# PERFORMANCE ANALYSIS OF INDOOR WLAN MOBILITY

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***Abstract :-*** In the new era of wireless communication, Wireless Local Area Network (WLAN) has emerged as one of the key players in the wireless communication family. There are many obstacles when deploying WLAN, which demands seamless indoor handover. While the access point, should have the appropriate coverage suitable to the propagation characteristic of the building. The wireless network planner needs a comprehensive tool to implement efficient WLAN network. In this paper, we have developed a mathematical path loss model using OPNET 10 simulation design tool. By using this simulation program, WLAN planner will be able to setup the access point for the optimum propagation coverage.

***Key-Words:-*** Wireless communication, mobility, propagation, handover, indoor path loss, mobile node

## 1 Introduction

WLAN products may exhibit the limitation in coverage when performing in crowded office or building due to the propagation loss, transmits power, receive power, fading and other basic obstacles. If the user needs a higher data rate for the WLAN, the burden to create seamless coverage becomes crucial. The network designers need a comprehensive method to locate the Access Point (AP) at the correct angle of the building. If more APs have been deployed, it may increase the cost unnecessary, however if less APs may jeopardize the coverage area. In other words the network planner need to have a first hand experience with the Radio Frequency (RF) characteristic of the facilities. This paper attempts to provide a helpful method to measure the propagation characteristic for indoor environment using the OPNET 10 simulation software. For the indoor environment, there are two types of elements; namely static and dynamic elements. The static elements such as natural and man made materials. The dynamic element comprises of moving objects [1]. Both terrain contour and human made structures strongly affect the received mobile signal strength. In an indoor environment, additional parameters must be considered, such as reflection, wall penetration, how fast the channel changes and etc. The complexity of these parameters make nearly impossible to derive a generic formula to accurately describe indoor propagation [2].

The capability of OPNET 10 to simulate this indoor environment scenario close to the real situation condition motivates us to employ this software to further the study on RF indoor characteristics [3]. Wireless LAN OPNET 10 Module permits mobile node to move from one place to another using trajectory attribute. We have done the simulation using this method and found that the mobile node stunned where no throughput occurs when mobile node switch from one access point to another access point. This model uses a distance method when a mobile node is far away from the access points by scanning phase and reauthentication phase with the new AP [4]. The propagation model employed in the Wireless LAN OPNET Standard is more on free space or Line of Sight (LOS) model rather than for an indoor environment.

## 2 Indoor Propagation Overview

Indoor propagation mechanism needs to overcome three specific main electromagnetic wave phenomena, namely the reflection, diffraction and scattering. These phenomena may occur and degrade the signal strength quality of the WLAN network. The indoor propagation characteristics should be considered fully in order to obtain the maximum signal quality without modifying the indoor facilities such as tables, chairs, walls and other elements [5]. The main complexity to model indoor propagation channel is its sensitiveness to site-specific and the low probability of line of sight (LOS) path between transmitter and receiver [6].

## 2.1 Indoor Mathematical Path Loss Model

An indoor path loss model is difficult to determine because of varieties in the physical barriers and materials within the indoor structure. There is no standard indoor path loss model for WLAN, although UMTS had. In order to derive the WLAN path loss model the basic principle can be derived from the UMTS model based on the COST 231 [Commission of the European Communities, COST 231 Final Report, Digital Mobile Radio Toward Future Generations Systems].

$$L = L_{FS} + L_c + \sum K_{wi} L_{wi} + n^{((n+2)/(n+1) - b)} * L_f \qquad (1)$$

where;

$L_{FS}$ = Free space between transmitter and receiver
$L_c$ = Constant loss
$K_{wi}$ = Number of penetrated wall of type I
n = Number of penetrated floor
$L_{wi}$ = Loss of wall type I
$L_f$ = Loss between adjacent floors
b = Empirical parameters
Note : $L_c$ normally is set to 37 dB
: n = 4 is an average for indoor office environment. For the capacity calculation in the moderately pessimistic environment, the model can be modified to n = 3; for indoor open plan with obstructed sight.

By assuming that;

$L_f$ = Typical floor structures (i.e. offices) such as hollow pot tiles, reinforce concrete with thickness below than 30 cm the factor is 18.3 dB.
$L_{w1}$ = Light internal walls, plasterboard or walls with large numbers of holes (e.g. windows) the factor is 3.4 dB
$L_{w2}$ = Internal walls such as concrete, brick with minimum holes the factor is 6.9 dB.
$L_c$ = Constants loss is 37 dB
$L_{FS}$ = 0
$\sum K_{wi} L_{wi}$ = Indoor office path loss model 30Log(R)

Under the simplified assumptions for office environment the indoor path loss model has the following form:

$$PL(R) = 37 + 30Log(R) + 18.3\, n^{((n+2) / (n+1) - 0.46)} \text{ dB} \qquad (2)$$

where;

R is the distance between transmitter and receiver in meters. n is the number of walls in the path. Assume that the coverage within a room with no in-between wall, thus n equal to 0 and the model can be written as:

$$PL(R) = 37 + 30Log(R) \text{ dB} \qquad (3)$$

## 2.2 The Friis Free Space Propagation Model

Before developing further on the path loss model, we have to take into consideration the propagation model. The relationship between power loss in propagation to the distance of transmitter and receiver is given as follows:

$$P_r(d) \propto k/d^2 \qquad (4)$$

The Friis free space model with distance d to the transmitter antenna can be written as:

$$P_r(d) = P_t G_t G_r \lambda^2/(4\pi)^2 d^2 L \qquad (5)$$

where;

$P_r(d)$= Receive power
$P_t$ = Transmitted power
$G_t$ = Transmitter antenna gain
$G_r$ = Receiver antenna gain
$\lambda$ = Wavelength in meters
d = Distance in meters between the receiver and transmitter antenna
L = System loss not related to propagation

Then $P_r/P_t = G_tG_r\lambda^2/(4\pi)^2d^2L$ (6)

If $10\log (P_t/P_r) = -\log10 (G_tG_r\lambda^2/(4\pi)^2d^2)$ (7)

The path loss represents the signal attenuation as positive quantity measured in dB.

$PL(dB)=10\log(P_t/P_r)= -\log10\ G_tG_r\lambda^2/(4\pi)^2d^2)$ (8)
If the antennas are assumed to have unity gain then;

$PL(dB)=10\log(P_t/P_r)= -\log10\ (\lambda^2/(4\pi)^2d^2)$ (9)

When the power received at a reference distance $d_o$ is known, the equation below can be used to find the power received at some distance d away;

$P_r(d) = P_r(d_o) + 20\log(d/d_o)$ (10)

This equation can be easily transform into path loss:

$PL(d) = PL(d_o) + 20\log(d/d_0)$ (11)

The relationship between the two path loss models; rewritten here from equations (3) and (11), both operate with a reference point and have similar logarithmic path loss;

$PL(d) = PL(d_o) + 20\log(d/d_0)$
$PL(R) = 37 + 30\text{Log}\,(R)$ dB

The frequency (wavelength) will affect the free space path loss, from the calculation between UMTS and WLAN frequency band there is a difference of the magnitude.

UMTS with $\lambda = 0.15$ m, d = 1
$PL(dB) = -10\log((0.15)^2)/((4\pi)^2d^2)))$
$= 38.46$ dB

WLAN with $\lambda = 0.125$ m (f= 2.4GHz), d=1
$PL(dB) = -10\log((0.125)^2)/((4\pi)^2d^2)))$
$= 40.00$dB

The difference in path loss due to frequency is 1.54 dB and the additional antenna gain must be subtracted from the path loss, with the reference value of 37 dB as constant loss at 1 meter for indoor office. The path loss from the reference point is the free space path loss model as:

$20\log(R)$, where R is distance in meter if $d_o$ is 1 meter.

The indoor space path loss model is:

$30\log(R)$, where R is distance in meter.

The indoor office path loss model will increase with a higher rate than the free space model.

# 3 Path Loss Model for Wireless LAN

The path loss model for wireless LAN is the Log-distance model that can be adjusted to suit different conditions and environments. The main equation for the path loss exponent without considering the deviation is:

$PL(dB) = PL(d_o) + 10n\ \text{Log}(d/d_o)$ (12)

This model can be develops using different methods by deriving based on theory, specification of equipment and on measurement. The WLAN coverage model is based on the theory of Friis free space path loss model with the reference point at 1 meter can be derives as:

$PL(1)= \log10(G_tG_r\lambda^2/(4\pi)^2d^2)$
$=10\log((0.125)^2)/((4\pi)^2d^2)))$
$= 40dB - G_t - G_r$ (13)

The total path loss depending on the distance between the transmitter and the receiver by using the equation

$PL(\ R) = 40 + (10{*}n\log(R)\ ) - G_r - G_t$ (14)

Where R is the distance in meter; $G_r$ and $G_t$ are the receiver and transmitter antenna gain. n is the path loss exponent.

The path loss exponent n can be assigned as follows:
In-building/factory with LOS condition: n is 1.6 to 2
Indoor open plan with obstructed sight: n is 2 to 4

Indoor with one to three floor separations and obstructed within residential building: n is 4 to 6.
The received signal strength $P_r$ in dBm can also be calculated with transmitter power $P_t$ in dBm as:

$$P_r(R) = P_t - (40 + 10*n \log (R) - G_r - G_t \quad (15)$$

## 3.1 The WLAN Testbed

The equipments used for our WLAN testbed consist of 2 access points and 3 notebooks with wireless LAN network cards and running on Windows XP. The equipment specifications are as follows:

Access Point D- Link 900 Plus (2 unit)
Network Card D- Link 650 DWL Plus PCMIA& USB
Aironet 350 AirPlus Cisco PCMIA Card
Mobile Node - Compaq Notebook Evo with Windows XP
Radiated Power = 63mW or + 18dBm
Range = 100 m

The path loss model exponent adopted for the mobile node is according to the assigned location and condition of the laboratory and based on theory are as follows:

i. n = 1.8 If there is line of sight in the lab
ii. n = 3 Combination of no and with line of sight
iii. n = 4 If there is no line of sight in the lab

By assuming unity gain for the receiver and transmitter and by using the path loss exponent as mentioned above the equation becomes;

i. For condition of line of sight (LOS) in the lab;

$$P_r(R) = P_t - (40 + 10*n\log(R) - G_r - G_t)$$

$$= 18 - ( 40 + 10*1.8\log(R)) \quad \text{dBm}$$

$$= - 22 - 18\log(R) \text{ dBm}$$

ii. For combination condition

$$P_r(R) = - 22 - 30\log(R) \text{ dBm}$$

iii. For condition of no line of sight

$$P_r(R) = - 22 - 40\log(R) \text{ dBm}$$

# 4 Experimental Measurement

We have recorded the signal strength in our wireless laboratory and the results are as shown.
Laboratory dimensions:
Length = 21 m
Height = 6 m
Width = 10 m
Walls - Concrete and wood and a few windows.
Object - Desks, chairs and computers
Reference point $P(d_0)$ $d_0$ = 1 meter.
Distance to outer point R = 23 meter
AP = D-Link 9000 Air Plus.

| Distance (m) | Signal Strength (dBm) | Percentage |
|---|---|---|
| 1 | -39 | 57.3 |
| 2 | -42 | 54.8 |
| 4 | -45 | 52.4 |
| 5 | -47 | 50.8 |
| 7 | -53 | 46.0 |
| 9 | -59 | 41.1 |
| 11 | -58 | 41.9 |
| 13 | -59 | 41.1 |
| 16 | -62 | 38.7 |
| 21 | -63 | 37.9 |

Table 1: Indoor Signal Strength

Reference point $d_o$ = 1 meter
P(1) = 58 % or -39dBm
Distance R = 21 meter
P(21) = 38% or -63dBm

Calculates the path loss exponent for percentage model

$$P(R) = P_r(d_o) - 10*n\log(R/d_o) \text{ with } d_o = 1 \text{ m}$$

$$P(21) = 38\% \quad P_r(d_o) = 57.3\% \text{ with } R= 21\text{m}$$

$$38 =57.3 - 10*n\log(21/1) \text{ so } n = 1.46$$

Then calculating the range,

57.3–10*nlog(R) = 25%   25% =-76dBm

57.3–10*1.46log(R) = 25% so R = 62.9m
Find the path loss exponent n for distance 162.9m

P(162.9) =-22–10*nlog(162.9) =-76 dBm
n= 2.441

Inserting the path loss exponent for Friis model

P(R) = -22 - 24.4log(R) dBm

## 4.1 Result

All the measurement has been done in our wireless laboratory and a long the laboratory corridor.

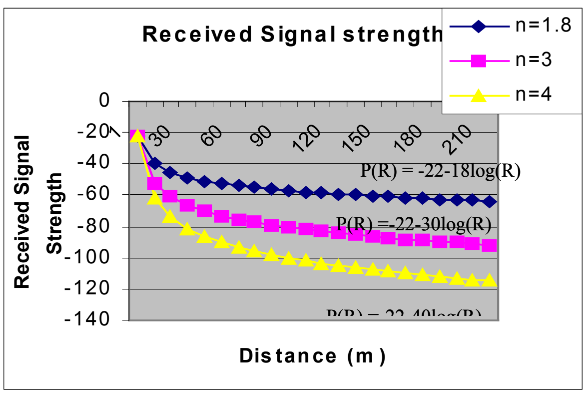


Fig. 1 Measured Path Loss

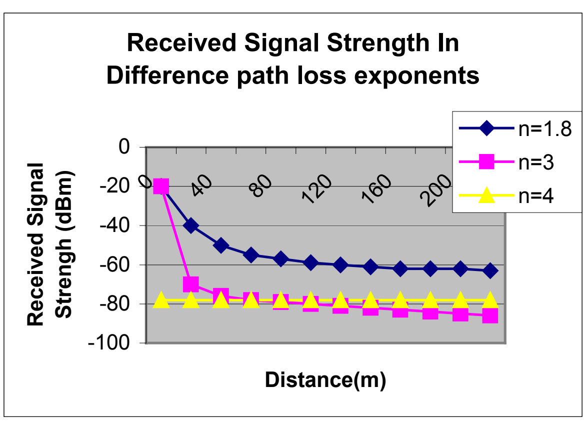


Fig. 2 Theoretical Path Loss

Fig. 1 and Fig. 2 show that similar results have been achieved for both experimental and mathematical path loss model for indoor WLAN coverage. The derived mathematical model has been adopted for simulation in OPNET environment. This model in OPNET can assist the wireless LAN network planner to deploy the access points for indoor application or hot spot more effectively.

## 4.2 Path Loss Model In OPNET

Fig. 3 shows that the mobile node moves from access point 1 to another access point 2 using OPNET 10 simulation program.

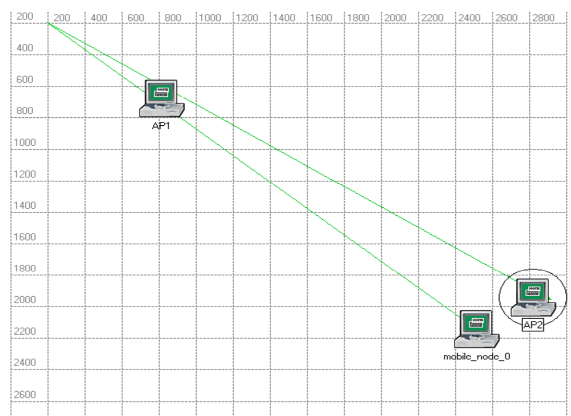


Fig. 3 Mobility in OPNET Environment

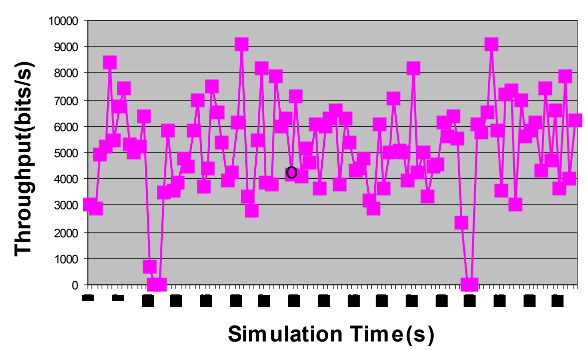


Fig. 4 WLAN Path Loss in OPNET Environment

Fig. 4 shows that the mobile node lost connection after 14 second of simulation time and equivalent to 280 meters away from access point 1. OPNET 10 employs free space model for path loss calculation. Thus the need to develop a new method of path loss calculation in OPNET 10 that permits indoor mobility such as the use of appropriate handover mechanism. The following mathematical model is used in OPNET 10 simulation.

P® = -22 – 24.4log® dBm

We found that when the mobile node moves away from the access point the maximum distance is about 100m before the output drops completely for the indoor condition.

## 5 Conclusion

The path loss model developed using OPNET 10 simulation package has provided some means to evaluate the performance of indoor WLAN mobility. However there are still problems to be resolved as this mathematical model exhibits an unstable condition. When more than three access points available within range of the mobile node coverage, the mobile node starts to change connectivity with the access point around it. There is no handoff mechanism for 802.11 wireless LAN standards, and vendor implements by applying the mobile nodes associated with wireless network [8]. In order to resolve this unstable connectivity condition a handover mechanism such as controlled handover can be employed [9]. In this situation the mobile node needs to make connection before break and connectivity will be maintained until the old access point's path loss drops to a certain threshold.

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