# WIRELESS NETWORK VISUALIZATION USING RADIO PROPAGATION MODELLING

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**ABSTRACT**

Wireless technologies have had an enormous impact on networking in recent years. It can create new business oppurtunities and allow users to communicate and share data in a new fashion. Wireless Networks decrease installation costs, reduce the deployment time of a network and overcome physical barrier problems inherent in wiring. Unfortunately this flexibility comes at a price. The deployment, installation and setup of a WLAN is not a simple task and a number of factors need to be considered. Wireless Networks are notorious for being insecure due to signal spill, ad-hoc unauthorized access points and varying encryption strengths and standards. RF (Radio Frequency) interference and physical barriers suppress a signal. In addition the channel frequencies each access point will be using in order to provide maximum roaming but minimum inter access point interference need to be considered. It is a complex balancing act to take these factors into account while still maintaining coverage, performance and security requirements. In this paper the benefits and feasibility of a model will be discussed that will enable the network administrator to visualize the coverage footprint of their wireless network when the above factors are taken into consideration. The program will be able to predict the strength, propagation and unwanted spill of signals which could compromise the security of an organisation prior to the deployment of a WLAN. In addition the model will provide functionality to visualize a signal from audit data once the WLAN is operational. The end result will be a program that can aid in the configuration, installation and management of a secure WLAN.

**KEY WORDS**

802.11, Radio Propagation, Signal Visualization, Wireless deployment

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## 1 INTRODUCTION

In recent years Wireless technologies have become widely adopted as an extension of wired networks to provide mobility and flexibility to users. It is becoming an integral part of most organisational networks. Using it, new applications can be develop to enhance data sharing amongst users and add value to production processes [1]. Wireless technologies provide mobility, flexibility and a low alternative for mobile networking.

The IEEE 802.11 family of protocols used by most wireless networking equipment will be the focus of this project. The Security issues and relevant solutions related to this standard will be investigated. The aim is to develop a software tool that will enable the wireless network administrator to visualize the coverage footprint of a wireless network. The tool will require signal propagation models built into it, therefore various signal propagation models will be investigated. Models will be compared with 'real world' data collected.

## 2 GENERAL WIRELESS NETWORKING ISSUES

Even though wireless technologies are inexpensive and easy to install, designing and maintaining a Wireless Local Area Network (WLAN) is a process which requires careful planning and understanding of the technology. Each wireless network set up is unique as the environment of a wireless network will always be different. Therefore it is important to understand the factors which will affect the performance of a wireless network. It is not necessary to have a detailed understanding of Radio Frequency (RF) technology, more importantly it is better to understand the nature of connectivity. To name a few:

- Antenna Selection - An antenna has an impact on the range of a wireless network. A variety of antennas exists eg. omni directional, yagi, sectional and the Parabolic dish, each antenna have a unique pattern. Antennas focus the signal into a particular direction which may provide a stronger signal in a smaller area. For example a Omni directional Antenna, as seen in Figure1, provide 360 degree coverage within a given plane. These antennas are used on access points or in a point-to-multi-point WLAN system. In comparison

the Parabolic antennas, Figure2, focus on a specific direction and are used in point-to-point applications or client side [2].

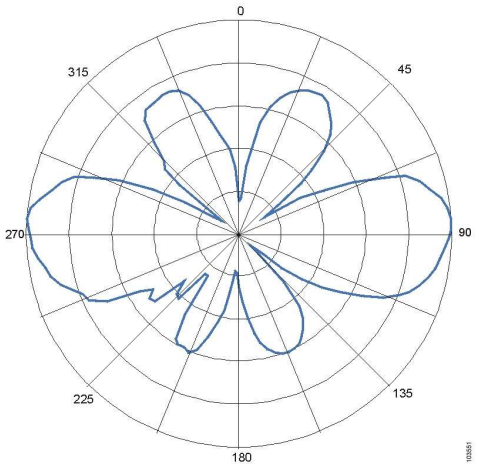


Figure 1: Omni Directional Pattern[6]

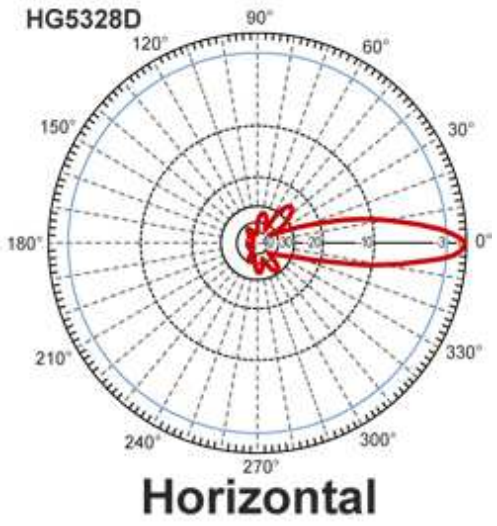


Figure 2: Parabolic Signal [12]

- The maximum density of users need to be considered. People are a source of interference for the signal therefore the amount of people in the wireless network environment can influence the strength of the signal[14].
- The user needs to decide on the location of the Access Points. This step can be closely associated with antenna selection. Once an antenna has been selected its location needs to complement the pattern. In addition the deployment environment will influence the signal because it might be subject to change. For example an office environment could be moved around, trees grow and develop leaves in summer. These factors will influence the placement of an antenna.
- Security features. The carrier of a wireless signal is the air, therefore it is easy to sniff a wireless signal. It is commonly known that the original WEP (Wired Equivalent Privacy) encryption is inherently flawed and easy to break [3]. Therefore it is crucial to be aware of the various encryption standards and methods used by Wireless network.
- In a scenario of a campus wide network, the user should be able to roam freely from one access point to another without experiencing any difficulties. However some security solutions do not support roaming from one subnet to another, IP addressing must be considered when roaming is allowed [11].

Wireless technologies have enormous potential, benefits and can provide new functions, but it contain flaws inherent in the nature of the technology.

- The power consumption of wireless equipment for mobile usgoing ers is prohibitive [1]. It can therefore shorten the life span of a mobile battery.
- The bandwidth of wireless networking is less than wired networking, however the transmission rate of wireless is increasing.
- The coverage areas of wireless technologies are often unpredictable.
- The radio waves of wireless is susceptible to noise, RF (Radio Frequency) interference and Multi-path Propagation of the signal. These factors cause the signal to be distorted and fade which influences the reliability of the network. These are explained in the next section.

The potential and capabilities of wireless technologies is based on cost, speed and its transmission medium. The cost of wireless equipment and knowledge to install a wireless network is less than that of a wired network. Installation and

maintenance cost is lower compared to wired networking[13]. The time required to configure and install wireless equipment is less than for a wired network therefore it will speed up the deployment of the network. It can provide an alternative solution to wired networking where physical barriers are a problem. New scenarios and applications can be developed which may aid in developing productive business processes [1].

The aim of this section is to provide the reader with an idea of some of the factors which influence a wireless network. The issues discussed are only a few and there is space for considerable expansion. In the next section the characteristics of the signal used by the 802.11 family of protocols will be discussed. This will provide the reader with an understanding of issues inherent in the nature of the technology.

## 3 INFLUENCES ON THE 2.4-GHZ FREQUENCY BAND.

In order to design a Wireless LAN it is necessary to understand the characteristics of the Radio Frequency signals used by the 802.11 family of protocols. The 2.4-GHz frequency range used by the 802.11 standard have a range of up to 100 meters in an office environment . The high frequency used by 802.11 is able to penetrate obstacles such as walls and ceilings [8]. However there are several factors which degrades the signal from the transmitter to the receiver. The Radio Frequency (RF) wave is susceptible to fading and distortions caused by reflection, diffraction and scatterings [14]. Data rates are influenced by the distance from the antenna, noise level and propagation environment. It is difficult to accurately predict the signal strength in its expected coverage range due to these factors. This section will aim to discuss these factors and their influence on the throughput of a signal.

### Attenuation

Attenuation can be defined as the decrease of the amplitude of a signal between its transmission and reception points. As the radio waves propagate through the air it loses power over a distance. Therefore signal strength is less. The loss a signal will undergo between the transmitter and receiver is referred to as Free Space Path Loss. Free Space Path Loss refers to power lost as energy disperses into the air [10]. The following formula is often used to calculate the path loss.

$$L = 20 \log(\mathrm{d}) + 20 \log(\mathrm{f}) + 36.6$$

In this formula L represents the loss in dB, d is the distance in miles and f is the frequency in megahertz [2]. This formula is used to calculate signal strength at a certain distance from the AP (Access Point), it does not take any other factors, such as the influence of signals travelling through objects, into account.

**Interference**

The 2.4-GHz which is used by 802.11, 802.11b and 802.11g standards falls into the unlicensed Industry Scientific Medical (ISM) band; therefore it is subject to interference from other wireless electronics like cordless phones. The interference will result in performance degradation [8].

**Channels**

The 2.4-GHz range used by the 802.11 standard is subdivided into 11 channels. Setting up more then one access point might cause a channel overlap, as seen in Figure3 which results in signal interference. Channel overlap can severally influence signal throughput and it is an important factor to consider when deploying a WLAN [4].

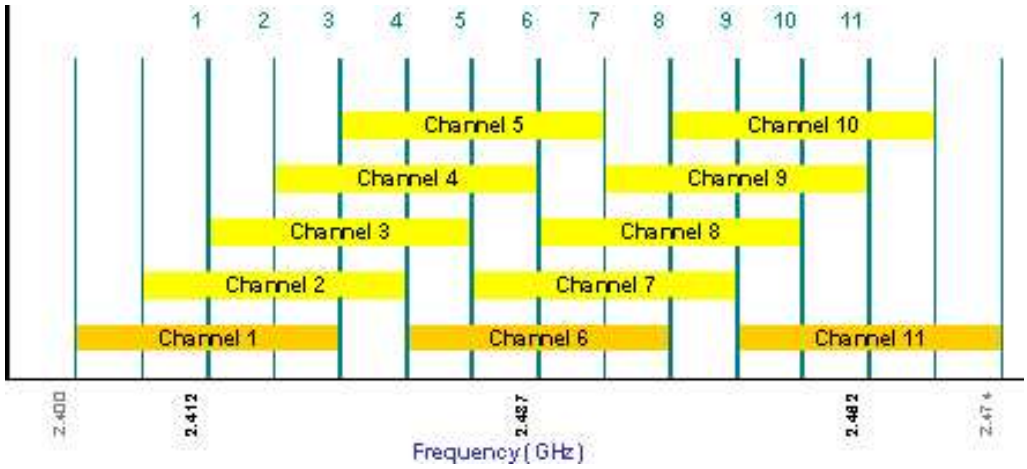


Figure 3: 802.11 channels [9]

**Multi Path Propagation**

This phenomena occurs when the RF signal take different paths to reach its destination. The signal bounces off obstacles like chairs, walls and desks and are reflected in different directions [10]. The observance properties of the different

materials will result in different strength reflections. A part of the signal will reach its destination directly while another part will bounce from the chair to the ceiling and finally its destination. When the receiving end receives the signal and its CRC (Cyclic Redundancy Check) checksum does not calculate correctly it does not send a ACK back and therefore the transmitting station resends the packet after some time. This can cause the throughput of LAN to be lower if radio propagation is a major problem. The problem of Multi Path Propagation is unavoidable but its severity depends on the environment. For example multi-path problems will be more severe in warehouses and processing plants where there are lots of metal surfaces as compared to an office environment [5].

**Noise**

Noise refers to the background RF radiation available in the environment of the signal. These include cordless phones and microwaves. It is the task of the receiver to differentiate between the signal and noise [10].

Keeping these elements in mind the aim is to create a realistic model which can be used to simulate signal propagation.

## 4 SECURITY

The security risks posed by wireless networks are significant. Nevertheless these risks can be mitigated by the proper installation, configuration and management of the wireless network. There exists a vast number of issues to address surounding wireless security. However in this section only a few will be introduced.

Becuase of the radio nature of the transmission medium it is easy to *sniff* a wireless signal. This is often possible from parking-lots or nearby roads outside the building perimeter due to signal spill . Frequently WEP is not enabled on wireless networks and due to the number of vulnerabilities in WEP encryption it is easy to compromise the system . Therefore it is important to consider the range of an AP when deciding where to place it. If its range extent beyond the physical perimeters of the building it could create a security vulnerability [7]. A radio propagation tool can assist the administrator with the placement of an AP. It displays the coverage and signal spill from an AP. The administrator can move the AP around in the program in order to find the spot with maximum coverage but minimum spill.

Another common security risk are rogue Access Points. These are often deployed by users without the consent from the IT department. Usually they are configured with default factory settings. This may provide an easy access point into a network as it does not require any authorization [7]. Performing a wireless audit and inserting it into a propagation tool will enable the administrator to detect these.

This section introduced the relevant security issues that a radio prpagation model will aim to solve. In the next section radio propagation is dicussed.

## 5 RADIO PROPAGATION

A radio propagation model will predict the propagation of a signal within an environment. The following section will discuss the advantages of using a Radio Propagation model for the design of a wireless network. Taking the above menioned characteristics into account mathematical radio propagation models can be developed which will predict the potential propagation of a signal within an environment. Each implementation of a wireless network is unique therefore the Radio Propagation software will require the identification of the elements which will influence the propagation characteristics of the signal, as input. The mathematical models will then calculate a scenario of the predicted propagation based on the input provided. The signal will then be graphically displayed on a 3D model of the environment.

Propagation models have been developed and successfully implemented in commercial software packages. For example AWE Communications have done extensive research into radio propagation modelling. The practical use of radio propagation software will be explained in this paragraph. The key benefit of a radio propagation tool consists of better planning before installation. It assists the wireless administrator to determine the placement of APs. Access points can be moved around in the program, providing the administrator with a view of the signal propagation in each instance. This will aid the administrator in the correct placement of the access point. In order to get maximum coverage where needed and avoid unwanted signal spill.

The administrator can change the types of antennas in the program to make

a more informed decision about the choice of directional antenna to use. Once the WLAN is deployed it will provide the administrator with a visualization of his wireless network using audit data collected by the WLAN administrator. This will enable her to see the propagation of her signal and view the wireless signal spill of her network.

The modelling of the WLAN can be broken into two phases. The aim of the first phase is to help with the design and planning of a wireless network. During the second phase, after the implementation, the real signal is mapped from audit data. Providing the user with a image of the wireless network. The aim of this section was to provide the reader with a concept of the usefulness of radio propagation software. In the next section the approach towards the completion of the project will be discussed.

## 6 PROPOSED METHODOLOGY

This section gives a description of the proposed approach to use in order to develop the program.

### Data Acquisition

The first phase of the project will focus on the data acquisition of the vital statistics of a wireless signal. It will include the signal strength, noise, SNR (Signal to Noise Ratio) location, distance and altitude, providing spatial data for later visual plotting. It will entail doing field measurements of signals at different locations and distances from an AP. This will require the use of GPS (Global Positioning System) device, PDA and a tool to detect and measure wireless signal characteristics. A variety of freely available tools exist which can achieve this task, Kismet, AirSnort and MiniStumbler are some of the more popular ones. The GPS unit will be used to pin point the locations where the measurements was taken.

Measurements of wireless networks will be taken in and around Grahamstown and the University campus, also on occasion in different cities. An IEEE 802.11b antenna will be set-up in a field, from which measurements in open space can be taken. After mapping its propagation signal, the same antenna will be set-up in an office environment and measurements will be taken. It must be noted that the measurements of these signals are for scientific purposes for the validation of the mathematical propagation models and not for malicious intend.

**Data Analysis**

As discussed above the 2.4GHz signal is influenced by various factors in the environment. The purpose of taking measurements in free space is to eliminate most of these. Taking the environmental characteristics into consideration these readings can then be compared with the measurements taken from different environments like an office. Both these measurements will be mapped and displayed. Thereby evaluating the performance of a signal in different environments and when different factors are influencing it. Furthermore the "real" open space measurements will then be compared with those from the predicted theoretical propagation model.

The measurements taken in and around Grahamstown will be mapped to create a picture of the wireless activity and propagation of signals in Grahamstown. It will also serve as a comparison to the predicted propagated signal, in this manner the accuracy of the model can be evaluated. The aim of collecting data on the signal is to evaluate the overall performance of a signal and compare these with the theoretical models.

**Program Development**

The final product will display the proposed signal propagation of a wireless network in a 3D environment. The user will be required to build a model of the environment from the building database. The program will have the capability to adjust parameters, for example building material and activity density. A crucial factor the user needs to provide is the type of antenna that will be used.

The visualization features of the program will be implemented using OpenGL. With OpenGL graphical objects can be visualized and interacted with in a real time environment. In addition the program will require various antenna patterns build into it. This is an essential factor for accurate propagation modelling.

A database of environmental objects will be build. With this database the user will be able to build an outlay of the wireless network environment. Mathematical propagation models will be built into the program to determine signal strength at various locations in the environment. The program will be capable to accept signal and location data. From field data collected by the user it will provide the user with an accurate footprint of the propagated signal. This will enable the user to detect unwanted signal spill and problem areas.

## 7 CONCLUSION

Even though wireless technologies have huge potential, it requires a solid understanding of the technology for the proper deployment of a Wireless LAN. The network administrator needs to be aware of the environment in which the Wireless LAN will be deployed, to identify problem areas in the environment. Installing a Wireless LAN requires careful planning and consideration of the discussed issues. A radio propagation tool serves as a planning tool for the installation of a wireless network. It does this by providing the user with a graphical model of the propagated signal. The signal propagation predicted by this model will not be completely accurate but will provide a good estimate. Using this software it is possible to play around with various factors like antenna position before spending money on any equipment. After the successful deployment of the wireless network the actual real signal can be displayed from audit data. This will provide the user with a visualization of the wireless network. Wireless access points are cheap and easy to install and do not require a significant amount of technical knowledge. The downside to this quality is that anyone can install their own access point without proper authorization, potentially providing unauthorized access into a network. Collecting audit data these rogue access points can be located and pin-pointed using radio propagation software [14].

Wireless technologies can be a headache from a security perspective due to signal spill. Signals leak into traffic lots, neighbouring buildings and travel beyond its expected range. From a performance perspective signals often do not perform to the users expectations [10]. A radio propagation tool will aim to minimize these factors and provide the user with a complete picture of the network.

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