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RESEARCH ARTICLE

Design of a Wireless Local Area Network for A 3-Floors Library

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ABSTRACT

This paper reports plan and map out design of a functional and secure Wireless Local Area Network for a 3-floors, Kashim Ibrahim Library at Ahmadu Bello University, Zaria - Nigeria using simulated computer tests to aid planning. The purpose of the wireless network is to give end users (students and staff) access to electronic journals and online educational databases without having to be confined to restricted sections of the library, and to pave a way for the possible replacement of the traditional wired networks in Educational Institutions. The use of simulation for the Network Design greatly cuts down time and cost spent on performing site surveys to deploy wireless networks, and consequently, the monetary value of implementing wireless networks in the long run. The results showed optimal placement of the Access Points and channels allocation that avoided interference. Good results were obtained at 15 meters from the Access Point.

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INTRODUCTION

A wireless Local Area Network (LAN) is a moderate to high-speed flexible data communications system implemented as an extension to, or as an alternative for, a wired Local Area Network. Using radio frequency (RF) technology, Wireless LANs transmit and receive data over the air, minimizing the need for wired connections. Thus, wireless LANs combine data connectivity with user mobility. Wireless LANs also implement shared access technology in their communication. The IEEE 802.11 specification for wireless is a shared medium of communication that transmits information over wireless links for all IEEE802.11 stations in its transmission range to receive. IEEE802.11 Wireless networks can be configured in two different modes: ad hoc and infrastructure modes. In ad hoc mode, all wireless stations within the communication range can communicate directly with each other; whereas in infrastructure mode, an Access Point (AP) is needed to connect all stations to a Distribution System (DS), and each station can communicate with others through the AP. IEEE802.11 standards actually include a family of standards. Among them, the original standard called IEEE802.11 provides the data rates up to 2 Mbps at 2.4 GHz ISM band [1]. Later, IEEE802.11 working group published its enhanced version named IEEE802.11b that extends the data rate up to 11 Mbps at this ISM band [2]. Its high-speed version at 5 GHz UNII band, i.e. IEEE802.11a, was also defined later [3]. IEEE802.11a standard can achieve data rate of up to 54Mbps by using OFDM (Orthogonal Frequency Division Multiplexing) modulation technique at physical layer. Today, IEEE802.11 wireless networks are widely installed at homes, corporate buildings and hot spots. With the application of WLAN increasing, the customers demand more and more new features and functions of IEEE802.11 WLAN.

Radio based LAN's provide an attractive alternative to fixed network systems if the data rate can be increased to a comparable rate. [4,5] The data rate of the system is limited by the severe multipath and fading which is a characteristic of the indoor radio channel. Adaptive equalization is one method of increasing the transmission rate to justify the use of radio based links. [6] presented the design of a 100 Mbps indoor communication system based on orthogonal frequency division multiplexing (OFDM). The goal was to build a wireless local area network that can compete with today's wired solution in terms of performance. A major novelty of the system is the use of OFDM in a multi-user system. The high bit rate of the OFDM modem necessitates dedicated VLSI.

The design of a wireless local area network (WLAN) has two major issues: determining the best placement of base stations (BS) and assigning the frequency channels for those stations.[7]. The correct BS placement minimizes installation costs. Adequate channel assignment reduces signal interference and improve network throughput.In [8] a WLAN design process is composed of the following steps:

a. Estimation of the demand area map: The WLAN service area will be given to Internet Service Providers (ISPs) according to user demand. Then, ISPs should draw the complete map of the service area by investigating the physical space with walls or barriers. The service area map will be divided into smaller demand points where signal is measured from APs and the number of users or traffic demand is estimated. For example, the demand point can be a small square unit of 1x1 m^2
b. Selection of candidate locations for APs: As the physical location of APs may be restricted to particular areas because of the connection to the wired LAN, the power supply, and the installation and administration costs, ISPs will select the candidate locations to APs.
c. Signal measurement at the demand point in the service area: In order to provide the maximum coverage and throughput, signal measured or estimated at each demand point should be greater than the threshold with which the minimum rate is guaranteed. For example, in IEEE 802.11b, the automatic rate fallback (ARF) function will provide several kinds of rates such as 1/2/5.5/11 Mbps according to the distance between APs and mobile computers. In addition, as the barrier to the wave will change the power of the signal even if two demand points are located in the same distance to an AP, the signal measurement procedure is important to provide the maximum service coverage.
d. Decide APs without channel interference: In general, given the service areas and the signal measurement information map, ISPs will decide the best locations of APs to meet user traffic demand and performance metrics in the minimum cost. In IEEE 802.11b, if one AP uses the same channel assigned to a neighboring AP, WLAN performance is significantly degraded due to the channel interference. Therefore, neighboring APs should use different channels with the minimum channel distance which is defined to avoid the channel interference. When deciding APs, usually, the optimization objective for the maximum WLAN service area is to maximize the sum of the signal throughout the demand points. However, the throughput of mobile hosts can be improved by placing APs appropriately according to user popularity and traffic demand.
e. Re-configuration of APs and channels with feedback information: After installation of APs, ISPs will collect the utilization statistics of APs and incoming/outgoing traffic flows per AP. Then, new APs may be installed at congested

areas, or idle APs may be moved to other areas in order to enhance the WLAN service. In addition, channel assignment may be reconfigured to avoid interference.

This paper reports plan and map out design of a functional and secure Wireless Local Area Network for Kashim Ibrahim Library at Ahmadu Bello University, Zaria - Nigeria using simulated computer tests to aid planning. The purpose of the wireless network is to give end users (students and staff) access to electronic journals and online educational databases without having to be confined to restricted sections of the library, and to pave a way for the possible replacement of the traditional wired networks in the Educational Institution. The use of simulation for the Network Design greatly cuts down time spent on performing site surveys to deploy wireless networks, and consequently, the monetary value of implementing wireless networks in the long run.

Wireless Local Area Networks (WLAN) have become more capable of competing with traditional local area networks because of their many benefits for users, their components have become cheaper and also wireless technology has improved so quickly. Currently wireless data transmission technology is one of the fastest developing branches of Information Technology. In 2003, NOP World Technology, on behalf of Cisco Systems Incorporated, conducted a study on the Benefits of Wireless Local Area Networks showing significant rates of penetration in sectors such as education, government, manufacturing, and healthcare. Obvious benefits outlined were: Increased employee productivity, greater accuracy in everyday tasks and greater financial returns to each of these sectors. [9]

METHODOLOGY

In the perspective of wireless network planning, a site survey is the process of measuring wireless signals around the area under consideration. Equipment from various vendors may be used to carry out site surveys and typically, readings obtained from surveys with multi-vendor equipment will vary. In most cases, a team of two or more people visits the desired wireless network location to carry out a site survey of the area. Measurements are taken and findings recorded. Transmitting equipment will be setup in areas believed to be suitable for equipment placement and additional measurements are taken to test the adequacy of the transmitter in that location. Any unsuitable position is noted and the process of collecting measurement information is repeated. This paper is targeted at reducing the amount of time spent conducting site surveys and proposing a simple, low cost and efficient method of designing wireless networks by taking all possible affecting factors into consideration at the start of the design instead of a trial and error method. Basic security requirements will also be considered and the best possible configuration for the design will be chosen.

The methodology that has been chosen is outlined as follows:

i) Obtain a plan of the area that has been chosen for the wireless network deployment
ii) Identify areas where the wireless signal should be present, areas where it is not necessarily needed and areas where it should not be present under any circumstances
iii) Determine where wireless Access Points will be placed based on transmit power levels, type of antennas used, maximum possible number of users and possible external interference
iv) Chose an appropriate wireless security solution
v) Map out the design

WIRELESS LAN DESIGNS FOR COVERAGE

A coverage oriented Wireless LAN is designed to provide maximum WLAN coverage with the least amount of Access Points. Some characteristics of a coverage oriented deployment include:

- Bursty, low packet rate application types, such as barcode scanning and database queries
- Low bandwidth requirements, allowing data rate scaling down to lower data rates such as 1 or 2 Mbps
- Ease of maintenance

In coverage oriented deployments, the typical applications have low packet rates and low bandwidth requirements. Typical users of the library will have most of the traffic over the WLAN consisting of queries of information from the database of journals and encyclopedia. Figure 1 illustrate the ground floor plan of Kashim Ibrahim Library and the same floor plan and Figure 2 is the picture of the AP socket calculator screen.

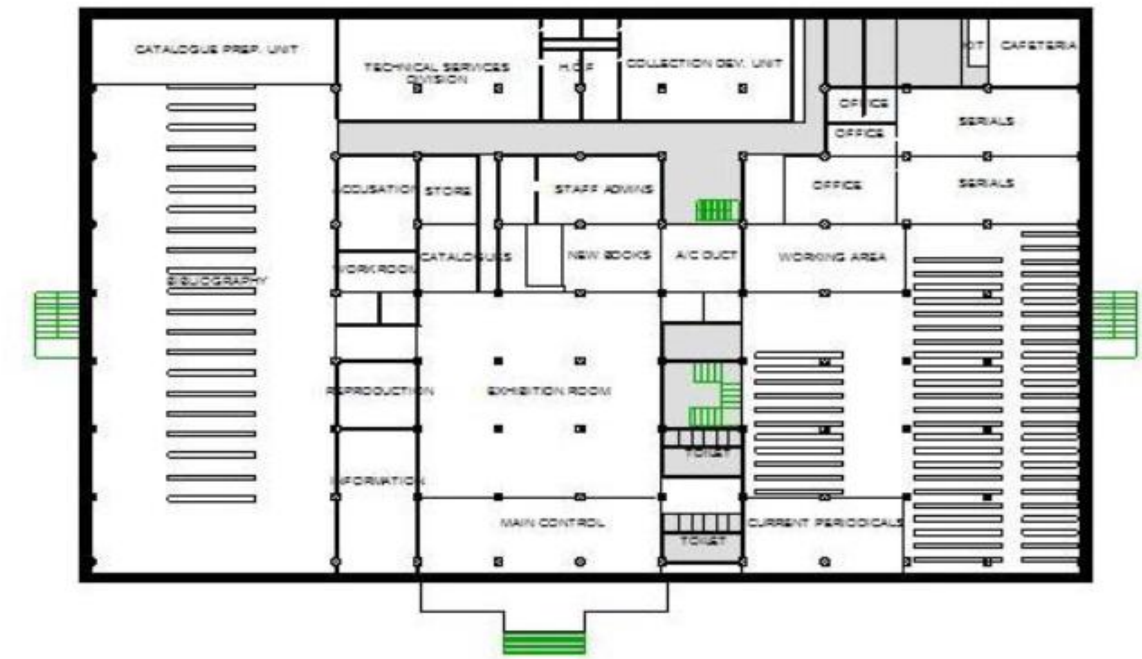

Figure 1: Ground floor plan of Kashim Ibrashim Library

The estimated number of Access Points that will be required to provide adequate coverage in all required areas of the library is calculated using the Bluesocket Access Point calculator. The Bluesocket calculator is based on Access Points with transmit and receive properties similar to the Linksys WRT54GC.

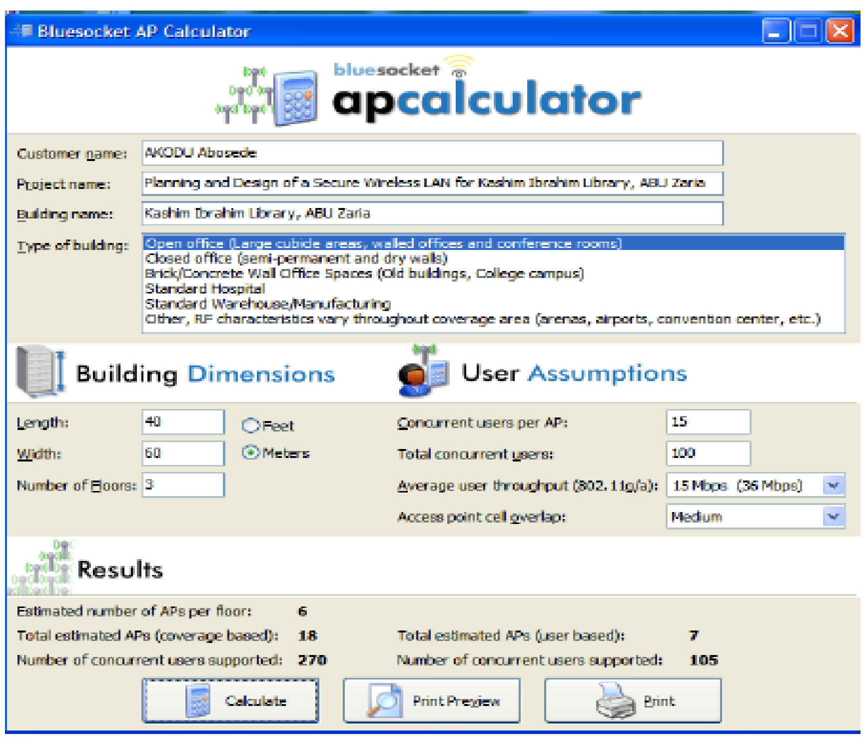

Figure 3: Bluesocket Access Point Calculator

The dimensions of the building are keyed into the Bluesocket Access Point Calculator to get an estimate of the number of access points that will be required based on the total in-building coverage. The following information is from the dimensions of the building were used::

Building length:	40 metres
Building width:	60 metres
Number of floors:	3

The assumed number of concurrent users for every access point and the total number of concurrent users expected at any time in the library is keyed in to obtain an estimate of the number of access points that will be required based on capacity. The following information is used:

Number of concurrent users per access point: 15
Total number of concurrent users: 100
Desired user throughput: 15Mbps
Degree of access point overlap: Medium

The design limits the number of concurrent users per access point to fifteen (15) due to the fact that when the number of users connected to one access point (in a particular BSS) grows beyond 25, signal quality begins to degrade very rapidly. Fifteen is assumed to be a safe number to accommodate for any possible increase in the number of users per access point as users roam from one BSS to another.

FREE SPACE PATH LOSS

Free Space Path Loss refers to the loss incurred by an RF signal due largely to "signal dispersion" which is a natural broadening of the wave front. The wider the wave front, the less power can be induced into the receiving antenna. As the transmitted signal traverses the atmosphere, its power level decreases at a rate inversely proportional to the distance traveled (**d**) and directly proportional to the wavelength of the signal (**λ**). The power level becomes a very important factor when considering link viability.

The Path Loss equation is one of the foundations of link budget calculations. Path Loss represents the single greatest source of loss in a wireless system. Equation (1) is the formula for Path Loss.

$$\text{PATH LOSS} = 20Log_{10}\left[\frac{4\pi d}{\lambda}\right]dB \qquad (1)$$

ACCESS POINTS AND CHANNEL ALLOCATION

This configuration is very flexible since the channel allocation can be rotated between access points if any form of interference exists from external sources. Figures 3-5 show the positions of the APs and the channel allocation based on the plan of the library. It is important to note that while interference is considered horizontally as well as vertically to ensure that stray signals from floors directly above or below do not interfere with signals on a particular floor.

Figure 3: Ground floor WLAN design

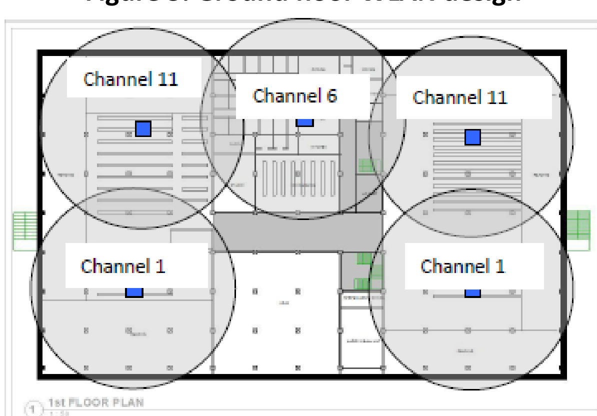

Figure 4: First floor WLAN design and Channel allocation

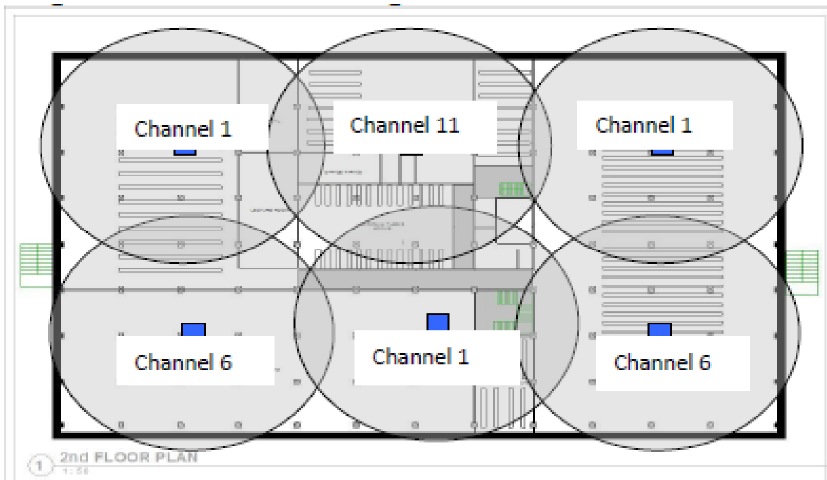

Figure 5: Second floor WLAN design

RESULTS AND DISCUSSION

In addition to the simulation using the Bluesocket access point calculator, a number of tests were carried out to determine cell size and link behaviour under various conditions. The behaviour of the wireless link was simulated under conditions of rain and dry weather and the signal strength was measured through brick walls, metal obstructions and in free space at varying distances. The results of these measurements are shown in figures 6 to 8:

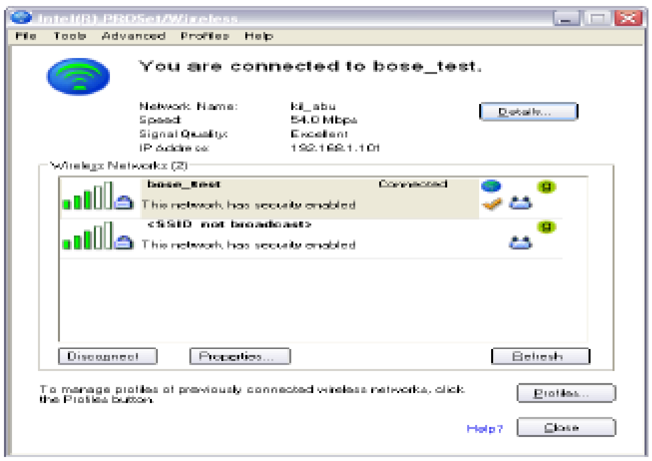

Figure 6: Signal measurement in free space at close range

Packets sized 1024bytes were sent to the access point under varying ambient conditions and at different distances. The following figures illustrate the results:

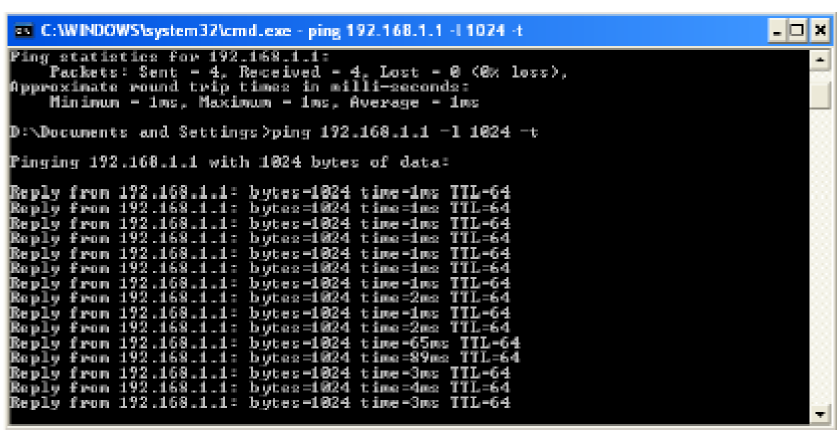

Figure 7: Packet return time within 5m of access point

Within 5m meters of the access point, packet return time was very good and signal level was very good. Measurement through concrete walls, metal doors and varying obstacles (human beings moving across the theoretical line of sight) was taken.

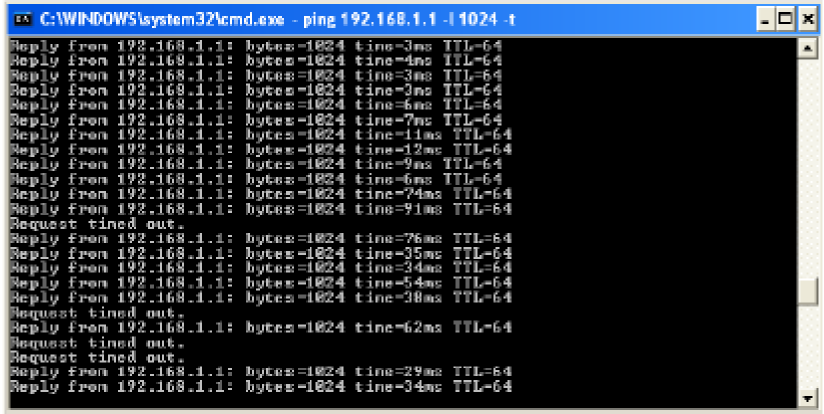

Figure 8: Measurement at 15m with varying obstacles

The result shows that signal is still at good quality 15 metres away from the access point with very few dropped packets possibly due to human obstacles and walls Human obstacles contain a high percentage of liquid and as such a large portion of a 2.4GHz signal is absorbed by the obstacles. Since a very large portion of the traffic that will be passing over the wireless link does not require a constant and uninterrupted connection, this factor is not a great source of concern. Transmission through the air during rain is not a source of concern since the wireless LAN deployment is an indoor deployment.

Based on the measurements taken, it is safe to assume that the design should be made assuming a cell size of approximately twelve (12) metres. This cell size with a moderate degree of cell overlap should suffice for any areas of poor signal quality since signal will still be present at fifteen (15) metres. The plan of each floor of the library with the proposed access point placement and channel allocation is shown in figures 3 to 5.

The design places five (5) access points on the ground floor and the first floor but six (6) access points on the second floor. Only five access points are required on the first and ground floors due to the void which exists at the centre of those floors. Since users of the wireless LAN will not be present at this void at any point in time, providing coverage at this area would be wasteful. No similar void exists on the second floor as such, total coverage is necessary. From the design, it is clear that the wireless signal is kept within the confines of the library as much as possible to minimize the threat of the signal being hijacked by rogue users.

CONCLUSION

A Wireless Local Area Network for Ibrahim Kasim Library in Zaria-Nigeria was designed and results obtained for the 3-floors library. The design was based on coverage. The results showed that with the brick walls and other obstacles taking into consideration, the quality of signals obtained from an AP 15 meters away was good. However APs are placed at 12 meters to the farthest point. Channels were allocated to avoid interference. The results show that WLANs can be designed faster if the parameters of the building are available than taking manual site surveys.

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