Coverage Prediction of an AP by using SINR Analysis and Users Density Estimation

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Abstract
In W-LANs a single hop is all that is necessary or in fact acceptable. The region of connectivity around a given source is known as its coverage area. Commonly, a source and a destination may communicate using one or more intermediate relays, in which case a path through the network must be found where each hop has a SINR greater than ß. There are several ways to portray and quantify network connectivity, but at the core, they all require that individual pairs be are able to communicate, which is dictated by the SINR. This paper is going to take a survey on AP coverage based on interference analysis (within a cell for connected nodes) and user density estimation but also it will try to determine the radial distance where the far distance user is tolerable to interfere with a near user (Near far effect) to the AP in perspective of received signal strength and channel fading.
Keywords: SINR, users' density, ß, coverage

Introduction

An approach of providing high-capacity network access is characterized by randomly located nodes, irregularly deployed infrastructure, and uncertain spatial configurations due to factors like mobility and unplanned user-installed access points. Because spatial configurations may vary widely over an enormous (often infinite) number of possibilities, one cannot design most systems for each specific configuration but must instead consider a statistical spatial model for the node locations. Performance of a W-LAN can be altered dramatically by altering base station configuration, where by correlation shadowing plays a significant factor on the wide range of performance. (Butterworth, Sowerby, Williamson, & Neve, 1998).

In W-LAN we usually neglect cross-correlation of signals coming from different resources (Monserrat, Fraile, Cardona, & Gozalvez, 2005). The isolation offered by wall penetration loss is an attractive solution to cope with the interference. Second, the SINR can be worsened by uncoordinated transmission powers of BSs.

Thus, a coordination of BSs transmission power is needed to prevent a significant decrease in SINR(Sung, Haas, & McLaughlin, 2010). This highlights that interference is very important for optimal performance of an AP.

Fading

In proceeding to find the solution, environmental factor which will cause problems to the channel characteristics has to be computed. This paper takes into consideration the free-space path-loss and other attenuation associated with our environment. The following equations illustrate more about the equations which are to be used and next the table will also give different values of attenuation.

From the ITU-R models;

$$L_T = 20\log_{10}[f(MHZ)] + 10\alpha\log_{10}[r(m)] + l_f n_f - 28 \quad P_r(d) = \frac{P_t G_t G_r \lambda^2}{4\pi^2 d^2 L}$$

$p_r(d)$ = power received at a distance (d) from a transmitter

d = distance between a transmitter and a receiver

f= frequency of operation

$p_{t,\,Gt,\,Gr}$ = power and gain of a transmitter, receiver gain α = path loss exponent

$l_f n_f$ = product of loss and number of floors

Table 1 : Attenuation Losses of different Materials

RANGE	MATERIAL	LOSS
Low	Non tinted glass, Wooden doors, Cinder block walls, Plaster	2-4
Medium	Brick wall, Marble, Wire mesh, Metal tinted glass	5-8
High	High Concrete wall, Paper, Ceramic bullet-proof glass	10-15
Very High	Very high Metals, Silvering (Mirrors)	>15

Probability of Users in a Given Area

The number of users that are available in a given area is a probabilistic value but the number of those who wants to access a given AP in a given area (A) is a random variable. In general, the rate parameter λ may change over time; such a process is called a non-homogeneous Poisson process or inhomogeneous Poisson process.

Nodes are deployed randomly at positions specified by a Poisson distribution. For the space R^d, the probability that, the area A in a PPP has n number of nodes is the same as saying that; the probability that, there are 'n' users who may want to access an AP in a given area (A) is expressed as:

$$p_r(n) = (\lambda A)^n e^{-\lambda A} / n!$$

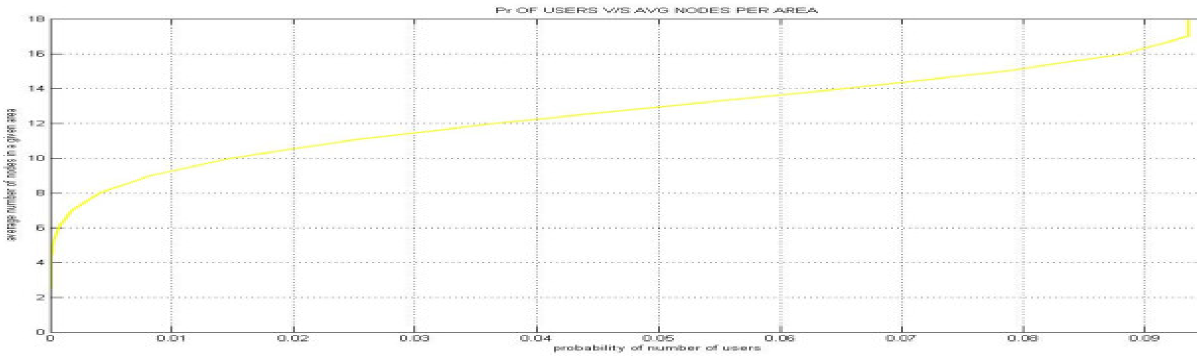
Where:

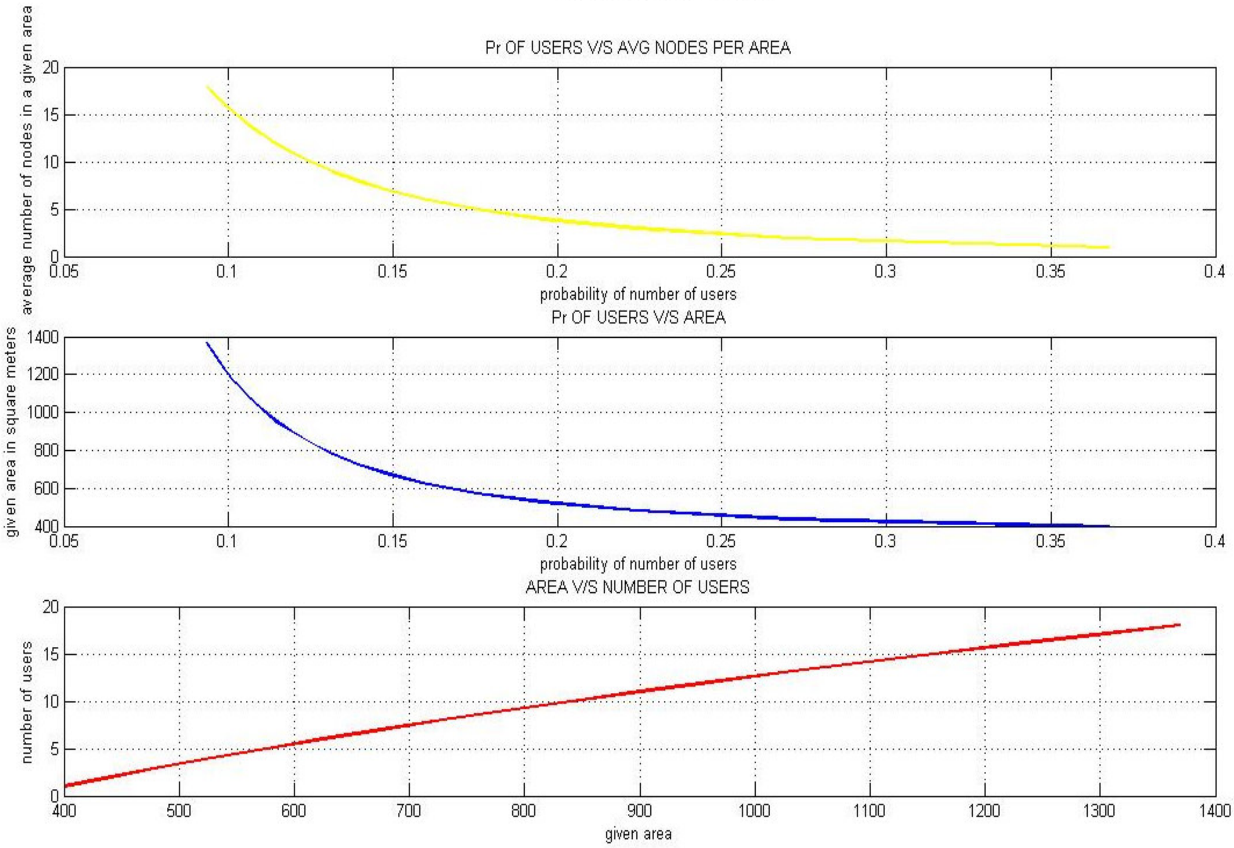
λA = average number of nodes (users) in a given area

λ = density of nodes in a unit area

n = number of nodes

Simulation Results





Results Interpretation

The objectives of the above simulation is to show the importance of λ (density of nodes=number of nodes in a given area). The value of lamda is very important on the calculations or simulations which are to follow. The choice of which value of 'n' I have to put on my simulations and what is the appropriate number of users in a given Area will also depends on the probabilities values obtained on my simulations. The simulation was done using two types of point processes, in homogeneous point process whereby the value of λ was a constant and we vary the number of users 'n' to find the probabilities. In in-homogeneous, the probabilities were obtained by varying the value of λ as well as the values of 'n' users. The idea behind was to find the best value of 'n' which will be used on my simulations by comparing the two point processes (users 'n' v/s Area 'A' was a preliminary key for the comparison). The results shows that, the homogeneous poisson point process gives out the best results on the probability of users and its number compared to in-homogeneous poisson point process.

Signal to Interference Noise Ratio (SINR)

The significance of signal to interference ratio has been explained in introduction. The additional information to the above scenario is that, the number of active transmitters with respect to each other doesn't have a significant impact on interference, instead the number of active transmitters and their distances from their intended receivers are the factors which contribute to the interference.

Below is the equation which was developed under the basics of stochastic geometry, and it was purposely for (multi-hop networks) BTS to femtocell link deployment (Baccelli & Błaszczyszyn, 2009). The abbreviations which are to be applied in simulation codes are also shown.

$$SINR_0 = \frac{h_{00} p_0 r^{-\alpha}}{N_0 + \sum_{i \in \phi} p_i h_{i0} |X_i|^{-\alpha}}$$

h_{00} = Pf = Mean power fading coefficient all active channels

N_0 =Noise power

p_0 = Transmit power of transmitter I

ϕ = Set of interfering nodes

α = Attenuation

r = Distance from the desired receiver

$SINR_0$= Signal to Interference Noise Ratio

Assumptions

- Users are modeled as nodes
- Users/nodes transmit power at a different levels
- Users are also interferers to each other when they are trying to access the access point (AP)
- Attenuation exponent is constant for each user (environmental factor)
- The numerator of the power fading is assumed to be the average of all the individual links which are connected to the AP.
- Only uplink traffic is considered (from users/nodes to access point)

Theoretical calculation of parameters;

Device	**Transmitted power**
Desktop	20 dBm,(-40 - 70) C^0
Laptop	18 dBm, (0 - 42) C^0
Mobile phones	23 dBm, (-20 - 65) C^0
Attenuation Constant	(3 - 5) dB

Users device parameters;

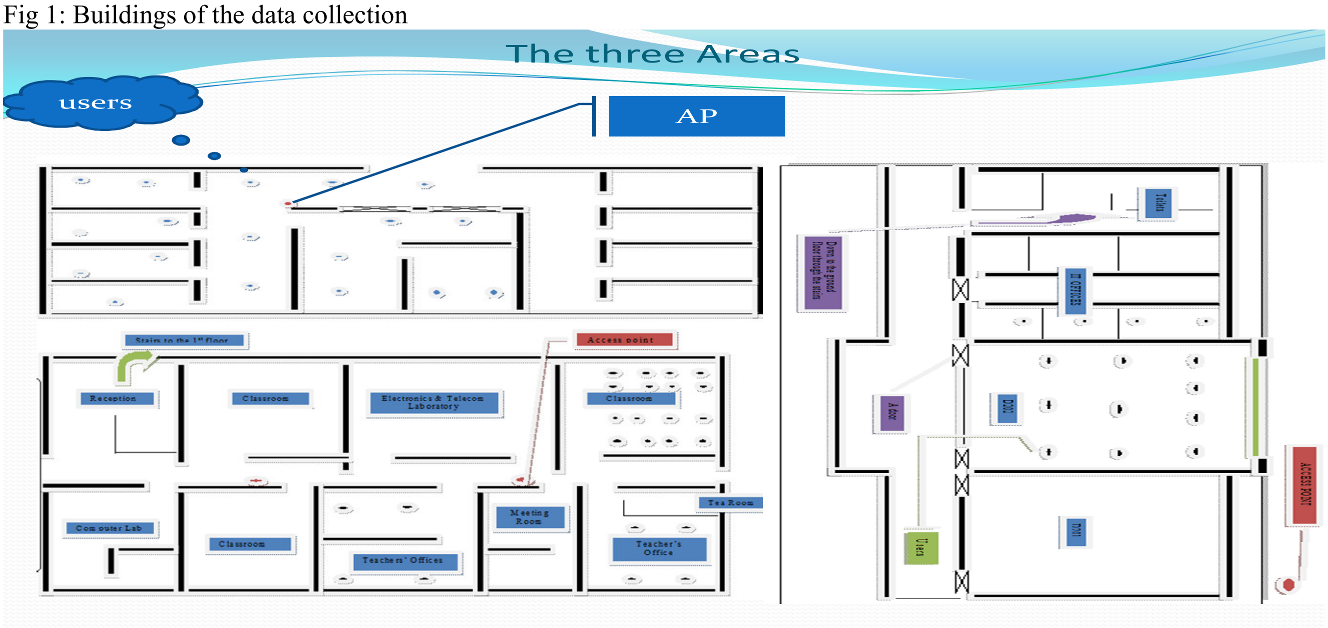
Device	**Thermal noise power (N_0)**
Desktop	-130dB
Mobile phone	-130.3939dB
Laptop	-130.0878dB

Data Collection

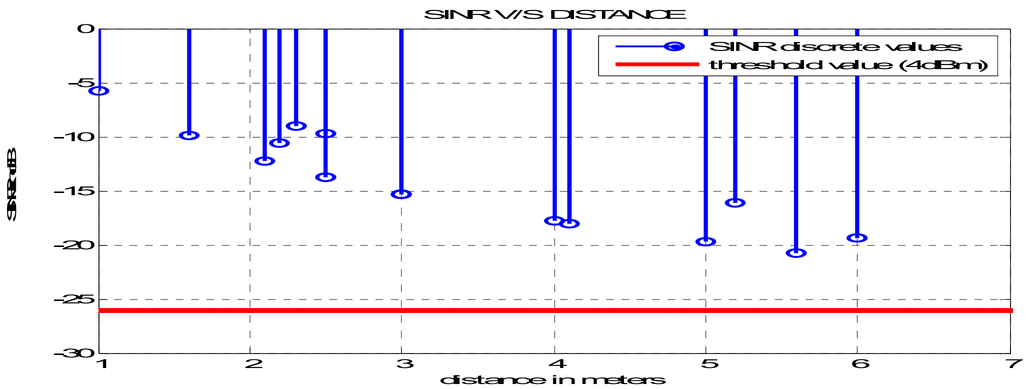
To get the results of coverage, data collection was done in three different areas. Different users in different locations inside the building where considered for data collection. The nodes which will access the AP (individual links) were collected based on position of each user and results were presented in simulations graphs. For each area SINR and probability of connectivity were used for estimating the coverage of an AP.

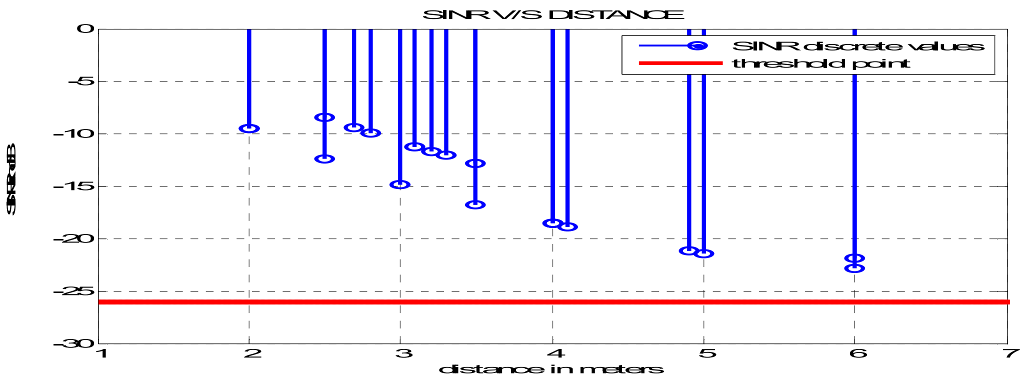
NOTE: For most commercial Wi-Fi devices, the minimum value of SINR where communication is reliable is 4dBm.

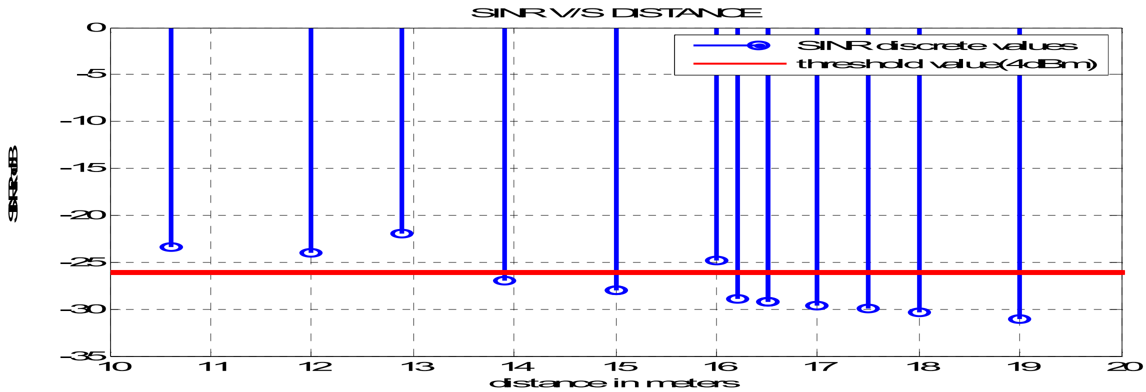
Fig 1: Buildings of the data collection



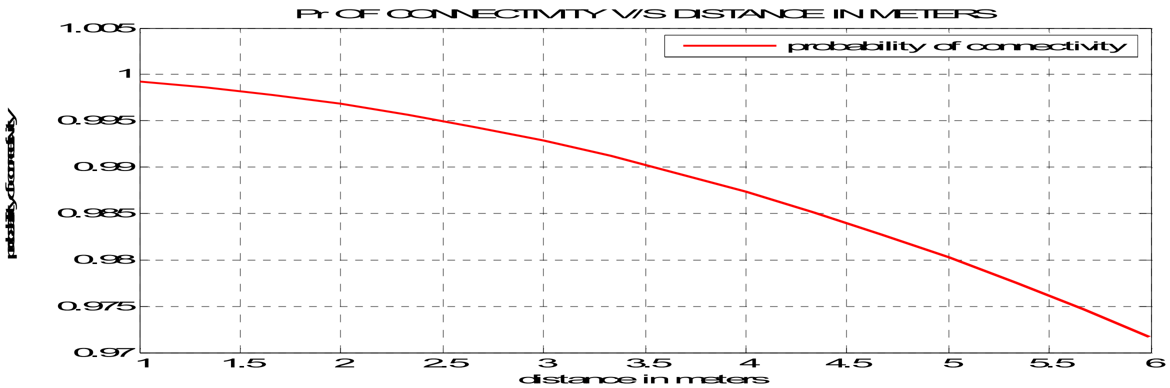
SIMULATION RESULTS

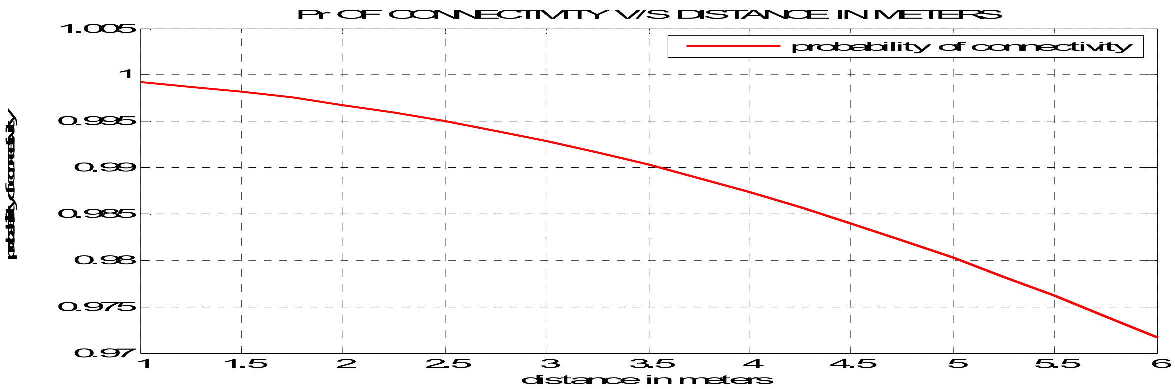


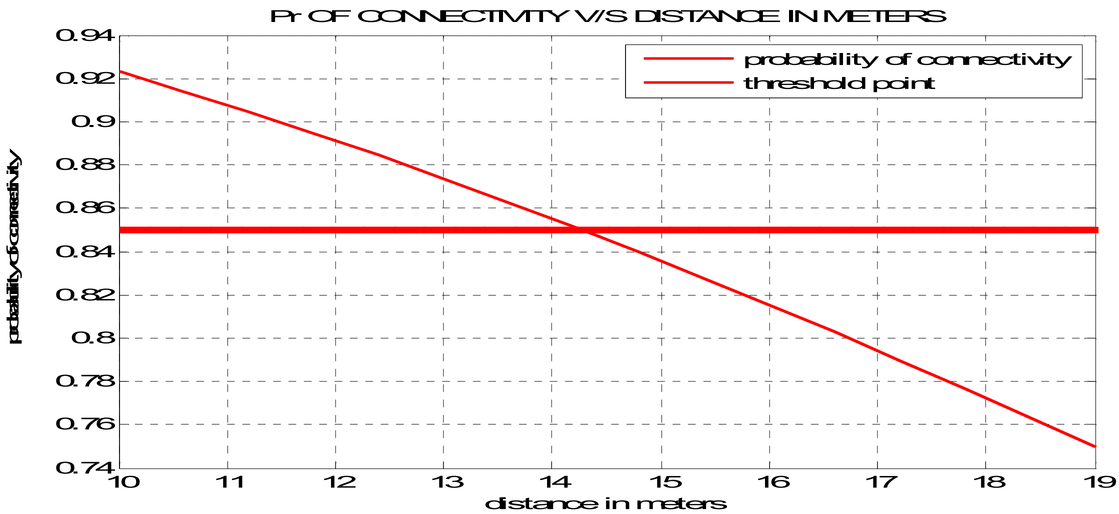




In this section, we have shown the effects of SINR on the overall performance of the W-LANs. The complexity of the situation has been shown using the simulated graphs whereby; the graphs shows that, there is a negative impact of SINR with, the distance, power fading of the channel but also even the location of the devices of the same power will yield different characteristics when they differ in distance as well as channel characteristics.







The last three graphs, shows the estimated areas of coverage in probabilistic terms (*possible connections*). It shows that, probability of connectivity (at beta value of 4dBm) has a negative impact (*The probability decreases when the distance increases*) on the distance.

ASSESMENT OF THE RESULTS

In this section, we have shown the effects of SINR and evaluate the probability of connectivity on the overall performance of the W-LANs. The graphs shows that, there is a negative impact of SINR and probability of connectivity with, the distance, power fading of the channel but also even the location of the devices of the same power will yield different characteristics when they differ in distance as well as channel characteristics.

The spatial theory says, interference is a cumulative term. It depends not on the number of transmitters but the number of active transmitters with their respective distances from each other. This means that; the probability of connectivity as well as SINR is low for number of active transmitters located far from the AP and it is higher for number of active transmitters located near to the AP. The phenomenon above corresponds to the concept of 'near far effect' of CDMA systems. If a nearby transmitter has just a little bit of out-of-band noise, it might swamp out the desired signal transmitted by a transmitter far away.

This near-far problem is reduced by controlling the power level that is transmitted by the mobiles to keep everyone on as close to the same power level as possible at the receiver base station. This means that antennas far away must transmit larger power than those nearby. This saves on battery life, as well as reducing adjacent channel interference.

When you are using your laptop or Mobile phone for accessing an AP far away and it is partially blocked by walls or any structure. Your Laptop or cell phone must send much higher power levels in order to get the power to the Access point (which isn't applicable in W-LANs devices).

With this case, the optimum parameter where interference is tolerable depends much on distance and attenuation (channel fading) of the far located W-LANs devices. My simulation results shows that, at an average radial distance of 15 meters (which depends on environment), is the point where SINR of user devices is tolerable at the AP.

COMPARISON

SUMMARY

This section is about comparison. The aim is to compare the simulation above with the practically collected datas in a perspective of Received Signal Strength at the point where Near far effect (interference) is tolerable. Before the comparison stage, three tools which are Wifi Analytic tool, WiEye and Wifi Analyzer were tested using a Mobile phone and one tool in a Laptop.

TOOLS COMPARISON

The test was taken on wing d of administration building on NM-AIST. The environment (outdoor) was having obstruction of trees and vegetations and some parts of partially blocking walls.

The wing channel is 6, however the free-space measurements were taken on the ground floor and the obstruction measurements were taken on the first floor of wing d.

A – B = free-space measurement, there is an obstruction of a tree. Distance is 30 meters

C – D = obstruction measurement, there is obstruction of walls, metal doors and glass windows.

Diagram 2: testing area

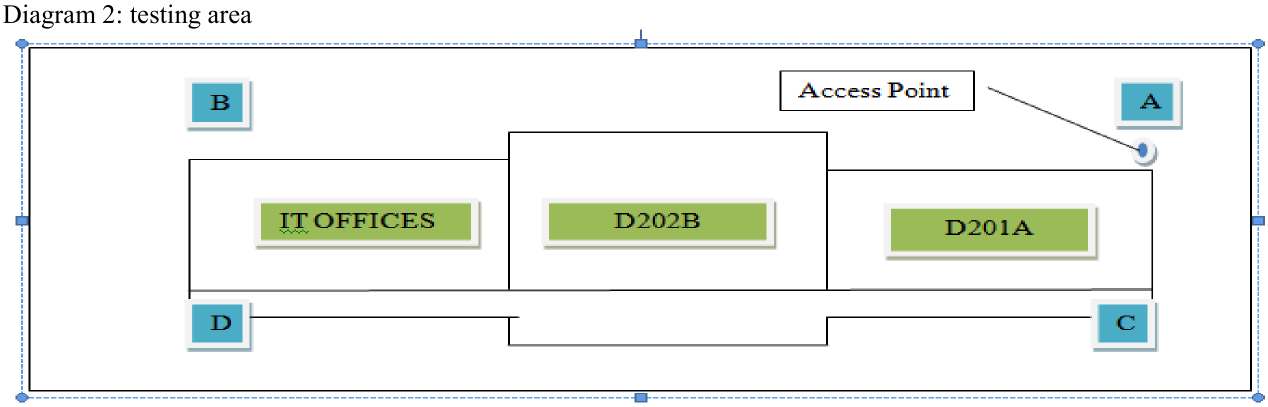
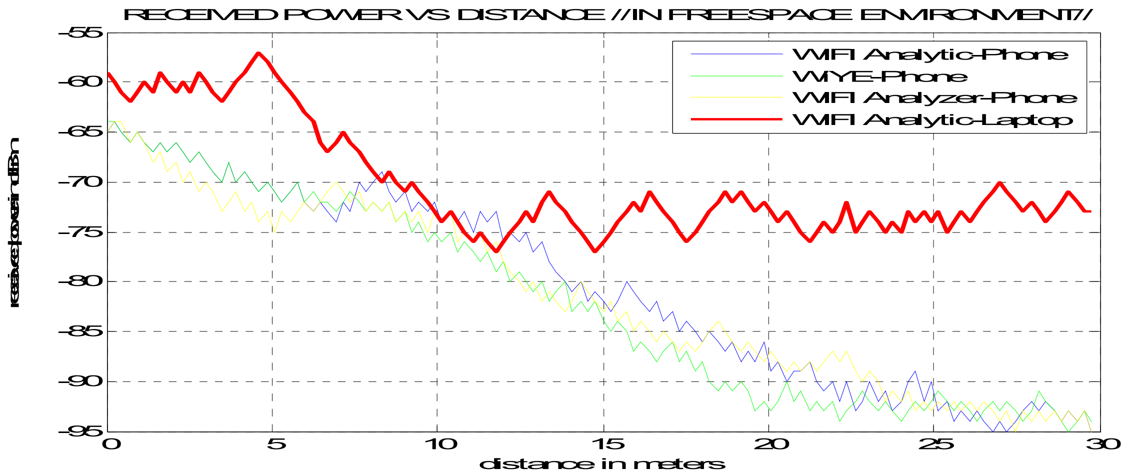
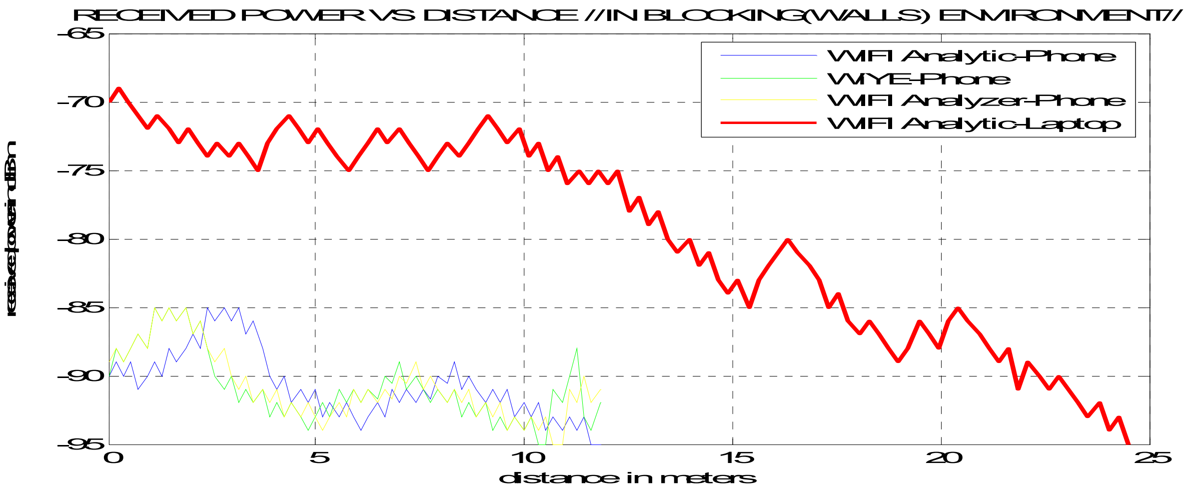


Table 1: testing tools and their characteristics

Tools	**WIFI Analytic (Ver 1.08)**	**WIFI Analyzer (Ver 3.6)**	**WiYE (Ver 1.5.2)**
Installation	Android phone Laptop	Android phone	Android phone
Characteristics	It shows : ✓ RSS ✓ Channel number ✓ Channel graph ✓ Signal graph ✓ Signal meter ✓ Channel interference	It shows : ✓ RSS ✓ Channel number ✓ Channel graph ✓ Signal meter ✓ Time graph ✓ Channel rating	It shows : ✓ RSS ✓ Channel number ✓ Channel graph ✓ Signal graph

Practical results





From the results above;
Two tests were done
1] Free space test
Under this test, a distance of 0-30 meters was done and the average signal strength of:
{-64dBm to -95dBm} was observed for Android Phone
{-57dBm to -76dBm} was observed for Laptop
2] Obstruction test
Under this test, a distance of 0-30 meters was done and the average signal strength of:
{-85dBm to -95dBm} was observed for Android Phone
{-69dBm to -95dBm} was observed for Laptop

ASSESMENT OF RESULTS

The result shows that, computers have a powerful set of capabilities, relative to mobile phones. For that reasons, Laptop was chosen as a data collection tool since it has higher processing power and speed but also RAM, ROM and Cache Memory is bigger compared to Android mobile phones. The advantage of using Android phone for data collection is portability.

SIMULATINON AND PRACTICAL DATAS COMPARISON

This section compares the simulation results versus practically collected datas.

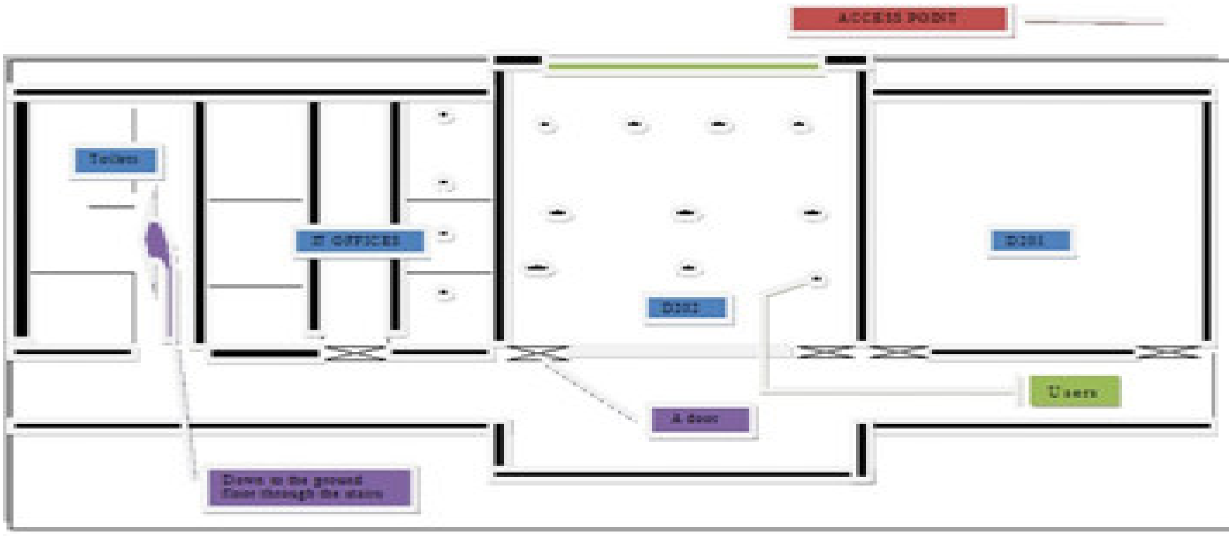
On this comparison section, Nelson Mandela African Institute of Science and Technology at the Administration building Wing D room D202B was taken as a testing area; one of the reason is that, it is area where users are located far away from AP and it also an area where Near far effect occurs due to the far located users.

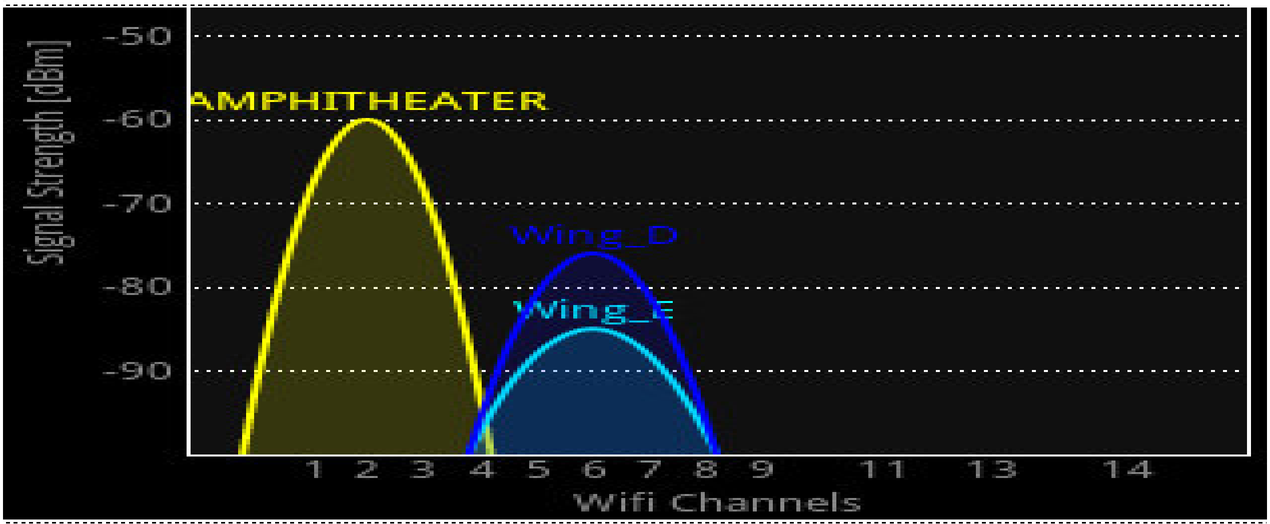
The received signal strength at the users' device and channel interference at the observed area are displayed on Area 1.

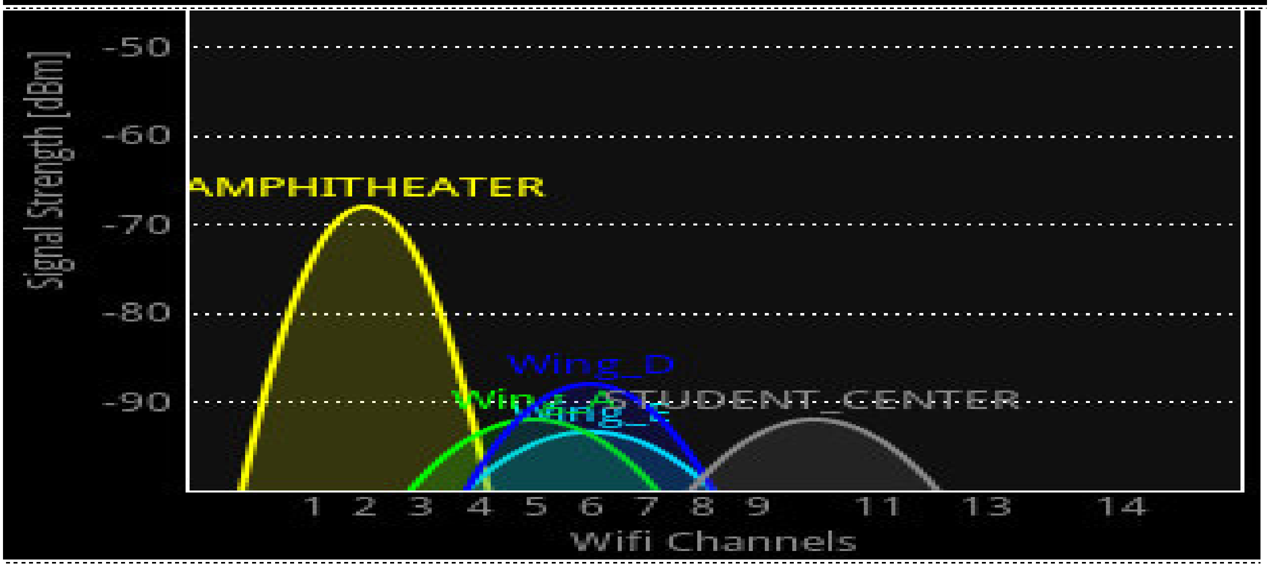
At last, the simulation of both practical and theoretical (ideal) RSS was compared using Matlab software.

Based on the data collected and experiments done by observing connectivity versus Received Signal Strength, At an average received power of below -78 dBm; is the point where a far away transmitter power (laptop far away from the AP) might be swamp out by a nearby transmitter (A laptop close) to the Access Point which has just a little bit of out-of-band noise (i.e. is the point where interference is tolerable).

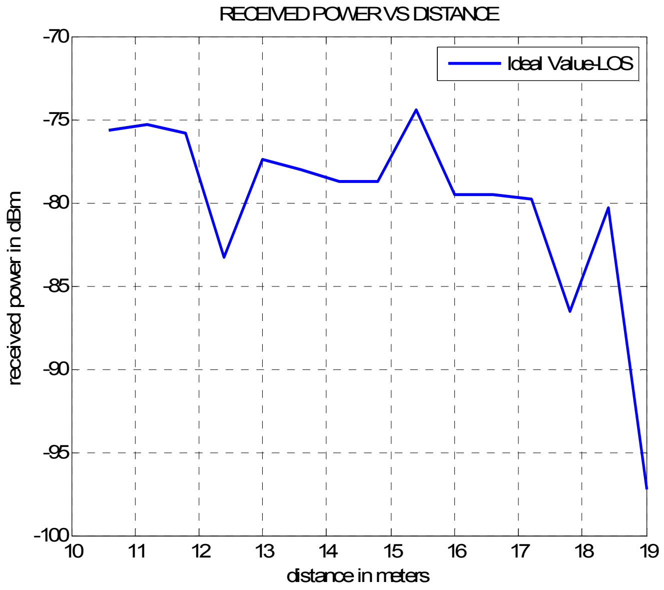
Area 1: data collection area (wing d of nelson Mandela institute) followed by observed channel interferences at different positions.



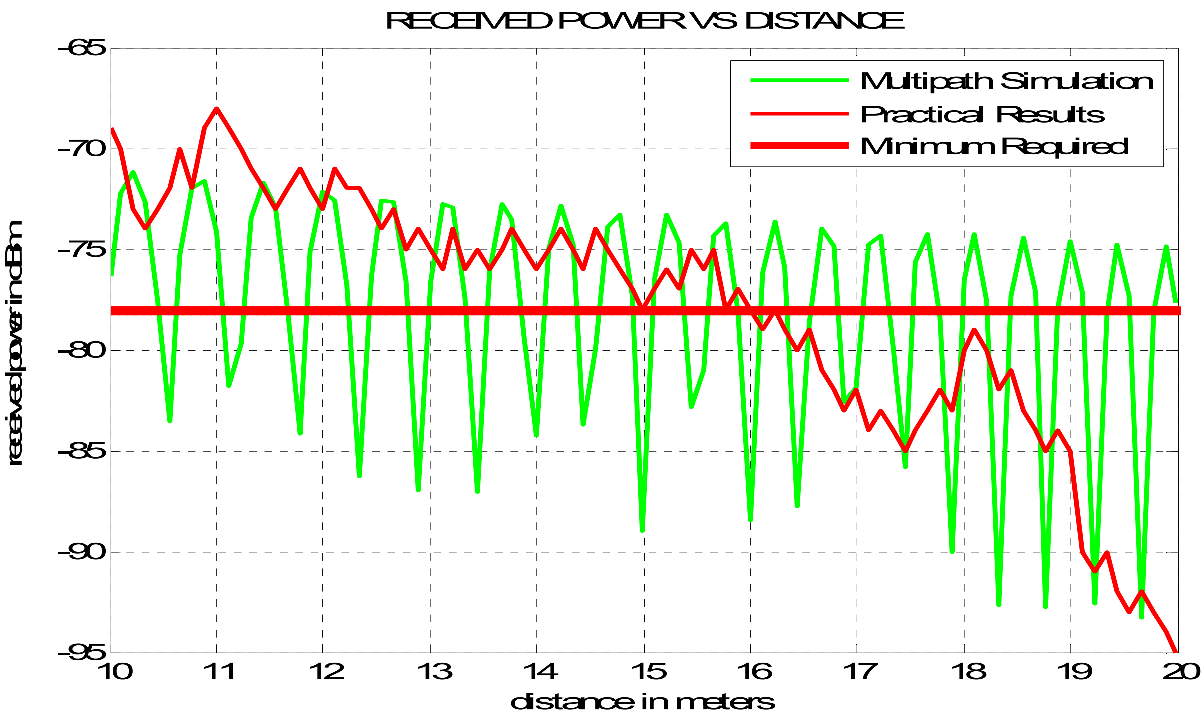




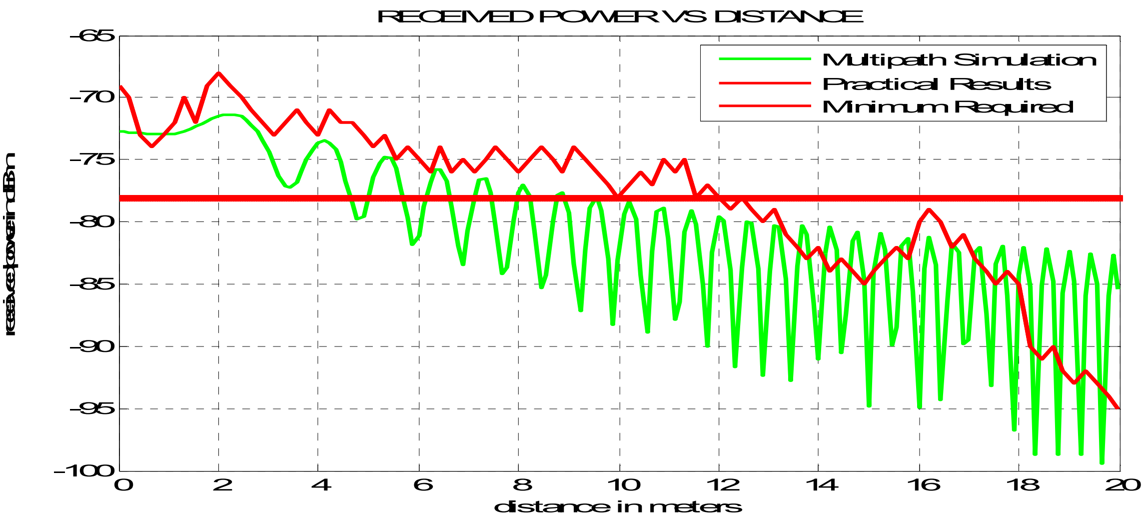
SIMULATION RESULTS UNDER - LOS



PRACTICAL RESULTS WITH MULTIPATH RESULTS



NORMALIZED RESULTS



ASSESSMENT OF RESULTS

The practical and multipath simulation results have been compared on the above graph. There is a little difference between the practical results and its simulation. The differences on the practical results are due to some factors like arrangement of chairs, tables which contain soft materials which absorb energy, user's body which contains water molecules of resonant frequency of 2.4 GHz and metal doors which causes reflection of electromagnetic waves in such a way that, they do cause interference. Apart from that, there is also Interference from other Wireless Local Area N networks as it is shown on the previous page.

The little difference between the practical data and simulation results are due to some factors such as interference and absorbing materials which can't be presented in simulation results.

CONCLUSION

The comparison has been made between practical results (for both three cases above) with simulation results. The results obtained says that at an average distance of 15meters and a channel fading (received power) of -74 to -79 dBm as a threshold points for reliable connectivity and tolerance for interference (for a far distant user) the values correlates to the practical results (with little difference) which were obtained on the graphs above showing received signal strength for ideal and practical results.

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