changes in this case are needed to consider getting suitable multiplier. For the free space propagation, there will only be changes of the width of corridor and the size of Fresnel zone, and all the rests are constants. So a multiplier depending on the width of corridor and the size of Fresnel zone was manually added to the basic losses of free space model with the consideration of MatLab programming language. It is obvious that the modified model effectively worked with the experimental data. It can adjust about 8-10 dB of losses.

The important consideration in radio wave propagation is the size of Fresnel zone. It is the region where the transmitted signal can be received like the effective area of antenna. So the size of Fresnel zone is needed to compute. If the heights of two antennas are the same, the maximum size of Fresnel zone is at the middle of the path between antennas. The following factor shows as a multiplier for free space model.

$$F_1 = \frac{b}{(3w)} \tag{9}$$

So the given formulae became;

$$L(d) = 32.44 + 20\log(f) + 20\log(r) - 10\log\left(\frac{b}{3w}\right) \tag{10}$$

Where
F_1= the multiplier
b = the size of Fresnel zone
w = the width of corridor

After adjusting the free space model with additional multiplier, the results were used to draw a curve with the help of MatLab programming language. Fig.6 shows how the modified free space model works with experimental data.

Secondly, like in free space propagation, there will only be the width of corridor and the reflected point between transmitter and receiver. So a multiplier depending on the width of corridor and the distance variable between antennas was added to the basic losses of two ray model. Then the modified model significantly worked with the experimental data. It can adjust about 8-10 dB of losses.

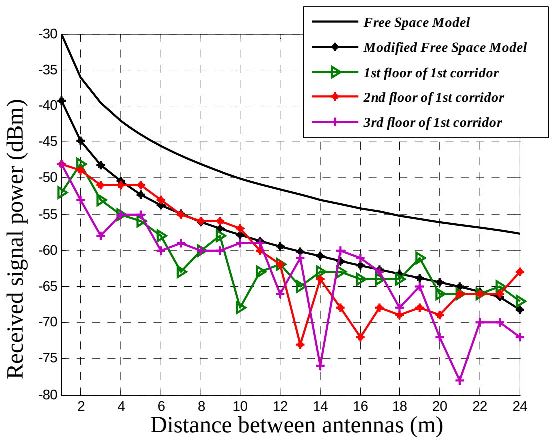

Fig.6 Comparison of modified free space model and experimental data

The following factor shows as a multiplier for two ray model.

$$F_2 = \left(\frac{w}{r_{point} + r}\right) \tag{11}$$

So the given formulae became;

$$L(d) = 32.44 + 20\log(f) + 20\log(r) + (N_B - 2).10\log\left(1 + \frac{r}{Ro}\right) - 10\log(p) - 10\log\left(\frac{w}{r_{point} + r}\right) \tag{12}$$

Where
F_2 = multiplier
r_{point} = distance from transmitter to reflective point between antenna (m)
w = the width of corridor
r = the distance between antennas

After adjusting the two ray model with additional multiplier, the results were used to draw a curve with the help of MatLab programming language. Fig. 7 shows how the modified two ray model works with experimental data.

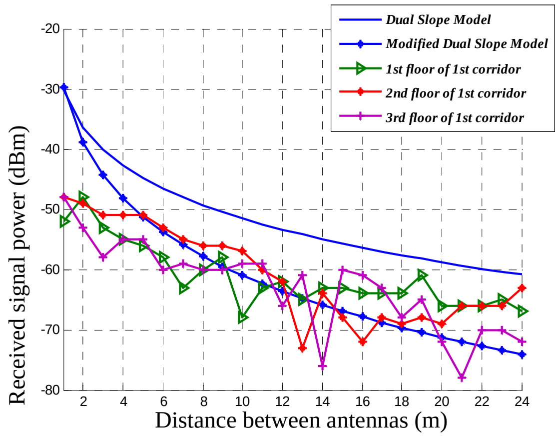

Fig.7 Comparison of modified two ray model and experimental data

For estimating people influence between transmitter and receiver, some experiments are carried at different floors and different days. At first the receiver and transmitter are placed in LOS environment with constant distance apart. After that, some students are forced to walk between them respectively of 1, 2, 3, 4 and 5 people. All measurements are written down, and compared with the help of MatLab programming language. All results are shown in Fig. 8 (a) and (b) below.

Fig. 8(a) Comparison of modified two ray model and experimental data

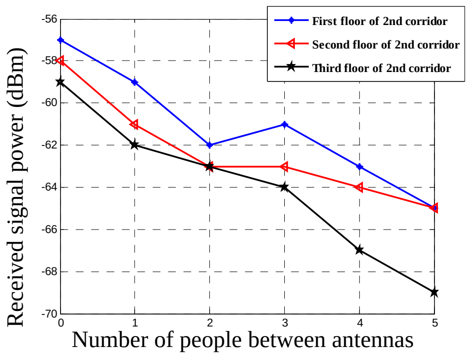

Fig. 8(b) Comparison of modified two ray model and experimental data

VII. Conclusions and Further Extensions

Conducted all experiments within two rooms and illustrated their results. The results were used to draw signal power curves 2D and 3D and also contour lines on the building layout. The results indicate that the changes in the signal strength depend significantly on the location and type of the obstruction. It is clear that the more away from the transmitter, the less signal strength. Signal losses nearby the wall increases 2-3 dB than that away from the wall.

This paper has presented indoor path loss model that can be used to predict indoor coverage area for wireless spread spectrum links.

Also it presented estimation of the signal attenuation depending on the number of different floors and different room.

By conducting all experiments, all possible ways to adjust or modify existing models can be chosen. This paper has presented free space and dual slope model based on two ray model that can be used to predict signal strength of planning wireless network based on experimental results. The new creating models can be used in all type of indoor radio wave propagation to estimate signal attenuation for both signal and multifloor wireless links using such building type. All multipliers that have been used in new modified models depend on participating parameters of building.

But in modifying two ray model, the new modified model can accurate after the distance of 2 meters from the transmitter. The larger the distance between antennas, the better the model works accurately. This method can be a useful tool to aid in estimating the signal power anywhere in the building, and in computing the indoor communication coverage. This engineering method can be applied for all types of indoor radio communications.

It is clear that the received signal power in free space model is better than that in two ray model because there is no obstacle or reflected area effect between transmitter and receiver.

As for further works, also need to conduct all useful experiments in NLOS environment for estimating all possible path losses within building using experimental data, to define all types of obstacles attenuation depending on various types of partitions, to find and study all possible models that can be modified or adjusted with our experimental data and to optimize the comparisons of all results and to estimate error accuracy % depending on the experimental data and estimating data.

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