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DESIGN OF AN INFRASTRUCTURE WIRELESS LOCAL AREA NETWORK FOR A MULTI STOREY BUILDING COMPLEX

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ABSTRACT

This paper presents the design of an infrastructure wireless local area network for a multi-storey building complex. National Board for Technical Education (NBTE) secretariat complex in Kaduna has been used as a case study. A site survey of the Secretariat was conducted included network documentation, spectrum analysis and coverage analysis using ***NetSurveyor*** *software. The simulation and design were conducted using OPNET IT Academic Guru. A 2.4 GHz frequency band was selected as optimum for the channels of the access points so as to avoid interference from wireless signals from nearby sources such as, nearby banks, cybercafés and corporate organizations. In addition, the coverage analysis showed that a total of fifteen (15) access points would be required to provide adequate coverage for ushers within the secretariat complex to link up to the network. It was also observed that the network follows the same pattern, regardless of the number of ushers and the medium access in use. However, the delay performance decreases before it stabilized when point coordination function (PCF) medium access functionally of the access points are disabled.*

1. INTRODUCTION

A wireless local area network (WLAN) simply connects two or more computers using radio frequency (RF) transmission. This differs from a wired local area network (LAN), which uses cabling to link together computers in a room, building, or site to form a network (Gerder, 2003). A site survey is a step-by-step procedure by which network engineers detect the Radio Frequency (RF) behavior, coverage interference and determine the actual access points (APs) in a site where Wireless Local Area Network (WLAN) would be deployed (Coleman and Westcott , 2006). The main objective of site survey is to ensure that mobile end users experience continually strong RF signal strength as they move from point to point within the area under consideration.

Site survey entails analysis of a facility from RF perspective and discovering what kind of RF coverage a site needs in order to meet the business goals of the customer. During the site survey process, the network engineers gather information that would provide the best options for hardware, installation, and configuration of a wireless LAN. It is an attempt to define the RF coverage from an access point in a particular site. A detailed site survey gives insight to detailed specifications addressing coverage, interference sources, equipment placement, and power considerations and wiring requirements (Peterson, 2008). The documentation from the results of site survey is used for network design and for deployment and verification of wireless communication infrastructure.

2. WLAN SITE SURVEY FOR NBTE SECRETARIAT COMPLEX

In the conduct of the WLAN site survey for the NBTE secretariat complex, spectrum analysis and coverage analysis were carried out as discussed below

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2.1 SPECTRUM ANALYSIS

The importance of undertaking the spectrum analysis is to determine the possible cause of potential interferences around the NBTE premises which might degrade the performance of the network. In addition, a noisy environment can corrupt the transmitted data in an 802.11 standard equipment while interfering devices can prevent an 802.11 access point radio and clients stations from transmitting data effectively. The site survey was carried out using network discovery/scanner software known as **NetSurveyor** as shown in Figure 1**.** It is used to verify WiFi coverage, maximize beacon signal strength, report the presence of WiFi networks, local access points and the signal strengths of their beacons, conduct wireless site surveys, and determine the presence of RF interference. Also, the software can be used to view a summary of all available access points with their signal strengths, encryption (WEP/WPA/WPA2), channel frequency, channel number and the bit rates. NetSurveyor was used to identify the potential sources of interference. The average result of data collected from the spectrum analysis conducted in the 2.4 GHz ISM band within the floors of secretariat building during the course of the research work is shown in Table 1 (A-E).

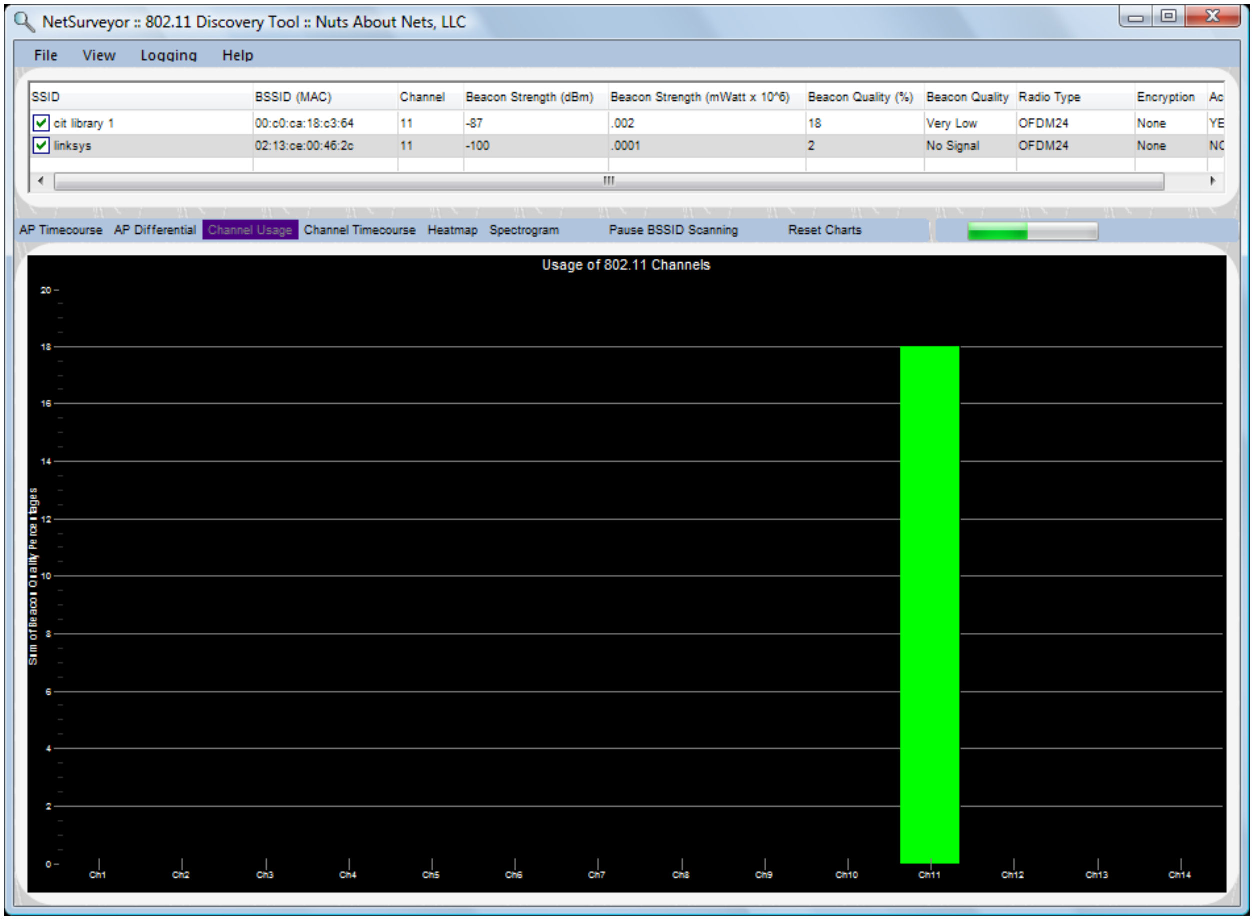

FIGURE 1 A SAMPLE SHOT OF NETSURVEYOR: 802.11 DISCOVERY TOOL

TABLE 1: SPECTRUM ANALYSIS OF THE NBTE SECRETARIAT COMPLEX

A) Basement

Location	Source of Interference	Received Signal Strength	Received Signal Quality	Channel No.	Frequency of Channel
Front Side	None	-	-	-	-
Rear side	LEXO1	-85 dBm	Very Low	6	2.437 GHz
Rear side (Extension)	AIGACCESS	-100 dBm	Poor	5	2.432 GHz
	LEXO1	-100 dBm	Poor	6	2.437 GHz

B) Ground Floor

Location	Source of Interference	Received Signal Strength (Average)	Received Signal Quality (%)	Channel No.	Frequency of Channel
Front side (Left wing)	TRADE_MARTINS	-100 dBm	Poor	6	2.437 GHz
Front side (Right wing)	None	-	-	-	-
Concourse	AIGACCESS	-100 dBm	Poor	5	2.432 GHz
Rear side	LEXO1	-80 dBm	Low	6	2.437 GHz
	Ajaka-Hotspot	-90 dBm	Poor	3	2.422 GHz
	UNKNOWN_ SSID_00	-86 dBm	Very Low	9	2.452 GHZ
Rear Side (Extension)	LEXO1	-85 dBm	Very Low	6	2.437 GHz
	AIGACCESS	-100 dBm	Poor	5	2.432 GHz
	Ajaka-Hotspot	-100 dBm	Poor	3	2.422 GHz
	hepzibah2	-100 dBm	Poor	6	2.437 GHz
	COPLAN WIRELESS	-100 dBm	Poor	11	2.462 GHz
	UNKNOWN_ SSID_00	-100 dBm	Poor	9	2.452 GHZ

C) First floor

Location	Source of Interference	Received Signal Strength (Average)	Received Signal Quality	Channel No.	Frequency of Channel
Front side (Left wing)	TRADE_MARTINS	-100 dBm	Poor	6	2.437 GHz
Board's Room	Ajaka-Hotspot	-100 dBm	Poor	3	2.422 GHz
	LEXO1	-78 dBm	Low	6	2.437 GHz
	TRADE_MARTINS	-100 dBm	Poor	6	2.437 GHz
Front side (Right wing)	AIGACCESS	-100 dBm	Poor	5	2.432 GHz
	Ajaka-Hotspot	-100 dBm	Poor	3	2.422 GHz
	LEXO1	- 100 dBm	Poor	6	2.437 GHz
	TRADE_MARTINS	-100 dBm	Poor	6	2.437 GHz
Sideway (Left wing)	None	-	-	-	-
Sideway (Right wing)	Ajaka-Hotspot	-100 dBm	Poor	3	2.422 GHz
	LEXO1	-100 dBm	Poor	6	2.437 GHz
	AIGACCESS	-100 dBm	Poor	5	2.432 GHz
	NC2	-100 dBm	Poor	3	2.422 GHz
	UNKNOWN_SSID_00	-100 dBm	Poor	9	2.452 GHZ
Rear side	Ajaka-Hotspot	-100 dBm	Poor	3	2.422 GHz
	LEXO1	-100 dBm	Poor	6	2.437 GHz
	UNKNOWN_SSID_00	-100 dBm	Poor	9	2.452 GHZ
Rear Side (Mid Point)	Ajaka -Hotspot	-100 dBm	Poor	3	2.422 GHz
	LEXO1	-76 dBm	Low	6	2.437 GHz
	UNKNOWN_SSID_00	-100 dBm	Poor	9	2.452 GHZ
Rear side (Extension)	AIGACCESS	-84 dBm	Very Low	5	2.432 GHz
	LEXO1	- 79 dBm	Low	6	2.437 GHz
	Ajaka-Hotspot	-100 dBm	**Poor**	3	2.422 GHz
	COPLAN WIRELESS_SAFE	-100 dBm	**Poor**	11	2.462 GHz
	hephzibah 2	-100 dBm	**Poor**	6	2.437GHz

D) Second Floor

Location	Sources of Interference	Received Signal Strength (Average)	Received Signal Quality	Channel No.	Frequency of Channel
Front side (Left wing)	AIGACCESS	-100 dBm	Poor	5	2.432 GHz
	Ajaka-Hotspot	-100 dBm	Poor	3	2.422 GHz
	EMIS1	-100 dBm	Poor	1	2.412 GHz
	HCP	-100 dBm	Poor	11	2.462 GHz
	hephzibah2	-100 dBm	Poor	6	2.437 GHz
	LEXO1	-100 dBm	Poor	6	2.437 GHz
	UNKNOWN_SSID_00	-100 dBm	Poor	9	2.452 GHZ
Library	AIGACCESS	-100 dBm	Poor	5	2.432 GHz
	Ajaka-Hotspot	-100 dBm	Poor	3	2.422 GHz
	HCP	-100 dBm	Poor	11	2.462 GHz
	hephzibah2	-100 dBm	Poor	6	2.437 GHz
	LEXO1	-100 dBm	Poor	6	2.437 GHz
	UNKNOWN_SSID_00	-100 dBm	Poor	9	2.452 GHZ
Front Side (Right wing)	AIGACCESS	-100 dBm	Poor	5	2.432 GHz
	Ajaka-Hotspot	-100 dBm	Poor	3	2.422 GHz
	EMIS1	-100 dBm	Poor	1	**2.412 GHz**
	HCP	-100 dBm	Poor	11	2.462 GHz
	hephzibah2	-100 dBm	Poor	6	2.437 GHz
	LEXO1	-100 dBm	Poor	6	2.437 GHz
	UNKNOWN_SSID_00	-100 dBm	Poor	9	2.452 GHZ
Sideway (Left wing)	AIGACCESS	-100 dBm	Poor	5	2.432 GHz
	Ajaka-Hotspot	- 87 dBm	Very Low	3	2.422 GHz
	hephzibah2	-100 dBm	Poor	6	2.437GHz
	LEXO1	-79 dBm	Low	6	2.437 GHz
	UNKNOWN_SSID_00	-91 dBm	Poor	9	2.452 GHZ
Sideway (Right wing)	AIGACCESS	-100 dBm	Poor	3	2.422 GHz
	LEXO1	-100 dBm	Poor	6	2.437 GHz
	Hephzibah2	-100 dBm	Poor	6	2.437 GHz
Rear side	Ajaka-Hotspot	-87 dBm	Very Low	3	2.422 GHz
	LEXO1	-78 dBm	Low	6	2.437 GHz
	UNKNOWN_SSID_00	-82 dBm	Very Low	9	2.452 GHZ
Rear Side (Midpoint)	AIGACCESS	-100 dBm	Poor	3	2.422 GHz
	Ajaka-Hotspot	-91 dBm	Poor	3	2.422 GHz
	hephzibah2	-100 dBm	Poor	6	2.437 GHz
	LEXO1	-84 dBm	Very Low	6	2.437 GHz
	UNKNOWN_SSID_00	-100 dBm	Poor	9	2.452 GHZ
Rear side (Extension)	LEXO1	-86 dBm	Very Low	6	2.437 GHz
	AIGACCESS	-100 dBm	Poor	5	2.432 GHz
	Comden Voucher	-100 dBm	Poor	7	2.442 GHz
	COPLAN WIRELESS_SAFE	-100 dBm	Poor	11	2.462 GHz
	UNKNOWN_SSID_00	-100 dBm	Poor	9	2.452 GHZ

E) Third Floor

Location	Source of Interference	Received Signal Strength (Average)	Received Signal Quality	Channel No.	Frequency of Channel
Conference Hall	LEXO1	-84 dBm	Very Low	6	2.437 GHz
	WonderNet B	-92 dBm	Poor	3	2.422 GHz
	WonderNet C	-100 dBm	Poor	3	2.422 GHz
	NC2	-100 dBm	Poor	3	2.422 GHz
	Ajaka -Hotspot	-100 dBm	Poor	3	2.422 GHz
Sideway (Left wing)	LEXO1	-100 dBm	Poor	6	2.437 GHz
	hephzibah2	-95 dBm	Poor	6	2.437 GHz
	NC2	-100 dBm	Poor	3	2.422 GHz
	WonderNet B	-100 dBm	Poor	3	2.422 GHz
	WonderNet C	-100 dBm	Poor	3	2.422 GHz
	Ajaka-Hotspot	-100 dBm	Poor	3	2.422 GHz
Sideway (Right wing)	LEXO1	-82 dBm	Very Low	6	2.437 GHz
	hephizibah2	-91 dBm	Very Low	6	2.437 GHz
	NC2	- 94 dBm	Poor	3	2.422 GHz
	UNKNOW_SSID_00	-100 dBm	Poor	9	2.452 GHZ
	WonderNet B	-100 dBm	Poor	3	2.422 GHz
	WonderNet C	-100 dBm	Poor	3	2.422 GHz
	hephizibah2	-100 dBm	Poor	6	2.437 GHz
Rear side	WonderNet B	-100 dBm	Poor	3	2.422 GHz
	WonderNet C	-89 dBm	Very Low	3	2.422 GHz
	LEXO1	-79 dBm	Low	6	2.437 GHz
	Ajaka-Hotspot	-100 dBm	Poor	3	2.422 GHz
	UNKNOWN_SSID_00	-100 dBm	Poor	9	2.452 GHZ
	Ajaka-Hotspot	-91 dBm	Poor	3	2.422 GHz
Rear side (Midpoint)	LEXO1	-100 dBm	Poor	6	2.437 GHz
	hephizibah2	-100 dBm	Poor	6	2.437 GHz
	NC2	- 94 dBm	Poor	3	2.422 GHz
	UNKNOW_SSID_00	-100 dBm	Poor	9	2.452 GHZ
	WonderNet B	-100 dBm	Poor	3	2.422 GHz
	WonderNet C	-100 dBm	Poor	3	2.437 GHz
	Ajaka-Hotspot	-90 dBm	Poor	3	2.422 GHz
Executive Secretary's Office	hephzibah2	-100 dBm	Poor	6	2.437 GHz
	LEXO1	-69 dBm	Good	6	2.437 GHz
	UNKNOWN_SSID_00	-100dBm	Poor	9	2.452 GHZ
	Wonderet B	-100 dBm	Poor	3	2.422 GHz
	WonderNet C	-100 dBm	Poor	3	2.422 GHz

From Table 1 it is observed that there might be a number of sources of interference to the infrastructure WLAN since the 2.4 GHz spectrum is not completely empty. Many of the interferences are from access points and routers from Banks, Internet Service Providers, cybercafés and corporate organizations close to the NBTE secretariat complex.

The highest received signal strength from all the identified sources of the interference is observed to be -69 dBm while the lowest received signal strength from them is -100 dBm. Since these values are lower than -65dBm which is the end point of an access point in the 2.4 GHz band (Coleman and Westcott, 2006). It is obvious that the power of these interfering signals would be weaker than those of the access points that would be deployed in the design.

However, looking at the channel number and frequency of these signals in Table 1, it is important to allocate channel number and frequency to the network devices that would be deployed to avoid the possibility of having co-channel interference with these signals which would drastically reduce the performance of the network.

2.2 COVERAGE ANALYSIS

The coverage analysis is the next step that was taken after the spectrum analysis of the site was conducted. It is meant to determine the proper radio frequency coverage inside the secretariat building and consequently the exact location of the access point in each floor.

The process of determining the correct placement of the access points involves taking the RF measurement at different points on each floor of the secretariat complex. The basic instruments and resources used for the coverage analysis were NetSurveyor, HP laptop computer with Atheros AR5007 802.11b/g WiFi Adapter, Linksys Wireless-G Broadband router, Stool, Extension cable and Writing materials.

The procedure that was followed to perform the coverage analysis are stated as follows:

Step 1: The wireless router was powered and placed at one end of the rear side of the basement floor of the building. The signal strength from the wireless router was measured by using the NetSurveyor software packages installed on the laptop. The recorded signal strength is -50dBm (10mW).

Step 2: From the wireless router, the laptop computer with received signal strength software was moved diagonally toward the other end of the basement to locate the point at which the received signal drops to -65dBm. This is the point that would be marked as the endpoint or cell boundary for the access point.

Step 3: The laptop computer was moved through the facility to find the -65dBm end points or cell boundary but the signal strength received was -59dBm at the other end of the basement. This was also recorded.

Step 4: Steps 1 to 3 were repeated again, in order to get a satisfactory result that would determine the location for the access point and size of the first coverage cell. Thus, the exact location for the access point is determined to be at the midpoint between the two ends of the rear side of the basement floor.

The same procedure is repeated for the ground floor, first floor, second floor and third floor to determine the proper locations of the access points that would ensure roaming and optimum performance of the network. Table 2 shows the RF measurement taken at the two end points at various locations in the NBTE secretariat building and the number of access points proposed for each location while the exact location of the Access Points (APs) locations at each floor of the building is shown in Figure 2.

TABLE 2: SIGNAL STRENGTH MEASUREMENT OF THE NBTE SECRETARIAT BUILDING

Floor	Signal Strength at the first end Point	Signal Strength at the Second End Point	Proposed Number of Access point
Basement			
Front Side	-50 dBm	-59 dBm	1
Rear Side	-50 dBm	-64 dBm	1
Extension	-50 dBm	-62 dBm	1
Ground			
Front Side	-50 dBm	-62 dBm	1
Rear Side	-50 dBm	-65 dBm	1
Extension	-50 dBm	-54 dBm	1
First			
Front Side	-50 dBm	-62 dBm	1
Rear Side	-50 dBm	-65 dBm	1
Extension	-50 dBm	-54 dBm	1
Second			
Front Side	-50 dBm	-64 dBm	1
Rear Side	-50 dBm	-67 dBm	1
Extension	-50 dBm	-54 dBm	1
Third			
Front Side	-50 dBm	-64 dBm	1
Rear Side	-50 dBm	- 67 dBm	1
Extension	-50 dBm	-54 dBm	1

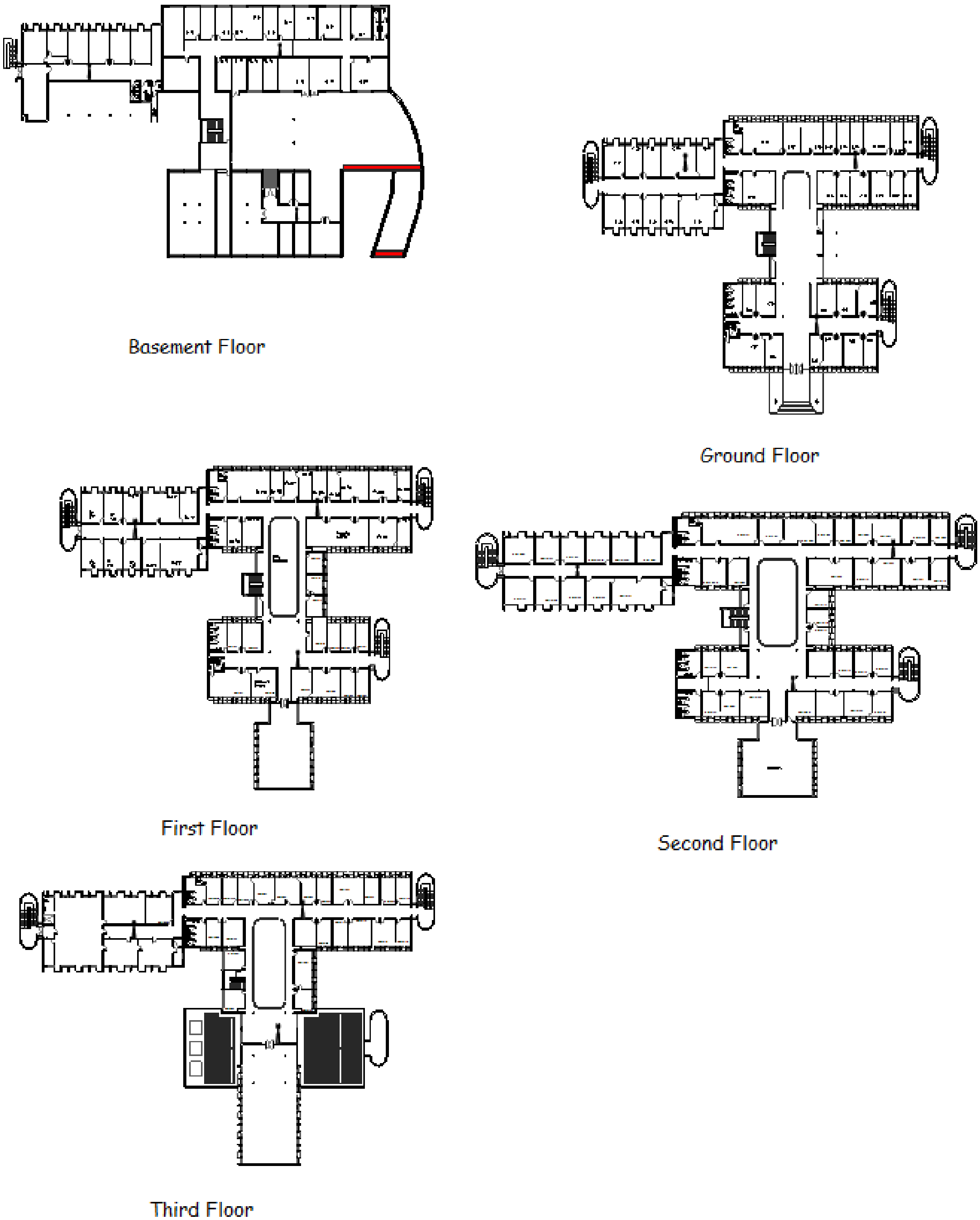

Fig. 2: Location of Access Points in each floor of the NBTE Secretatiat Complex

3.0 CHANNEL REUSE

The design of the wireless LAN takes into consideration the need for overlapping cells not to have overlapping frequencies. This is because when overlapping coverage cells have overlapping frequencies then a co-channel interference would result that leads to degradation in network's performance and throughput (Becta, 2006),

In order to avoid co-channel interference, a channel reuse technique is deployed for the design. The only three channels that meet these criteria in the 2.4 GHz ISM band are channels 1, 6, and 11.

From the results of site survey obtained in Section 2.0 , the channel distribution for the access points to be deployed for the design are shown in the Table 3.

TABLE 3: CHANNEL DISTRIBUTION TABLE

Floor	Channel Number	Channel Frequency
Basement		
Front Side	1	2.412 GHz
Rear Side	6	2.437 GHz
Extension	11	2.462 GHz
Ground Floor		
Front Side	6	2.437 GHz
Rear Side	11	2.462 GHz
Extension	1	2.412 GHz
First Floor		
Front Side	11	2.462 GHz
Rear Side	1	2.412 GHz
Extension	6	2.437 GHz
Second Floor		
Front Side	1	2.412 GHz
Rear Side	6	2.437 GHz
Extension	11	2.462 GHz
Third Floor		
Front Side	6	2.437 GHz
Rear Side	11	2.462 GHz
Extension	1	2.412 GHz

4.0 CONCLUSION

This paper has presented the design of an infrastructure WLAN for NBTE secretariat complex, Kaduna. Simulation and design were carried out to determine the network performance for varying numbers of ushers on the network under high and low loads, and also to find the impact of enabling and disabling the PCF functionality of the access points. The NetSurveyor software was used carrying the spectrum analysis and coverage analysis of the secretariat complex. The spectrum analysis indicated that there could be interferences from nearby sources such as: banks, cybercafés, and so on. A frequency band of 2.4 GHz was selected to minimize the interferences.

The coverage analysis showed that each floor of the secretariat complex would require at least three access points for adequate coverage for all ushers within the complex. It was further observed that the traffic patterns of the four scenarios for the throughput analysis of the network was the same irrespective of the number of ushers and the medium access in use. However, the delay performance decreased before it finally stabilized when PCF medium access functionality of the access points are enabled. Therefore, the throughpoint and analysis show that when the WLAN is deployed, its performance would not suffer enormous degradation.

5.0 REFERENCES

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