

Empirical Analysis of Signal-to-Interference Ratio Variations in IEEE 802.11b WLAN

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Abstract- This paper presents an experimental evaluation of the signal-to-interference ratio variations in IEEE 802.11b WLAN. Afrihub network at Nnamdi Azikiwe University was studied using a network sniffer called Network Stumbler (NetStumbler). The network has three functional access points at the time of the study. The mean of the detected signal strength of the access points was calculated. Matlab was used to calculate the signal distance and the signal to interference ratio and the analysis were plotted for several scenarios: for one, three, six, ten and thirty interfering access points. It was observed that the signal to interference ratio decreases as the number of interfering access points increases.

Key words: IEEE 802.11b, Signal to interference ratio, signal distance, Access point, NetStumbler

I. INTRODUCTION

With the increased popularity and deployment of wireless local area networks, efficient management of wireless spectrum is becoming increasingly important [1]. The transmission characteristics of a radio wave and its attenuation in a particular environment depend upon its operating frequency, the distance between the transmitter and the receiver and various obstructing obstacles. However, the more a channel is congested, the more the throughput decreases [2].

The great popularity of IEEE 802.11 along with channel scarcity may lead to a degraded overall performance. A channel allocation unaware of other network's presence in an area may increase medium access contention and co-channel interference and harm networks' aggregate capacity [3]. However, minimization of interference sources achieves high accuracy in data transmission. Since the signal to interference ratio is directly proportional to network throughput, improving the total signal to interference ratio over the network will lead to better data throughput.

II. IEEE 802.11 STANDARD

IEEE 802.11b extends the original IEEE 802.11 direct sequence spread spectrum (DSSS) standard to operate up to 11Mbps in the 2.4GHz unlicensed spectrum using complementary code keying (CCK) modulation. The four data

rates of 1,2,5.5, and 11Mbps are specified on up to three non-overlapping channels and the lowest two rates are also allowed on up to 13 overlapping channel [4].

The IEEE 802.11 standard defines two kinds of services: The Basic Service Set (BSS) and the Extended Service Set (ESS) [5]. IEEE 802.11 defines the basic service set (BSS) as the building block of a wireless local area network. A basic service set is made of stationary or mobile wireless stations and an optional central base station, known as the access point (AP). Basic service set can be viewed as the minimum structure on which a group of mobile stations communicating with each other can be organized [6].

An extended service set (ESS) is made up of two or more basic service set with access points. An extended service set is simply a network comprised of a group of basic service set where the connectivity between the basic service sets is provided owing to the bridging functions of the access points.

All implementations, except infrared, operate in the industrial, scientific and medical (ISM) band, which defined three unlicensed bands in the three ranges 902-928MHz, 2.400-2.4835GHz and 5.725-5.85GHz.

Wireless local area network deployment dictates that the placement of transmitters and their frequency assignments be done systematically to minimize impact. Even though wireless local area network networks are designed to work in an interference-rich environment, and manufacturers may downplay the importance of planning, the ability to measure or predict the coverage and interference effects caused by specific placements of access points can provide orders of magnitude of improvement in cost and end user data throughputs in a heavily loaded system.

Research conducted in [7] showed that the user throughput performance changes radically when access points or clients are located near an interfering transmitter or when frequency planning is not carefully conducted. According to [8, 9] channels being at least 24MHz apart are often considered to be non overlapping. This yields at most three non overlapping channels; channels 1, 6, 11.

III. SIGNAL STRENGTH MEASUREMENTS

Signal strength of Afrihub Network was measured using a network sniffer and it was observed that it has three Access Points that are operational at the time of performing the measurement. The location of the testbed is at the Electronics and Communication laboratory of the Department of Electronics and Computer Engineering of the University having dimensions of 16m by 7m and an area of 112sqm was used. The test bed is as shown in Fig. 1.

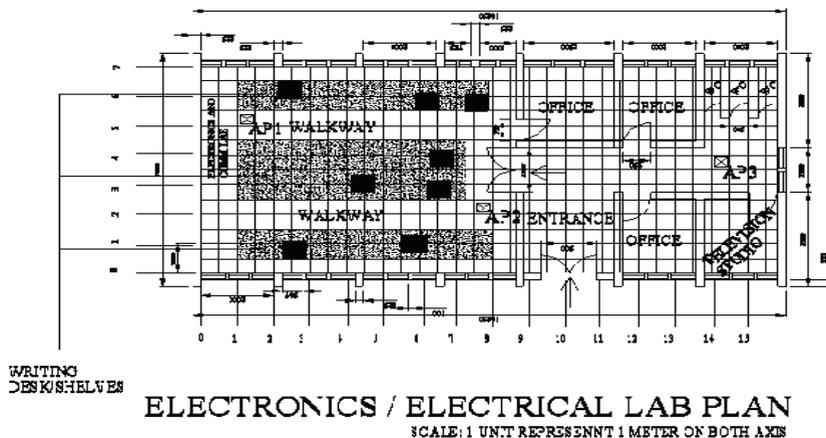


Fig. 1: Experimental testbed

The test bed is segmented by a square of 1m x 1m dimensions. Each square in the test bed represent a user/client and each user is assigned to a particular channel/frequency. The measurements were taken to see how distance correlates to signal strength. This was achieved by recording the level of the signal at various distances from the access points. The data obtained were used to simulate the system using Matlab. Matlab software tool was used to calculate the mean of the measured signal strength, the signal/ Euclidean distance and the signal to interference ratio.

Distance (m)	AP1 (dBm)	AP2 (dBm)	AP3 (dBm)
1	-65	-75	-65
2	-82	-65	-70
3	-68	-68	-72
4	-70	-70	-75
5	-75	-72	-78
6	-80	-75	-80
7	-90	-78	-85
8	-75	-78	-90
9	-78	-80	-70
10	-78	-78	-75
11	-80	-78	-75
12	-83	-80	-80
13	-85	-80	-82
14	-85	-81	-83

A. Estimation of the measured signal strength values

Table 1 shows the values of the signal strength measurement taken using Network Stumbler (NetStumbler). The measurements were taken at various distances. The signal strength decreases with increase in the distance, though there are some exceptions which may be due to line of sight reception. The mean of the measured Signal Strength values of the access points was calculated using Matlab program. It was inferred from the program that signal strength decreases with increase in distance which is in line with the theory.

B. Estimation of Signal distance

The Signal distance between mean measured Signal Strength vectors X1 [X11, X12, X13, ..., X1n] and the mean Signal Strength vector in the data base R1 [R11, R12, R13, ..., R1n] is computed. The Euclidean distance between the two vectors was used and is given by

$$d_i = \left(\sum_{i=1}^n |X1i - R1i|^2 \right)^{1/2} \quad (1)$$

A matlab program was written to compute the Euclidean distance of the access points. The relationship between the Distance (D) in meters and the Euclidean distance in dBm was observed.

C. Estimation of the Signal to Interference Ratio (SIR)

The theoretical signal to interference ratio model used is based solely on path-loss, and it takes no account of fading of any kind. In a simple case, where there is just one interfering access point and both the user and interferer are transmitting at the same power, the Signal to Interference Ratio is expressed as:

$$SIR(dB) = PL(d_s)dB - PL(d_i)dB \quad (2)$$

where d_s is the distance between the user and its base station, which is interfered, while the distance between the interfering user in a co-channel cell and the interfered base station is denoted by d_i . Assuming a 35 dB/decade inverse power law path loss approximation, the signal to interference ratio for a single interferer can be simplified to:

$$SIR(dB) = 35 \log_{10} \left(\frac{d_i}{d_s} \right) \quad (3)$$

When there is more than one interferer, the signal to interference ratio is defined by equation 4, where S is the signal power and I_k is the power of the k_{th} interferer:

$$SIR = \frac{S}{I} = \frac{S}{\sum_k I_k} \quad (4)$$

Under the best and worst interferer positions, all the interferers are at the same distance from the interfered base station. This simplifies equation 4, so that the summation becomes a multiplication. This is shown in equation 5, where n is the number of interferers and I is the interference:

$$SIR = \frac{S}{I} = \frac{S}{n * I} \quad (5)$$

This application is valid only when the interferers are approximately at the same distance from the base station and when all the interferers are continuously transmitting. The signal-to-interference ratio in decibels can be simplified as shown in equation (6), where n is the number of interferers and SIR_{si} is the signal to interference ratio for a single interferer.

$$SIR(dB) = SIR_{si} - 10 \log_{10}(n) \quad (6)$$

Therefore, the signal to interference ratio decreases by 7.8 decibels, when the number of interferers increases from 1 to 6 for the same interferer distance. Using a power pathloss exponent of 35, for multiple interferer, signal to interference ratio expression of equation 6 can be written as

$$SIR(dB) = 35 \log_{10} \frac{d_i}{d_s} - 10 \log_{10}(n) \quad (7)$$

where d_s is the user distance and d_i is the distance of the interferer from the interfered base station. Having derived the equations for the theoretical signal to interference ratio values, and having calculated d_i as the Euclidean distance in equation (1), the signal to interference ratio were calculated as shown in (7).

D. Simulation of Signal-to- Interference Ratio for Single and Multiple Interferers

Equations 3 and 7 were used to simulate the signal to interference ratio (SIR) for single interferer and multiple interferers respectively. The simulation was categorized into various scenarios depending on the number of interfering access points (APs) involved.

Matlab software tool was used to simulate the signal to interference ratios and a graph of Euclidean distance (d_i) against the signal-to- interference ratio (SIR) were plotted for several scenarios: one, three, six, ten and thirty interfering access points as shown in Figs. 2-6.

Scenario 1

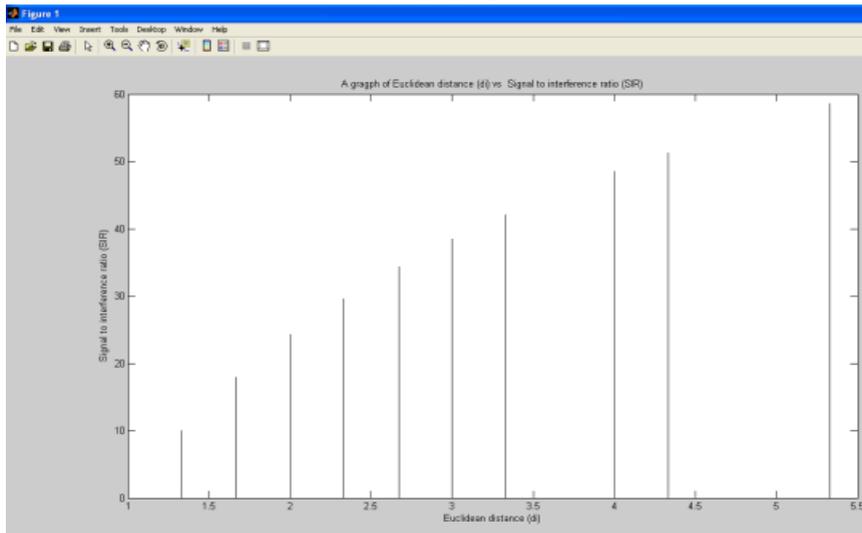


Fig. 2: A graph of d_i Vs SIR when there is one interfering APs

Scenario 2

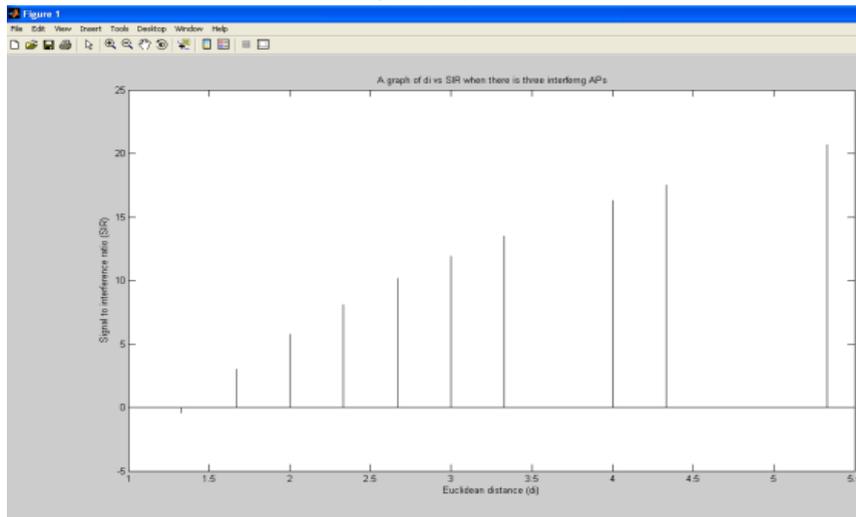


Fig. 3: A graph of d_i Vs SIR when there is three interfering APs

Scenario 3

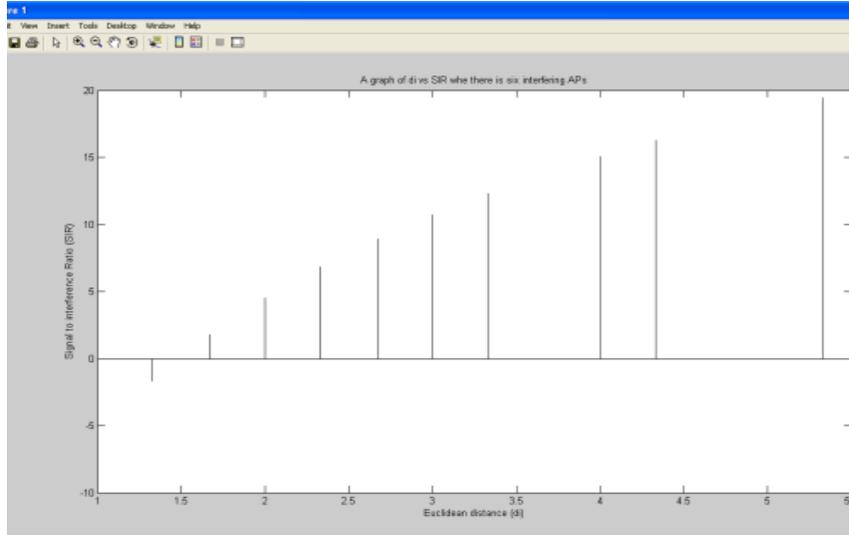


Fig. 4: A graph of d_i Vs SIR when there is six interfering AP

Scenario 4

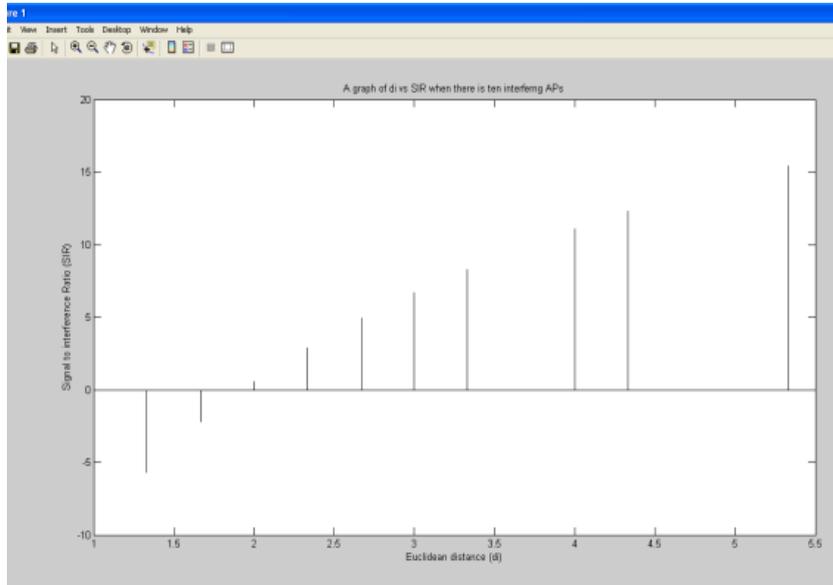


Fig. 5: A graph of d_i Vs SIR when there is ten interfering AP

Scenario 5

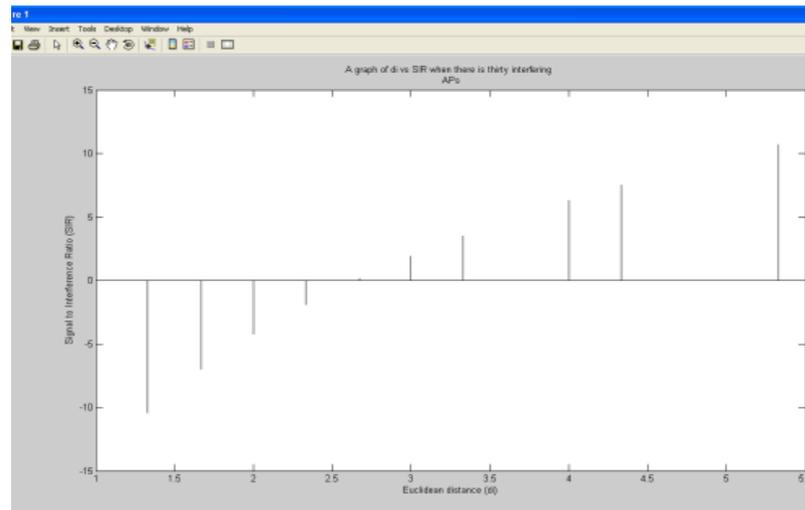


Fig. 6: A graph of d_i Vs SIR when there is thirty interfering APs

IV. CONCLUSION

From the graphs, it was observed that signal-to-interference ratio (SIR) depends on signal distance (Euclidean distance) because the higher the Euclidean distance, the higher the SIR and so the minimal the interference. Also, it was deduced that as the number of interfering access points increase the SIR reduces. Since the SIR must reach a minimum threshold for the signals to be detected, it is important therefore to do a site survey before installing an access point to avoid performance degradation of the network and achieve a better throughput.

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