GENERIC MODEL FOR ESTIMATING WLAN INFRASTRUCTURE COSTS

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Declaration

I declare that the work in this research project is my original work and has not been previously published or submitted elsewhere for award of a degree. I also declare that this research project contains no material written or published by other people except where due reference is made and author duly acknowledged.

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Abstract

In setting up LAN or WLAN infrastructure, the business has to make careful decisions on the choice of LAN or WLAN infrastructure to be laid for them to have a robust LAN infrastructure as well as have cost effective solution. (Cawley & Harman, 2005) has said that: “there is need for a tool enabling estimating LAN infrastructure costs that would lead to cost effective decisions. It will also provide an opportunity to compare network infrastructure choices which can be deployed in a network.” (p.2). There exist two cost estimation models; Tolly group – 2000 and TIA FOLS – 2005 which is always updated. From the Tolly group and TIA FOLS models, one can be able to estimate costs of having fiber on the vertical and either UTP or fiber on the horizontal using the standardized architectures; distributed or hierarchical star, FTTD/All-fiber and FTTE. Due to the advancement of technologies, there is also need for a tool to estimate the costs of WLAN infrastructure.

The WLAN cost estimation tool developed in this thesis can be used by WLAN users or designers to estimate costs of either hierarchical star design, centralized or FTTD design or FTTE design and compare between costs among the three architectures. It can be used to identify which of the standard-compliant architectures is cost effective without any compromise to the computer network performance. Therefore computer network users or designers are able to make decisions as to which standard compliant architecture is the cost optimal solution for their LAN.

Key words: [WLAN, Computer network, FTTE, FTTD, hierarchical star architecture]

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Table of Contents

Contents

Dedication

I lovingly dedicate this thesis to my family members and friends for their endless love, support and encouragement throughout the process.

List of figures

List of Tables

Acronyms and Abbreviations

AES	Advanced Encryption Standard
AP	Access Point
ATM	Asynchronous Transfer Mode
CAT	Category

CCK	Communications Commission of Kenya
dBm	decibels per mill watt
DES	Data Encryption Standard
DS	Distributed System
ER	Equipment Room
FOLS	Fiber Optic LANs Section
FTTD	Fiber-to-the Desktop
FTTE	Fiber-to-the Telecom-Enclosure
FTTZ	Fiber-to-the zone
GHZ	Gigahertz
IEEE	Institute of Electrical and Electronic Engineers
IP	Internet Protocol
IR	Infrared
IT	Information Technology
Kbps	Kilobits per second
LAN	Local Area Network
MAC	Medium Access Control
Mbps	Megabits per second
MER	Main Equipment Room
mW	milliWatt
NIC	Network Interface Card
NIST	National Institute of Standards and Technology
OFDMA	Orthogonal Frequency Division Multiplexing
PC	Personal Computer
PDA	Personal Digital Assistant

PHY	Physical (layer)
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RF	Radio Frequency
TE	Telecom Enclosure
TIA	Telecommunications Industry Association
UHF	Ultra-High Frequency
UML	Unified Modeling Language
UTP	Unshielded Twisted Pair
UWB	Ultra Wide Band
VoIP	Voice over Internet Protocol
Wi-Fi	Wireless Fidelity
WLAN	Wireless Local Area Network
WIMAX	Worldwide Interoperability for Microwave Access

Terms and Definitions

AES is an algorithm or specification for the encryption of electronic data established by the United States NIST in 2001(Souppaya & Scarfone, 2012).

AP is network equipment that connects wired and wireless networks together and enables the sending and receiving of data between wireless clients and the wired network (Trendnet, 2006).

DES is a previously predominant algorithm for the encryption of electronic data (Souppaya & Scarfone, 2012).

DS is the means by which client devices can communicate with the organization's wired LANs and external networks such as the Internet (Souppaya & Scarfone, 2012).

FTTE is defined as Standards based commercial building structured cabling system architecture that extends the fiber backbone from the equipment room, through the riser and telecom room, directly to a telecom enclosure (TE) installed in a common space serving the work area." (Humbert, 2012)

LAN Is a group of computers and associated devices that share a common communications line or wireless link and typically share the resources of a single processor or server within a small geographic area for example, within an office building (www.vfu.bg/en/e-Learning/*Computer-Networks--Networking_Hardware.ppt).*

Wi-Fi is an established world-wide networking standard which incorporates the use of radio waves to link computers and other network devices together (Trendnet, 2006).

WLAN is a group of wireless networking devices within a limited geographic area, such as an office building, that exchange data through radio communications (Souppaya & Scarfone, 2012).

CHAPTER ONE

INTRODUCTION

1.1 Background

In the modern business, it is a fact that everyone is moving away from the traditional way of doing business and relying on computers plus the new trends of technologies to perform their day-to-day activities which has also improved the way of doing business. For any business to share resources, they would need a LAN or WLAN. When planning to deploy a LAN or WLAN infrastructure, the business has to make careful decisions on the choice infrastructure to be laid for them to have a robust LAN infrastructure as well as have cost effective solution (Cawley & Harman, 2005).

In the recent past, network connectivity trend is shifting from wired to wireless; this is due to the cost incurred in wired LAN infrastructure is high than having a wireless LAN. Many devices to be used in the WLAN have emerged for instance handheld devices which can never connect to the network through wire but only through wireless connections. Due to this shift to wireless connectivity of these devices, there is need for setting up LAN that enables these devices to communicate using wireless connection using the standardized architectures.

WLAN or wired LAN is an enabler for most critical functions in any organization and to have the best LAN infrastructure there should be a tool to aid in choosing cost effective solution for vertical as well as horizontal cabling. TIA FOLS, 2005 argues that the tool allows users of the network to compare the installed first costs of UTP and fiber-based architectures for their networks.

Currently, the world is moving to wireless environment where many devices access the network through wireless connection and from the existing models; researchers have only considered wired LAN infrastructures forgetting about WLAN which is taking over. Therefore, in this project I propose a model that will allow users or designers of WLAN estimate setup costs using three standardized architectures that enables them to choose cost effective solution before deploying their WLAN infrastructure.

1.2 Problem Statement

TIA, FOLS have indicated in their website information retrieved August 2012 that, they welcome changes or improvements to their existing network model that allow designers/users compare first installed cost for the hierarchical star to centralized and FTTE architecture.

According to Cawley and Harman (2005), they have clearly stated that "there is need for a tool enabling estimating LAN infrastructure costs that would lead to cost effective decisions. It will also provide an opportunity to compare network infrastructure choices which can be deployed in a network". From the existing models (Tolly group, 2000 & TIA FOLS, 2005), researchers have only focused on wired infrastructure. Due to the tremendous shift in technology to wireless devices being used by most users such as hand held devices, laptops or even desktops that are now coming with wireless NIC; there is a great need for designing of WLAN infrastructures instead of still focusing on wired LAN as the technology advances. It is a fact that today users have adapted to handheld devices which have to get connected together through WLAN. However, despite the adoption of wireless networks, no study has been done on cost model that enable network planners/designers or users estimate the WLAN infrastructure costs using the standardized architectures; hierarchical star, centralized and Fiber-to-the-Telecommunication enclosure.

1.3 Objectives

1.3.1 Aim

The main goal of this project was to design a model that enable designers or users compare setup costs of WLAN infrastructure to have cost effective solution for their WLAN.

1.3.2 Specific objectives

i. To identify the existing models for estimating setup costs for both wired LAN and WLAN infrastructure.

ii. To Review and identify the gaps that exist in the available cost estimation models

iii. To Design the cost estimation model

iv. To test the cost estimation model

v. To validate the results of the cost model.

1.4 Scope

The scope of this study is to develop a cost model for estimating WLAN infrastructure setup costs of standardized architectures.

1.5 Limitation

This research was limited to only proposing a WLAN infrastructure cost estimation model to compare the costs of standardized architectures.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Network design architectures exist in different forms. In figure 2.1 below (Thompson, 2009), one may decide to have 802.11 wireless networks to a fiber riser or horizontal UTP to a fiber riser or horizontal UTP to a UTP riser or horizontal fiber to a fiber riser or fiber to the enclosure.

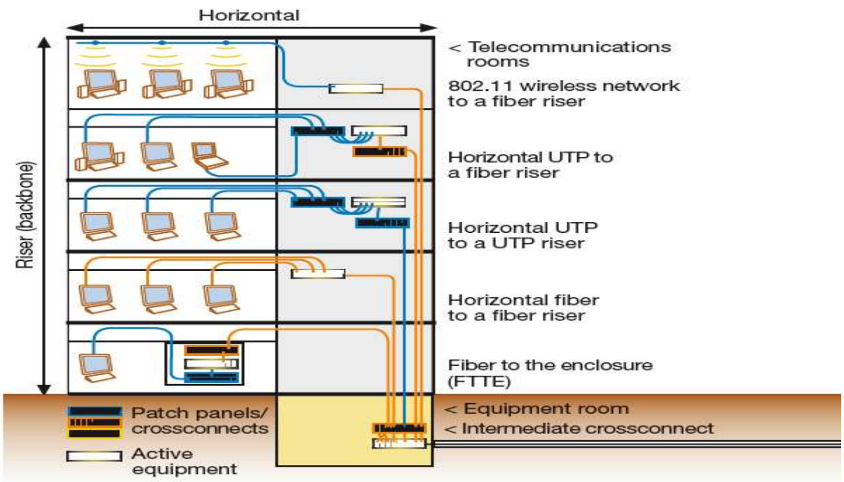

FIGURE 2.1: Network Architectures overview (Thompson, 2009)

Components of WLAN:

There exist two types of WLAN components (NIST Computer Security Division (CSD), 2012), they are:

i. ***Client devices:*** These are devices like laptops, PDAs, among others used by the users in a network.

ii. ***AP:*** This is a device that links or connects the user to the network by providing points at which users can have access to the network.

2.1.1 WLAN advantages

WLAN has the following advantages over wired LAN infrastructure:

WLAN is fast and simple network to setup. This is because there is no need for any cable to be installed at work area where users get connected to the network through the AP. It is also very flexible because it can be installed in places where wires cannot be installed and facilitate temporary set-up and relocation within the work area. Since WLAN requires no cabling at the work area, installation costs is reduced because the labor for laying up the cables has been eliminated. It is also scalable; that is its expansion and reconfiguration may be less complicated than expanding a wired network since it requires grueling task of reinstalling and sometimes addition of equipment such as the switch (Léger, 2007).

2.1.2 WLAN standards, Topologies and technologies

Standards:

National Telecom Regulatory Authority – Technical Affairs and Technology (2003), the IEEE 802.11 standards are classified as follows.

i. ***IEEE 802.11a***

This is also referred to as Wi-Fi5 and is a PHY standard working on unlicensed 5GHZ radio band using OFDM. It also supports data rates from 6Mbps to 54Mbps and is known to offer much less potential for RF interference than other PHYs like 802.11b and 802.11g. This standard is good for supporting multimedia applications and densely populated user environments. It covers an indoor range of 30-50 meters.

ii. ***IEEE 802.11b***

This is also referred to as Wi-Fi and supports data rates from 5.5Mbps to 11Mbps in 2.4GHZ radio band using Complementary Code Keying (CCK). It covers an indoor range of 30-50 meters.

iii. ***IEEE 802.11g***

It is an extension of 802.11b. It broadens 802.11b's data rates to 54Mbps within the 2.4GHZ using OFDM. It covers an indoor range of 30-50 meters.

iv. ***IEEE 802.11n***

Its daft was approved in 2006 and the final standard ratified in 2007. This supports data rates/speed of up to 300Mbps in 2.4GHZ radio band. It covers an indoor range of up to 150 meters.

IEEE 802.11a, 802.11b, and 802.11g are IEEE industry standard specifications. They define the proper operation of WLANs. The table below gives a summary of the comparisons between the above standards.

Topologies:

i. **Peer-to-peer based**

In this type of topology, devices communicate directly with each other as shown in the figure 2.2 below.

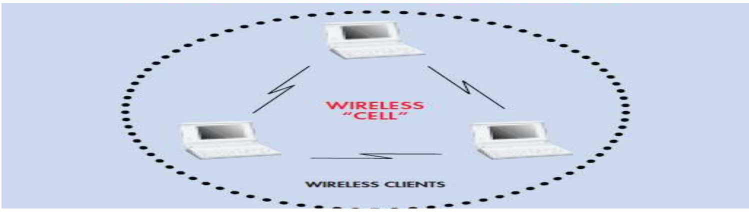

FIGURE 2.2: Peer to peer configuration (DDS, 1999)

ii. **Access point based**

In this topology, wireless devices get connected to the wired LAN backbone for communication with wired and wireless nodes as shown in the figure 2.3 below

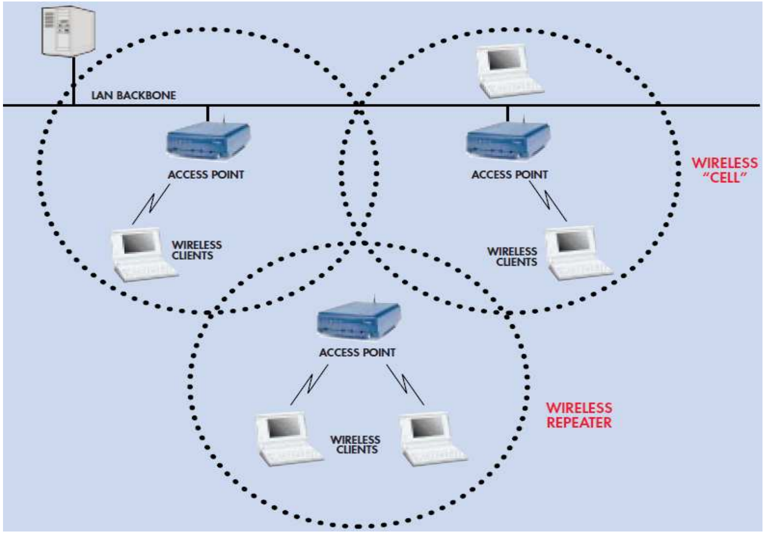

FIGURE 2.3: Access point based configuration (DDS, 1999)

iii. **Point-to-point or point-to-multipoint**

Point-to-point or point-to-multipoint topology, wireless bridges connect a LAN in one building to a LAN in another building even if the buildings are many miles away as shown in the figure 2.4 below.

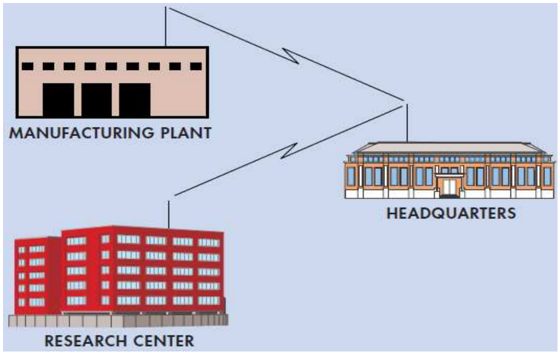

FIGURE 2.4: Point-to-point based configuration (DDS, 1999)

<u>Technologies (Umradia A. D., 2011):</u>

i. **Near Field Communication (NFC)**

NFC is used by various Applications in mobile phones like electronic keys, wallets, tickets, identity among others. It supports speeds of 106 kbps, 212 kbps and 424 kbps.

ii. **Radio Frequency Identification (RFID)**

This is used for near field identification of objects or people. It uses one antenna, one transceiver and one transponder. A reader has both the transceiver and the antenna which activates the transponder (RFID tag) when it is operating. The RFID in turn, transmits data back to the transceiver.

iii. **Wilbree**

This is a radio technology which works between small devices such as watches, wireless keyboards, gaming and sports sensors which can then be interoperated with devices like mobile phones and laptops.

iv. **Zigbee**

It is a low speed wireless application therefore is used for small, low power digital radios based on IEEE 802.15.4 standard. This standard stands for PHY and MAC layers which help in communicating with devices without making use of network delays. Hence we can use this for thousands of devices on a single wireless network.

v. **Bluetooth**

It is a low power radio standard and communication protocol that offers short range connectivity between different devices with communication speeds of 2.1Mbps.

vi. **Wi-Fi**

This is denoted by IEEE 802.11 standard and is commonly known as Wi-Fi. The 802.11 family contains multiple over-the-air modulation techniques which use same basic protocol. The family comprises of 802.11a, 802.11b and 802.11g and they are the amendments to the original standard. Other standards are c-f, h and j.

vii. **Ultra Wide Band (UWB)**

This is a radio technology which consumes low energy and especially for short range communication. It consumes high bandwidth for communication by utilizing great amount of spectrum. It was initially used in radar imaging but recently it has been used for sensor data collection, precision locating and tracking applications.

viii. **WiMAX**

It is an IEEE 802.16 standard. IEEE standard Board in 1999 introduced and worked on Broadband Wireless Access Standards which aimed for global deployment of broadband Wireless Metropolitan Area Networks. There is enhancement going on with 802.16e which is under development which would be known as WiMAX 2.0 or 802.16m. The family of 802.16 is known as WirelessMAN or "WIMAX" (Worldwide Interoperability for Microwave Access). This is named by an industry group called the WiMAX Forum.

2.2 Standardized LAN architectures

2.2.1 Introduction

The following figure illustrates LAN standard star topology. In the figure 2.5 below, there is work area which host devices such as a PC, laptop or any other device that can be used on the network. TR connects vertical cabling referred to as backbone to horizontal cabling. Finally, there is MER which host servers, routers etc. and acts as the control room for the entire network. In the horizontal cabling, the work area can be connected using different types of media according to the infrastructure used (Humbert, 2012).

FIGURE 2.5: standard star topology (Humbert, 2012)

2.2.2 Architectures

i **Distributed network design and hierarchical star architecture**

UTP cable is laid horizontally while fiber optic cable is laid on the vertical (backbone). In distributed cabling design; multimode fiber optic cable is laid vertically while the computers in the LAN are connected horizontally using UTP cable as shown in the figure 2.6 below (Tolly group, 2000).

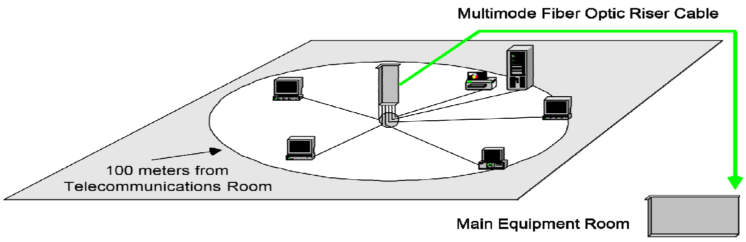

FIGURE 2.6: distributed network design (Tolly group, 2000)

In distributed network design, horizontal UTP cable is limited to the 100m limit. In case it exceeds the limit, more TR will be required as shown in figure 2.7 below. In this design the computers are connected through hubs or switches with high-speed uplinks like 10Base-T and the backbone connection using 100Base-FX.

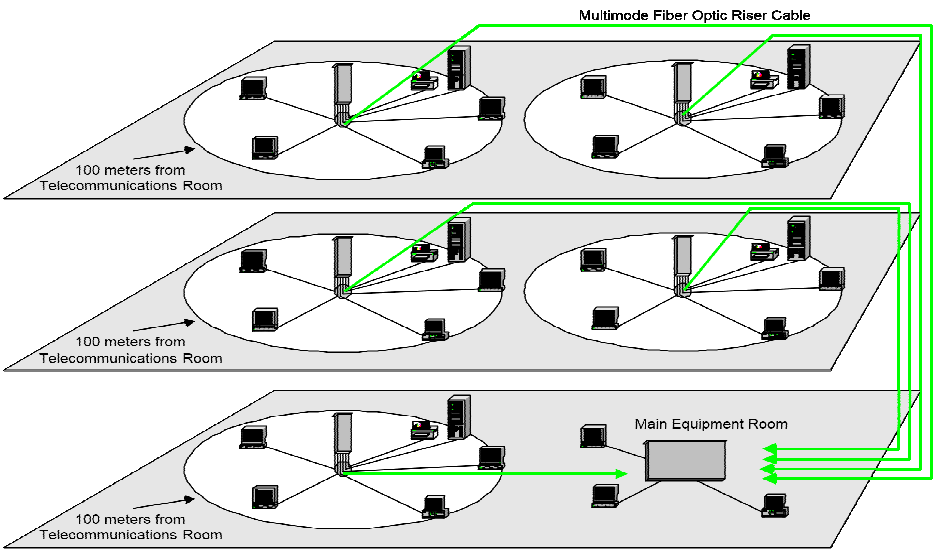

FIGURE 2.7: Distributed network design (Tolly group, 2000)

The hierarchical star layout can be designed as shown in the figure 2.8 below (TIA FOLS, 2005). UTP cable connects to the desktop computers on the horizontal cabling while fiber optic cable is in the vertical cabling.

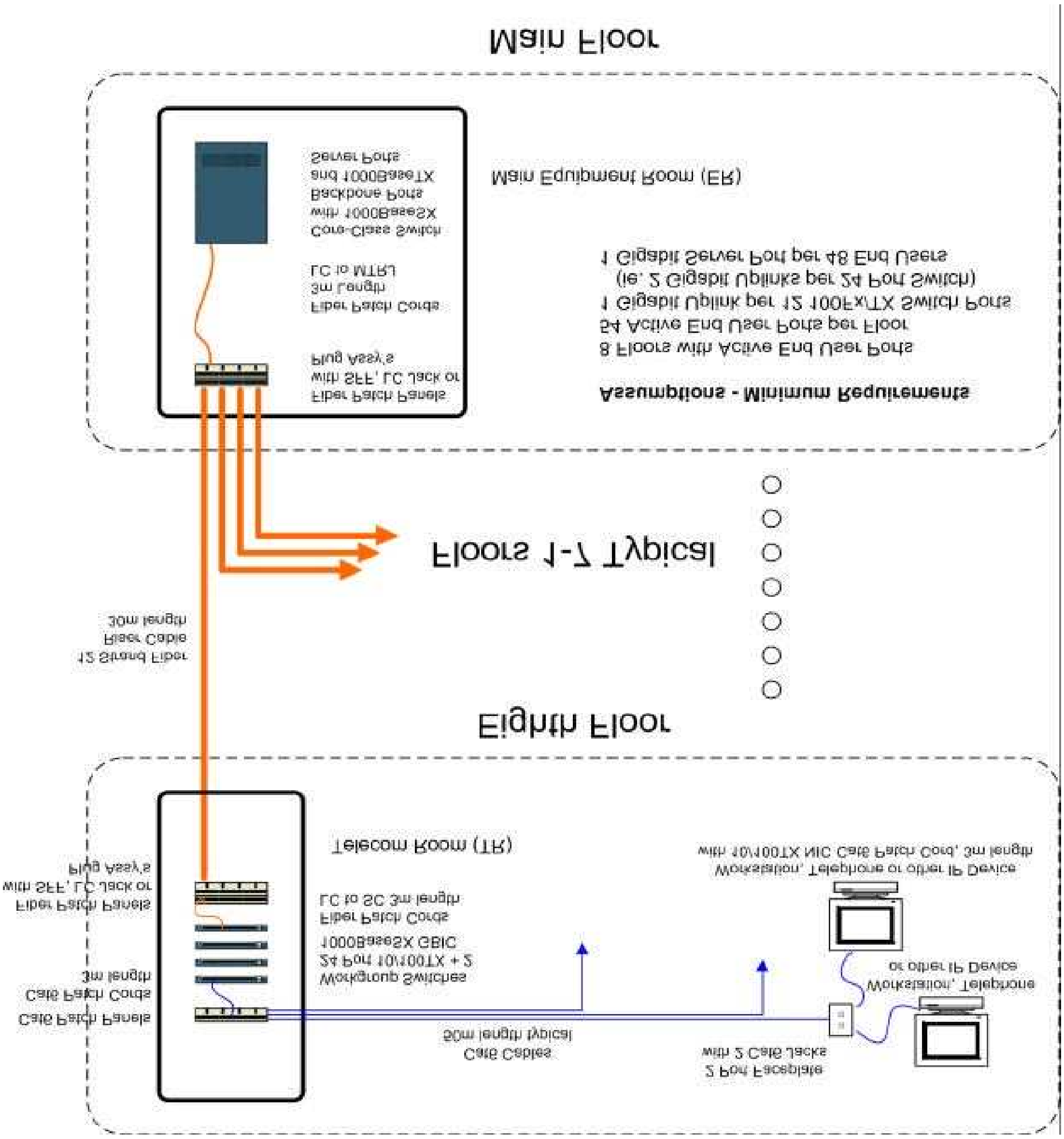

FIGURE 2.8: Hierarchical star design (TIA FOLS, 2005)

ii **Centralized cabling**

This is all-fiber network (fiber on horizontal as well as on vertical cabling). It is also referred to as FTTD (TIA FOLS, 2005). Figure 2.9 is centralized design by Tolly group, 2000.

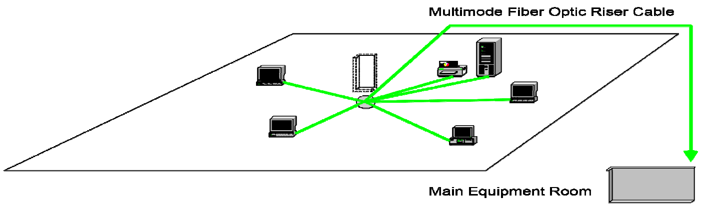

FIGURE 2.9: Centralized network design (Tolly group, 2000)

Since fiber supports long distances, it is optional to have more TR and incase of additional the design is as shown in the figure 2.10 below (Tolly group, 2000).

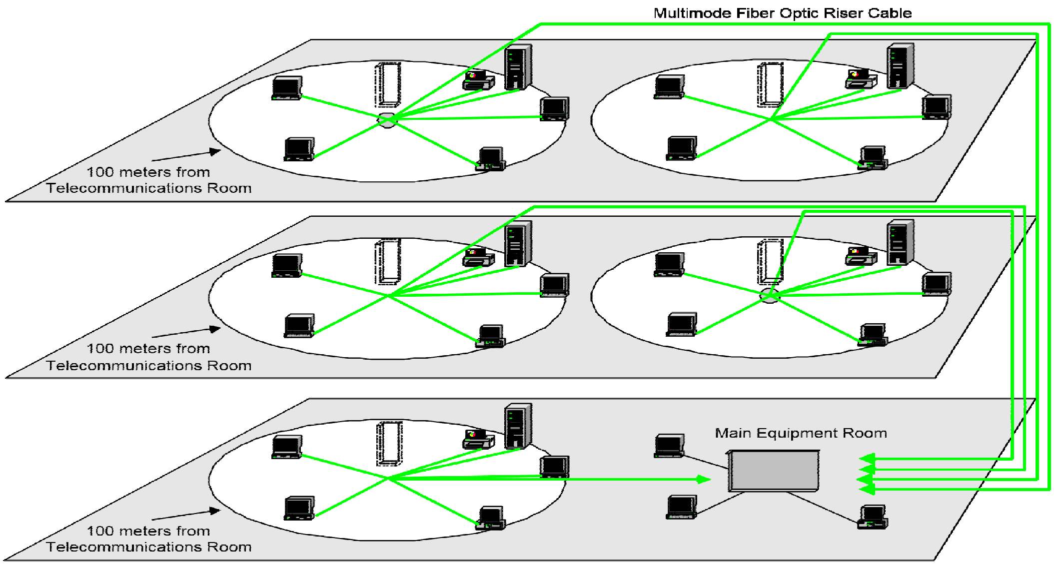

FIGURE 2.10: Centralized network design (Tolly group, 2000)

In the above design, a single fiber-optic cable runs from MER to the TR fiber-optic uplink to the telecommunications room is replaced by one or more high fiber count cables with dedicated fiber connections to each workstation.

The figure 2.11 illustrates (TIA FOLS, 2005) centralized fiber optic cabling (FTTD) with electronics centralized in a main equipment.

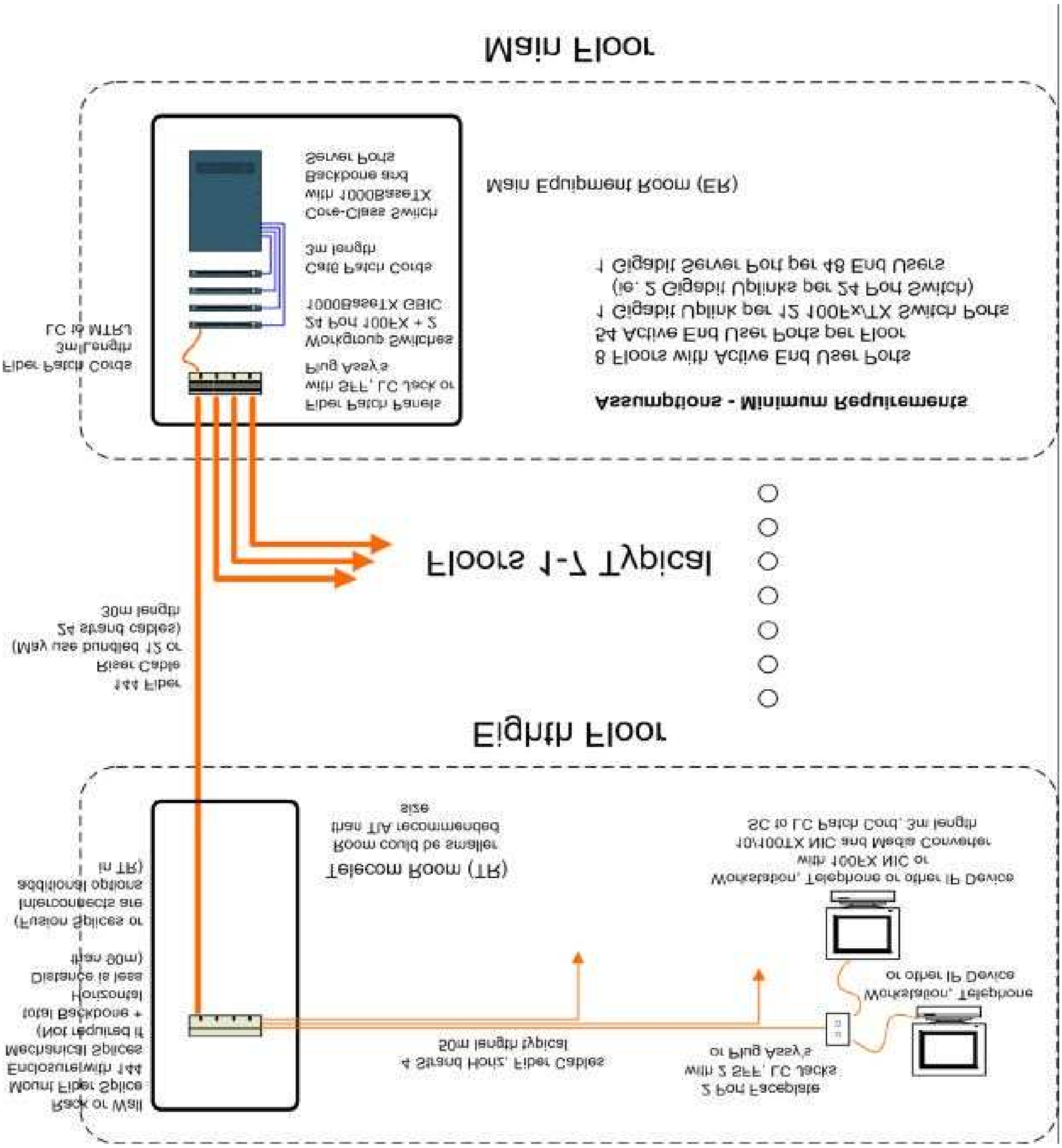

FIGURE 2.11: Centralized network design/FTTD (TIA FOLS, 2005)

iii **FTTE**

It is also referred to fiber-to-the-zone (FTTZ) or fiber-to-the-cabinet (FTTC) as shown in the figure 2.12 below (TIA FOLS, 2005).

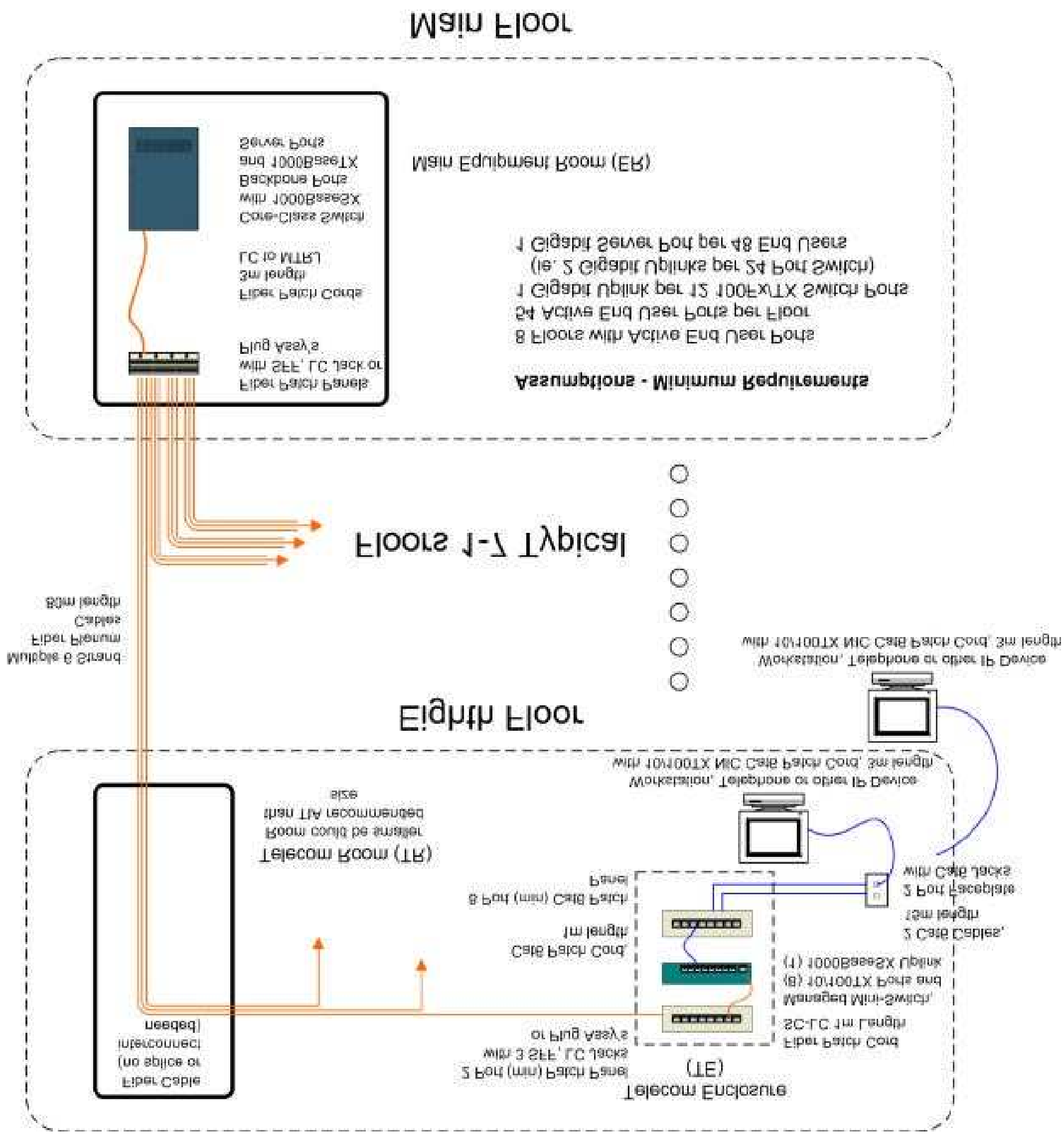

FIGURE 2.12: FTTE (TIA FOLS, 2005)

2.3 Existing Models

2.3.1 Tolly group model

The (Tolly group, 2000) model has focused on the costs associated with two architectures in a building; one is a distributed architecture with copper horizontals and fiber on the vertical, the second is a centralized architecture with fiber on both horizontal and vertical as shown in figure 1,2,4 and 5 above.

The first building of 60,000 sq. foot with 267 users, they proved that in a distributed architecture with five TR and one MER incurs average cost per user of $962.76 using UTP

CAT 5e cabling and $972.85 for UTP CAT 6 cabling. The costs are inclusive of horizontal hardware, TRs, risers and the MER.

In the case of centralized design (all-fiber design) requires only two TRs and one MER which costs $806.80 per user translating to an aggregate savings of more than $40,000 in hardware costs alone.

The second building of 240,000 sq. foot with 1067 users; in distributed architecture having 23 TRs and one MER, it incurs an average cost of $996 per user for CAT 5e cabling and $1,006.10 for CAT 6 cabling. The centralized design (all-fiber) requires only 11TRs and one MER for cost of $773.09 per user translating to savings in hardware costs of more than $235,000.

In both 60,000 and 240,000 square foot models, there is 10' by 11' TR at an estimated cost of $32,226.35 per room in distributed architecture and there is 2.5' by 4'TR at estimated costs of $ 13,328.25 per room in a centralized architecture. The 60,000 square-foot model also includes a 20' by 20' main equipment room at an estimated cost of $33,361.90 in a distributed architecture, and a 20' by 22' main equipment room (to accommodate more switch ports and cables) at an estimated cost of $37,428.30 in a centralized system. The 240,000 square-foot model also includes a 30' by 40' main equipment room at an estimated cost of $47,629.40 in a distributed architecture, and a 34' by 40' main equipment room (to accommodate more switch ports and cables) at an estimated cost of $56,893.20 in a centralized system. The table 2.1 below shows the summary of TR and MER costs (Tolly group, 2000).

TABLE 2.1: Summary of TR costs (Tolly group, 2000)

60,000-square foot building	Size	Cost
Telecommunications Room, Distributed Architecture	10' x 11'	$32,226.35
Telecommunications Room, Centralized Architecture	2.5' x 4'	$13,328.25
Main Equipment Room, Distributed Architecture	20' x 20'	$33,361.90
Main Equipment Room, Centralized Architecture	20' x 22'	$37,428.30

TABLE 2.2: Summary of MER costs (Tolly group, 2000)

240,000-square foot building	Size	Cost
Telecommunications Room, Distributed Architecture	10' x 11'	$32,226.35
Telecommunications Room, Centralized Architecture	2.5' x 4'	$13,328.25
Main Equipment Room, Distributed Architecture	30' x 40'	$47,629.40
Main Equipment Room, Centralized Architecture	34' x 40'	$56,893.20

2.3.2 TIA FOLS model

(TIA FOLS, 2005) model, allows planners or users compare the cost of hierarchical star layout (horizontal UTP/vertical fiber network) to the cost of FTTE (high density and low density) and Centralized fiber network (FTTD).

In their model, an eight floor building with 54 ports in each floor has been used to estimate installed first costs. Their analysis have proved that FTTE and FTTD costs less than UTP because UTP switch port utilization may drop below 70% of its value. They argue that labor cost does not affect the conclusions and comparisons since it costs about 10% of the UTP total cost and about 6% of the FTTD total cost.

From the model planners or end-users can compare cost of:

i. **Hierarchical Star Architecture (UTP horizontal with fiber riser backbone) to Centralized Fiber Optic Cabling (FTTD)**

In this case, 8 Floors with 54 Active End User Ports per Floor. The centralized cabling architecture has been proved to be competitive option than hierarchical star option. The results shows that cost of deploying FTTD infrastructure have decreased over time. The advantage of fiber network over UTP network is that it has longer usable life and has the bandwidth to support additional generation of high-speed LAN electronics.

ii. **Hierarchical Start Architecture (UTP horizontal with fiber riser backbone) compared to Fiber to the Telecommunications Enclosure (FTTE) Low Density**

The Telecom-Enclosure being located in office environment, it contains patch panel to connect to the Fiber from the vertical cabling and this connects also to horizontal cabling which in this case is UTP copper cable that extend to the 8 supported work areas. This has been proofed to be very low cost solution for the work area compared to UTP-fiber network, the low density.

According to their analysis FTTE offers 30.5% savings. They also proofed that per-port cost of FTTE is $198.69 less than hierarchical star thereby reducing the total cost by $85,845. FTTE has also been proofed to provide the highest workstation performance due to the non-blocking nature of the design.

iii. **Hierarchical Star Architecture (UTP horizontal with fiber riser backbone) compared to Fiber to the Telecommunications Enclosure (FTTE) High Density**

This is the last scenario where a building of 8 Floors with 54 Active End User Ports per floor. The difference between the low density and this case is the switch used in the TE which is 24-port workgroup switch and also High density FTTE is said to be 20% blocking unlike low density FTTE which is totally non-blocking.

In their analysis, FTTE is proved to offer savings than in the case of low density scenario by 41.8% compared to hierarchical star architecture. It reduces the network cost by $272.46 per port hence providing savings of $117,702 for the entire network.

2.4 Critique of the existing models

2.4.1 Tolly group model

It is confirmed that from this model, a designer or end-user can be able to determine the costs of distributed cabling to centralized cabling and have a cost effective wired LAN architecture hence note the differences in costs of using UTP or fiber on the horizontal cabling. In this model analysis of the results, fiber optic cabling has an advantage over UTP in bandwidth, distance and reliability. They have also shown that with the advent of new centralized LAN cabling designs, fiber also enjoys a cost advantage due to the reduction of TR by removing most of them thereby reduction in capital costs.

The model has not updated since its development and due to several changes since then especially on equipment or technologies used in networks as well as new standardized-compliant architectures such as FTTE/FTTZ. If used by current designer or end user, it will give misleading results concerning the comparison between distributed and centralized architecture. Since it compares cost of two standard –Based architectures, it cannot be used to estimate first installed cost of WLAN network of neither infrastructure mode nor point-to-point designs. It is basically comparing UTP and the fiber using distributed and centralized architectures respectively. Lastly, the model does not include labor cost of both the distributed and centralized architectures respectively.

2.4.2 TIA FOLS model

This model has been proofed to enable a network designer or end-user to compare first installed cost of horizontal UTP/ vertical fiber network to the cost of centralized network and FTTE implementation and have the results of the three standard compliant architectures. It has focused on the newly standardized-compliant architectures; centralized cabling/FTTD and FTTE and compares it to the traditional hierarchical star architecture which is a predominant architecture in the market. Despite the fact that the model has focused on the new standard compliant architectures, it has not put into consideration on the WLAN design for any of these architectures. It does not also put into consideration the labor cost which is very important and without it the network is not complete. It is part of first installed cost which must be incurred when deploying any kind of network in a business. One may also argue that the test building used for the model, which is 8 floors, makes it more complicated to understand and may not characterize a typical small to medium size organization's building. A building of 3 or 4 floors may have been more suitable and easier to comprehend when doing analysis of various input cost factors.

2.5 Conclusion

Computer network is very important in any business, therefore in deploying the LAN or WLAN infrastructure, it has to make careful decisions on the choice of LAN or WLAN infrastructure to be laid for them to have a robust LAN infrastructure as well as have cost effective solution (Cawley & Harman, 2005). Tolly group model enables a designer or end-user compare between costs of deploying distributed cabling to centralized cabling. According to their findings in the two architectures, the cost can be determined by getting the total cost of MER as well as TR and finally comparing distributed MER cost to centralized MER cost and distributed TR cost to centralized TR cost. This model has never been improved since the year 2000 and therefore cannot be used by any designer or user due to the advancement in the technology as well as the trends on the new standard compliant architectures; FTTE which are not considered in the model (Tolly group, 2000).

The TIA FOLS model enables a network designer or end-user to compare first installed cost of horizontal UTP/ vertical fiber network to the cost of centralized network and FTTE implementation and have the results of the three standard compliant architectures. Despite the consideration of the newly standardized architecture, it assumes that labor cost does not have any impact on the overall cost of deploying a wired LAN. Labor cost for different architectures may differ but should be considered when deploying a network. It does not also consider the first installed cost of wireless network infrastructure (TIA, 2005).

Due to the advancement of technologies, business is shifting to implementation of networks that can support the use of IP wireless devices and therefore there is also need for a model to estimate the costs of WLAN infrastructure which this research addresses.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter describes on how the research was conducted; indicating the population size and the sampling procedure applied to collect the intended information. The data collection technique and the steps are also discussed.

3.2 Population

The population that was targeted includes LAN infrastructure design companies to represent designers and one public and one private end-users company were used to collect the required data.

3.3 Sampling procedure

The study would benefit designers as well as users of the LAN; each should be represented in the data collection and only IT professionals from each of them will be the qualified and reliable respondents.

Purposive sampling was applied in this study. (Palys, 2009) confirms that "purposive sampling signifies that you see sampling as a series of strategic choices about with whom, where and how to do your research. Two things are implicit in that statement. First is that the way that you sample has to be tied to your objectives. Second is an implication that follows from the first, i.e., that there is no one "best" sampling strategy because which is "best" will depend on the context in which you are working and the nature of your research objective(s)".

3.4 Fact finding techniques

Both Primary data and secondary data were used in the study. Primary data was used to review the existing models. Questionnaires were sent to the intended respondents and interviews were conducted to few individuals targeted.

3.4 Research model

Figure 3.1 below indicates the sequence of steps on how the research was conducted.

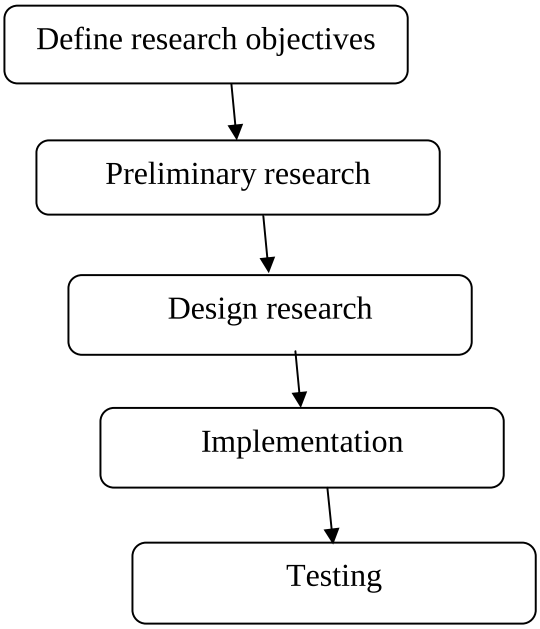

FIGURE 3.1: Research model

i. ***Define research objectives***

Decide on the questions that needed to be answered.

ii. ***Do preliminary research***

Collect any information that led to defining the objectives clearly through document analysis of the previously done research studies.

iii. ***Design research***

Come up with the questionnaires and interview questions; select the targeted group to collect data through purposive sampling.

iv. ***Implementation***

Design the generic model

v. ***Testing***

Find out if the model can work and compare it with existing models to find out which design is cost effective.

CHAPTER FOUR

CONCEPTUAL DESIGN

4.1 Introduction

This chapter gives a description of how the proposed generic model works and meet its performance requirements as well the field studies carried out and expected output.

4.1.1 Assumptions

A building with four (4) floors has been used to demonstrate the model with each floor having 20 active end users except the floor with the main equipment room. Due to the advancement in the technology and user or designers are shifting to fiber. The model will only focus on All-fiber and FTTE architecture with AP on the work area.

4.2 Proposed model Conceptual design for standardized architectures

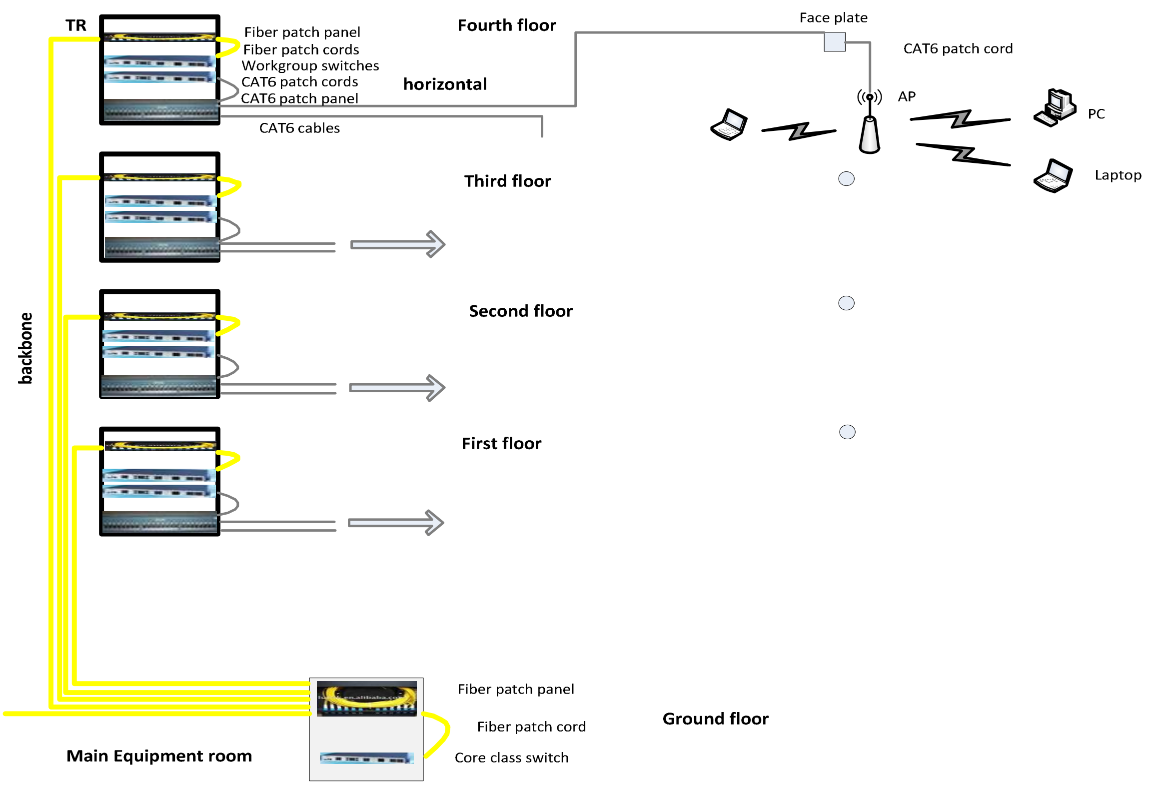

FIGURE 4.1: Hierarchical star layout

The hierarchical design as shown in figure 4.1 above, has vertical fiber running from MER to TR where it is terminated and on the horizontal runs UTP cable to the points where the AP device is connected which enable the computers get connected to the network.

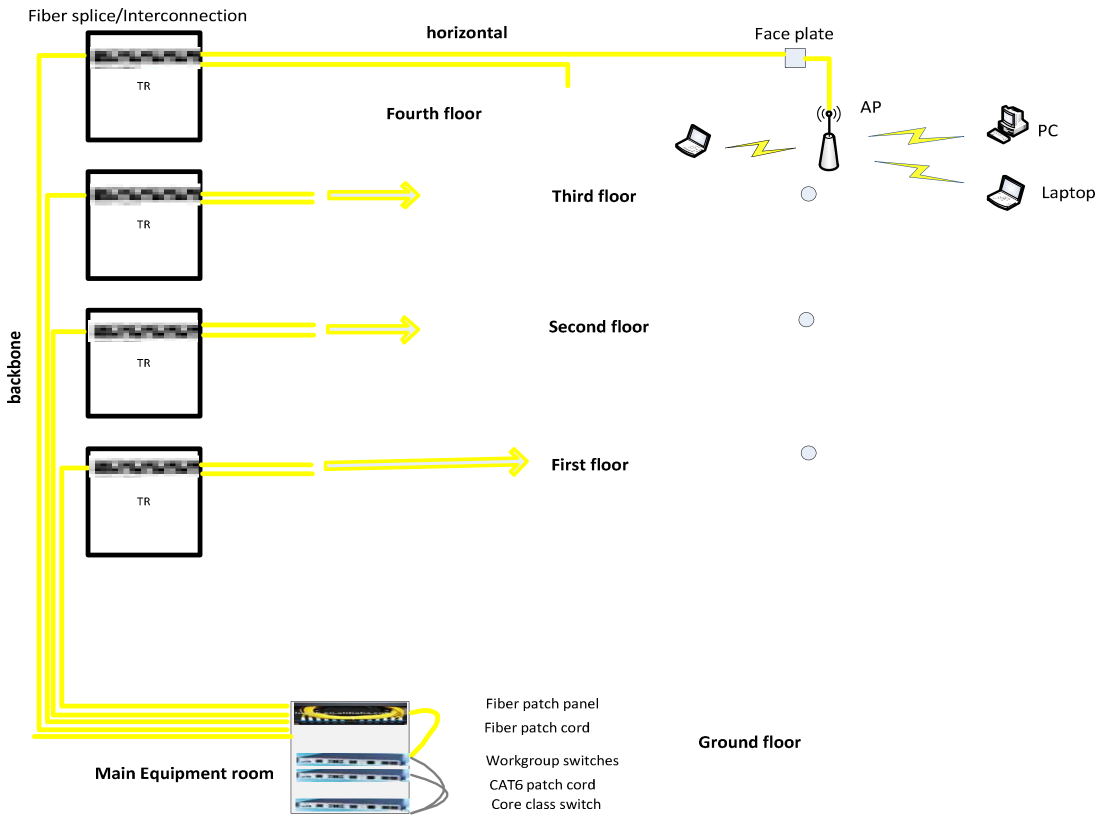

FIGURE 4.2: Centralized/FTTD layout

In the figure 4.2, fiber runs from the MER through the TR where splicing or interconnections can be done to the work area where it is terminated to a faceplate. An AP is then connected using fiber patch cord. Computers get connected to the network through the AP.

In the figure 4.3 shown below, the fiber cable runs from MER to the work area. Note that this design does not require any TR between vertical and horizontal cabling. On the work area is a small TR which hosts patch panels and the switches. AP is connected to the terminated points where the computers can get access to the network.

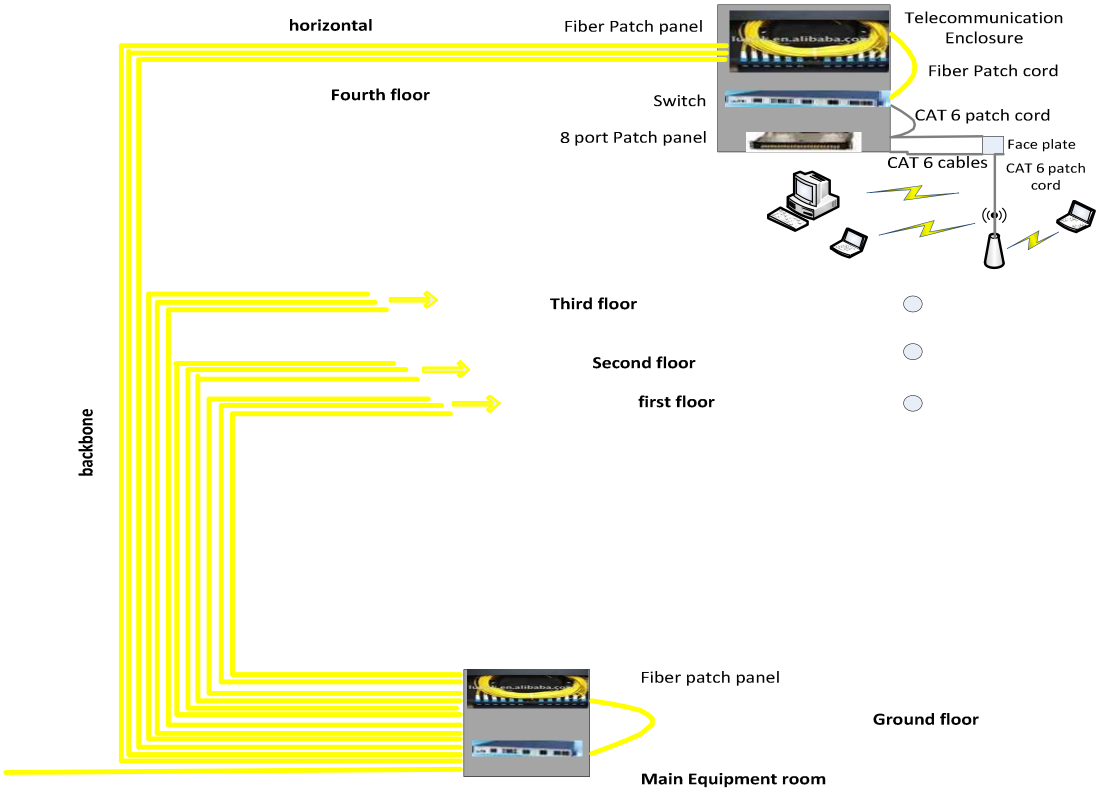

FIGURE 4.3: FTTE layout

The following UML diagrams depict the design aspects of the proposed model.

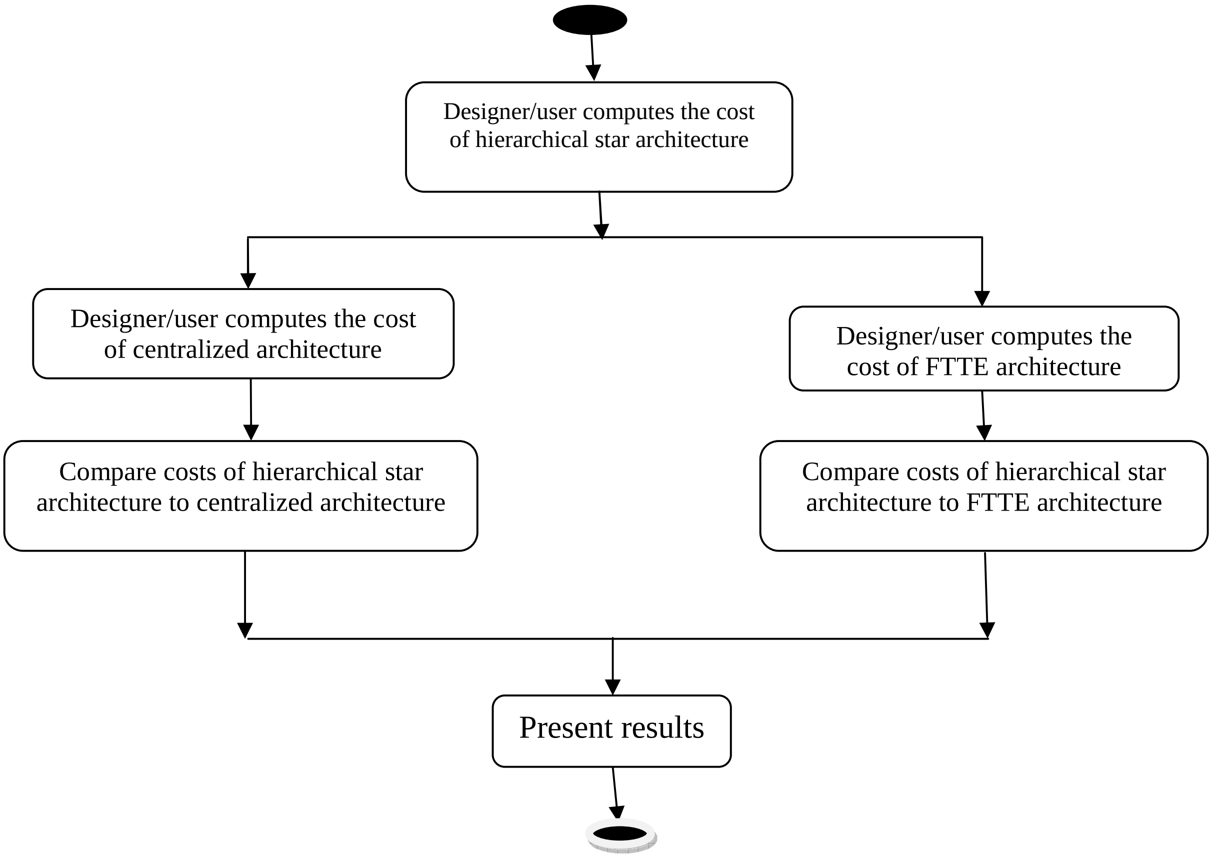

FIGURE 4.4: Activity diagram for the cost model

The activity diagram above represents the flow of one activity/operation to another in the cost model. From the diagram 4.4, the first operation is when the user/designer inputs data to the system to compute the costs of hierarchical star architecture. The next operation is to compute costs for the centralized and also FTTE architectures respectively then finally comparing the total costs of hierarchical star to FTTD and FTTE and the results will be presented to the designer/user.

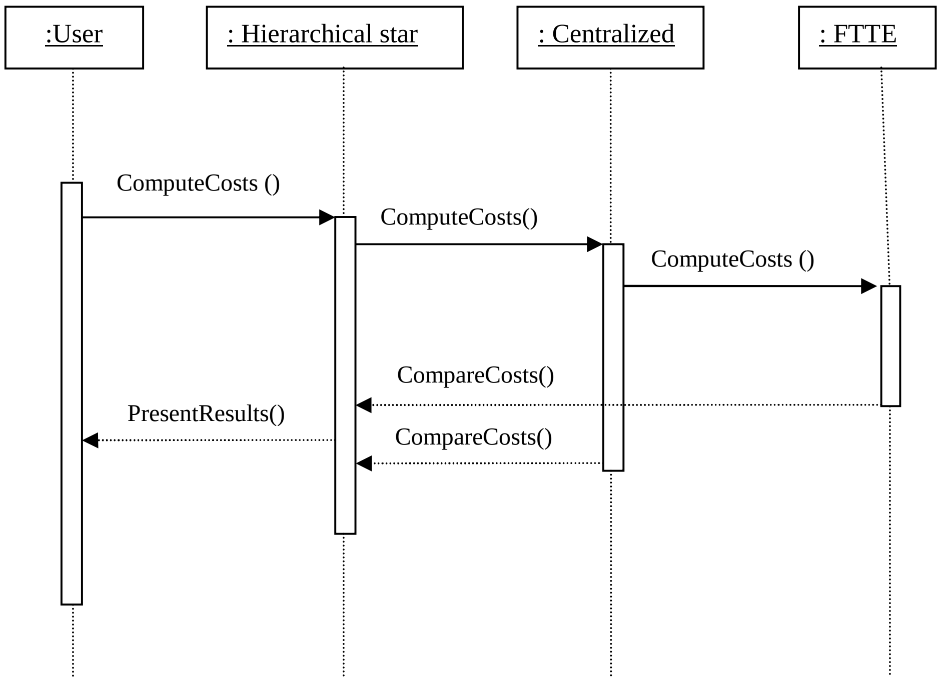

FIGURE 4.5: Sequence diagram for the cost model

The diagram 4.5 above describes interaction among different objects in the cost model. The interaction starts by the user inputting data to compute costs of hierarchical star architecture followed by centralized architecture and finally computing the costs of FTTE architecture. The user/designer receives feedback on the total costs of each which compares hierarchical star to FTTD and FTTE architecture. Finally the results are presented to the user/designer.

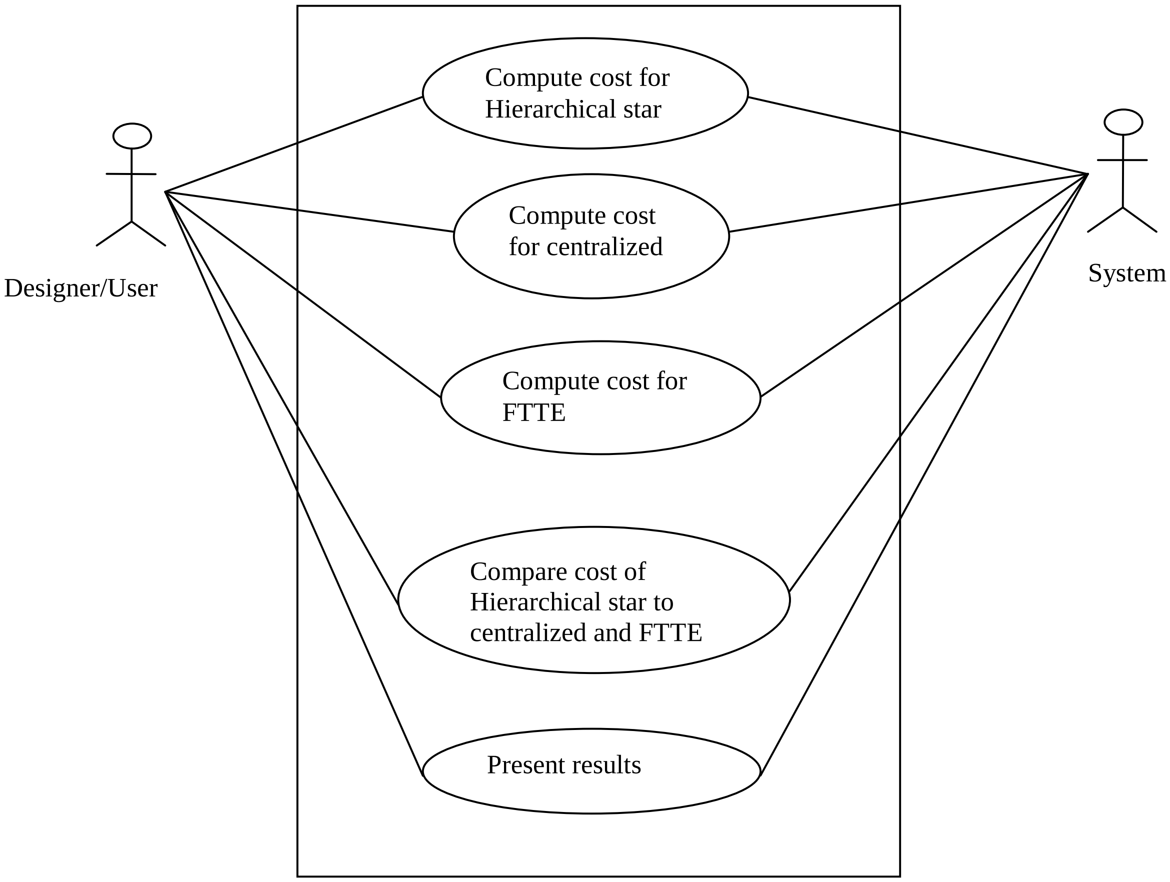

FIGURE 4.6: Use case scenario for the cost model

The following are the key functions of the cost model as captured from the use case scenario above;

i. To compute costs of hierarchical star architecture
ii. To compute costs of centralized architecture
iii. To compute costs of FTTE architecture
iv. To compare the costs of hierarchical star to centralized and FTTE architectures
v. To present results

CHAPTER FIVE

THE PROPOSED MODEL

5.1 Introduction

5.1.1 Model assumptions

Material cost for all the three standardized architectures is the average costs for each item in the market as at March 2013. Labor costs was 20% of the total costs of materials, it is an average calculated based on the 10-30% formula applied in the market place when designing WLAN as well as wired LAN.

5.1.2 System requirements

For the designer to user the cost model, the computer system should have either Windows Xp, Vista, 7, 8 or higher version with Microsoft office 2003, 2007, 2010 or higher version or Ubuntu with libre office or open office installed.

The computer system should at least have a processor Pentium 4, 1.7 GHZ or higher and memory size from 512MB and hard disk from 40GB.

Input devices (keyboard and mouse) are also required for inputting data to the cost model.

5.1.3 End-user requirements

It will be required that user inputs costs for the model to compute the total costs for each standardized architecture. This is because market prices are always dynamic with change in time.

5.2 Data analysis

Interviews were conducted for three individuals from IT private firms and one individual from public firm. Interview was not very successful since most interviewees were very busy and could not spare much of their time. Questionnaires were also sent to targeted group of individuals representing private and public firms by hand delivery and electronic mail. Only one respondent did not respond and this did not affect the progress of the research. The analysis is as follows:

Most of the respondents have worked over five (5) years as network designers and even users. The most used media on vertical cabling is fiber while the most used medium on horizontal is UTP CAT5 or CAT6.

Most have WLAN implementations and have users ranging between 200 – 500 for learning institutions and less than 200 for private companies. In the public, for instance ministries, Less than 10 users; but it depends on the type of user i.e. manager who may have laptop.

Most implementations or designing of LAN is outsourced (through tenders) and 100% of them depend on quotations from IT companies and charge it through the cheapest quote at the same time according to the specified requirements on the requirements of the tenders.

Most do not rely on WLAN and their reasons being its slow than wired LAN. 100% of the respondents have never used a tool to enable the estimate cost of setting up network infrastructure, but if they can have one it will do them good.

5.3 Proposed generic model

The proposed cost model focuses on three standardized architectures; hierarchical star, FTTD/FTTZ and FTTE. The architectures can be considered by WLAN designers or users.

The costs in each of the three architectures have been organized into; work area, TR, main cross connect/wiring closet, labor as well as others costs which will be incurred in the deployment of WLAN as shown in the figure 5.1, 5.2 and 5.3 below:

HIERARCHICAL STAR MODEL		
INPUTS	**ITEM**	**DETAILS**
Work Area/Desktop costs	***Wireless NIC***	10/100Base-T
	Access point	WAP54G
	Patch cord	3m CAT6
	Faceplate	CAT6 double plus module
TR costs	***Horizontal cabling***	CAT6 plenum, meters
	Patch panel	24-port patch panel CAT6
	Patch cord	CAT6 3m
		Fiber 3m LC-SC
	Fiber adapter panel	24-port Adapter Panel Enclosure Fiber
	Adapter Panel (Pre-loaded)	Pre-Loaded Adapter Panel- LC Adapters
	Switch	Layer 3, 10/100Base-T
		GBIC 1000Base-SX
	Fiber connector	LC Connector, Simplex MMF
Wiring closet/Main cross connect costs	***Equipment cabinet***	42 U floor standing
	Vertical cabling	Fibre Riser Cable 50/125 microns, 32*30 m
	Fiber Connector	LC Connector, Simplex MMF
	Fiber Connector Duplexing Clip	LC Duplexing Clip
	Fiber Adapter Panel (Pre-Loaded)	Pre-Loaded Adapter Panel- LC Adapters
	Patch Cord	Fiber 3m SC-MTRJ
	Switch	Core switch
Labour costs	***Calculation is 20% of costs of materials***	
Other costs	***Uninterruptible Power Supply***	1KVA UPS Smart
	Fiber Termination Consumables	LC Consumable Kit

FIGURE 5.1: Hierarchical star- cost model

CENTRALIZED FIBER MODEL		
INPUTS	**ITEM**	**DETAILS**
Work area costs	***NIC wireless***	100Base-FX
	Patch Cord	Patch Cord 3m LC-SC
	Access point	WAP54G
	Face Plate	CAT6 double plus module
	Duplex Adapter	LC Adapter, Duplex
	Connector	LC Connector, Simplex MMF
	Duplexing Clip	LC Duplexing Clip
TR costs	***Horizontal Cabling***	Fibre Plenum Round 50/125 microns, 4*50 m
	Splice	Mechanical Splice
	Enclosure	Splice Enclosure, Rack Mount
	Splice Tray	Splice Tray, for Rack Mount
Wiring closet costs/Main cross connect	***Equipment Cabinet***	For the main telecommunications room
	Vertical Cabling	8-fibre Riser Cable 50/125 microns -30m
	Connector	LC Connector, Simplex MMF
	Adapter Panel Enclosure	Adapter Panel Enclosure, Fibre
	Adapter Panel (Pre-loaded)	Pre-Loaded Adapter Panel-LC Adapters
	Duplexing Clip	LC Duplexing Clip
	Workgroup Switch	Switch, Layer 3, 100Base-FX
	Core Switch	Core Switch
	Patch Cord	Patch Cord, 3m LC-MTRJ
Labour costs	***Calculation is 20% of costs of materials***	
Other costs	***Uninterruptible Power Supply***	1KVA
	Fiber Termination Consumables	LC Consumable Kit

FIGURE 5.2: Centralized fiber - cost model

Fiber-to-the-telecommunication enclosure		
INPUTS	**ITEM**	**DETAILS**
Work Area costs	*NIC wireless*	10/100Base-T
	Access point	WAP54G
	Patch cord	1m Fiber SC-LC
		1m CAT6
	Faceplate	CAT6 double plus module
	Jack	CAT6
		LC
	Cable	2 CAT6 (15m)
	Switch	Managed mini-switch 10/100TX 8 ports and 1000BaseSX Uplink
	Patch panel	8 port CAT6
		With 3 SFF, LC jacks or Plug Assy's
Wiring closet/Main cross connect costs	*Cable*	Fiber (from main equipment room to Telecom enclosure) 8*50m
	Patch Panel	Fiber with SFF, LC jack or Plug Assy's
	Patch cord	3m LC to MTRJ
	Switch	Core switch
Labour costs	*Calculation is 20% of costs of materials*	
Other costs	*Uninterruptible Power Supply*	1KVA
	Fiber Termination Consumables	LC Consumable Kit

FIGURE 5.3: FTTE - cost model

5.4 Proposed cost model parameters

The table 5.1 below shows the parameters useful in the estimation of costs and comparing costs for the standardized architectures.

TABLE 5.1: cost model parameters

Inputs	**Parameters**
TR	Hierarchical star costs vs. Centralized fiber costs Hierarchical star costs vs. FTTE costs
MER	Hierarchical star costs vs. Centralized fiber costs Hierarchical star costs vs. FTTE costs
Work area/Desktop area	Hierarchical star costs vs. Centralized fiber costs Hierarchical star costs vs. FTTE costs

CHAPTER SIX

DISCUSSIONS OF FINDINGS

6.1 Discussions of Findings

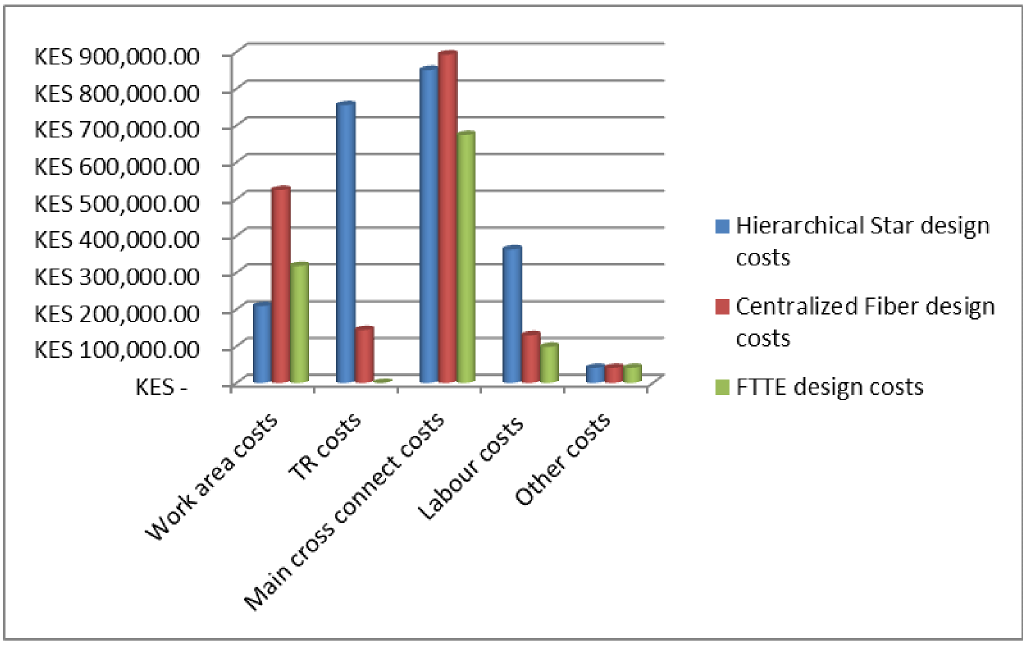

FIGURE 6.1: Graph showing comparison between three standardized

From the figure 6.1 hierarchical star is more expensive when it comes to TR costs and the labor costs compared to FTTD and FTTE while centralized fiber design is costly on main cross connect costs.

TABLE 6.1: Summary of the proposed cost model costs

Description	Hierarchical Star design costs		Centralized Fiber design costs		FTTE design costs	
Work area costs	KES	208,800.00	KES	524,320.00	KES	317,600.00
TR costs	KES	754,800.00	KES	143,500.00	KES	-
Main cross connect costs	KES	850,480.00	KES	892,474.00	KES	674,000.00
Labour costs	KES	362,816.00	KES	129,514.00	KES	98,080.00
Other costs	KES	41,000.00	KES	41,000.00	KES	41,000.00
TOTALS	**KES**	**2,217,896.00**	**KES**	**1,730,808.00**	**KES**	**1,130,680.00**

i. ***Hierarchical star vs. centralized fiber architecture***

From table 6.1 above, the costs difference between hierarchical star to centralized fiber is that it costs more by approximately KES. 487,088.

ii. ***Hierarchical star vs. centralized fiber architecture***

From table 6.1 above, it costs hierarchical star architecture more of an approximately KES. 600,128 compared to FTTE architecture.

6.2 Recommendation

The new FTTE standardized architecture has been proven to be cost effective. This will no matter how many users will be connected on the work area or desktop area. This architecture reduces the costs of interconnection in between vertical and horizontal cabling (TR costs) while it has a mini TR at the work area or desktop area.

6.3 Conclusions

Two LAN cost estimation models exists; Tolly group and TIA FOLS. From these two models, TIA FOLS has been updated regularly and all have focused on wired type of LAN.

According to this research, WLAN has been widely implemented by many users and this is due to the advancement in technology demanding wireless connections like smart phones among others being used by end – users in a network. Most network installation is done by outsourcing through tenders. Users normally specify their network requirements and the designers will do the deployment. According to the users or designers, they are not normally guided by any tool to estimate the costs for network infrastructure.

The generic model developed in this research can best assist WLAN infrastructure cost estimation. This tool was developed, market prices for equipment/materials were input into the model and tested, therefore users or designers can be able to use it to estimate the first installed costs of WLAN infrastructure costs of either hierarchical star design, centralized or FTTD design or FTTE design and compare between costs among the three architectures.

Computer network users or designers are able to make decisions as to which standard compliant architecture is the cost optimal solution for their networks by inputting their own costs for equipment and others to the model and get the totals for each of the standardized architecture and finally get the results from the model.

6.4 Future

It will be important if this research is extended by having an integrated model for estimating both wired and wireless LAN and should not be limited (dynamic) to a number of users or floors in a building. Additional research can be done by developing a model to estimate wireless FTTE to wired FTTE using fiber optic cable or UTP on the work area using APs instead of wireless connection through infrastructure mode.

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APPENDIX A - Questionnaire

My name is Vancy Kebut, a student from KCA University pursuing MSc-Data Communication. I am currently carrying out research on WLAN infrastructure and kindly requesting you to assist me by filling this questionnaire. Thank you in advance.

---

1. How long have you worked as network designer/user/administrator/manager?

   ☐ 1 year

   ☐ 2 years

   ☐ 3-5 years

   ☐ 5-10 years

   ☐ Over 10 years

2. Which type of cable do you use on vertical and horizontal cabling?

   Vertical: ☐ Unshielded Twisted pair (UTP) ☐ Fiber ☐ both

   Horizontal: ☐ UTP ☐ Fiber ☐ N/A (if WLAN)

3. Which type of standardized architecture do you currently deploy or use?

   ☐ Hierarchical network design (UTP horizontal/fiber vertical)

   ☐ Centralized network design/Fiber-to-the-Desktop (FTTD)

   ☐ Fiber-to-the-Telecommunication enclosure (FTTE)

4. Do you have any WLAN implementation in your organization/company/institution

   ☐ Yes

   ☐ No

5. If "yes", what is the approximate number of users of WLAN?

   ☐ Less than 10 users ☐ 31 – 50 users

   ☐ 10 – 20 users ☐ 50 – 100 users

   ☐ 21 – 30 users ☐ 100 – 200 users

☐ 200 – 500 users ☐ More than 500 users

6. How is your organization/institution WLAN deployed?

☐ All Access points (AP) are connected through wired infrastructure

☐ An AP is used to connect other Aps on the LAN

7. If "no", do you have any plans of deploying WLAN?

☐ Yes

☐ No

8. What are the reasons of not implementing WLAN?

☐ It is expensive

☐ It is very slow

☐ It cannot cover long distance

☐ We have to upgrade machines LAN cards to wireless

Other reasons:

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

9. What are the advantages your organization/institution can get with WLAN over wired LAN?

☐ Mobility and flexibility

☐ Saves cost of installation & maintenance

☐ Uubiquitous access systems throughout the global enterprise

☐ Easy maintenance

Others:

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

10. Are aware of any tool to estimate LAN infrastructure first installed costs?

☐ Yes

☐ No

11. If “Yes”, which one are you aware of?

………………………………………………………………………………………………

12. When making decision on which type of LAN to deploy, do you think that a tool can assist in having cost effective solution?

☐ Yes

☐ No

13. If “No”, what is the reason for your answer?………………………………………………………………………………

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APPENDIX B – Generic model

HIERARCHICAL STAR ARCHITECTURE							
INPUTS	ITEM	DETAILS	ITEMS REQUIRED	COST PER UNIT		SUB- TOTAL (Ksh)	
Work Area/Desktop costs	*Wireless NIC*	10/100Base-T	80	KES	1,500.00	***KES***	***120,000.00***
	Access point	WAP54G	8	KES	9,000.00	***KES***	***72,000.00***
	Patch cord	3m CAT6	32	KES	300.00	***KES***	***9,600.00***
	Faceplate	CAT6 double plus module	16	KES	450.00	***KES***	***7,200.00***
TR costs	*Horizontal cabling*	CAT6 plenum, meters	4	KES	3,000.00	***KES***	***12,000.00***
	Patch panel	24-port patch panel CAT6	4	KES	4,100.00	***KES***	***16,400.00***
	Patch cord	CAT6 3m	40	KES	250.00	***KES***	***10,000.00***
		Fiber 3m LC-SC	40	KES	600.00	***KES***	***24,000.00***
	Fiber adapter panel	24-port Adapter Panel Enclosure Fiber	4	KES	8,000.00	***KES***	***32,000.00***
	Adapter Panel (Pre-loaded)	Pre-Loaded Adapter Panel- LC Adapters	4	KES	5,500.00	***KES***	***22,000.00***
	Switch	Layer 3, 10/100Base-T	4	KES	150,000.00	***KES***	***600,000.00***
		GBIC 1000Base-SX	4	KES	8,000.00	***KES***	***32,000.00***
	Fiber connector	LC Connector, Simplex MMF	16	KES	400.00	***KES***	***6,400.00***
Wiring closet/Main cross connect costs	*Equipment cabinet*	42 U floorstanding	4	KES	65,000.00	***KES***	***260,000.00***
	Vertical cabling	Fibre Riser Cable 50/125 microns, 32*30 m	960	KES	100.00	***KES***	***96,000.00***
	Fiber Connector	LC Connector, Simplex MMF	16	KES	400.00	***KES***	***6,400.00***
	Fiber Connector Duplexing Clip	LC Duplexing Clip	8	KES	10.00	***KES***	***80.00***
	Fiber Adapter Panel (Pre-Loaded)	Pre-Loaded Adapter Panel- LC Adapters	4	KES	5,500.00	***KES***	***22,000.00***
	Patch Cord	Fiber 3m SC-MTRJ	4	KES	4,000.00	***KES***	***16,000.00***
	Switch	Core switch	1	KES	450,000.00	***KES***	***450,000.00***
Labour costs	*Calculation is 20% of costs of materials*		1	KES	362,816.00	***KES***	***362,816.00***
Other costs	*Uninterruptible Power Supply*	1KVA UPS Smart	1	KES	30,000.00	***KES***	***30,000.00***
	Fiber Termination Consumables	LC Consumable Kit	1	KES	11,000.00	***KES***	***11,000.00***
TOTAL COSTS (Ksh)						KES	2,217,896.00

CENTRALIZED ARCHITECTURE

INPUTS	ITEM	DETAILS	ITEMS REQUIRED	COST PER UNIT	SUB-TOTAL (Ksh)
Work area costs	*NIC wireless*	100Base-FX	80	KES 5,000.00	***KES 400,000.00***
	Patch Cord	Patch Cord 3m LC-SC	32	KES 600.00	***KES 19,200.00***
	Access point	WAP54G	8	KES 9,000.00	***KES 72,000.00***
	Face Plate	CAT6 double plus module	16	KES 450.00	***KES 7,200.00***
	Duplex Adapter	LC Adapter, Duplex	32	KES 400.00	***KES 12,800.00***
	Connector	LC Connector, Simplex MMF	32	KES 400.00	***KES 12,800.00***
	Duplexing Clip	LC Duplexing Clip	32	KES 10.00	***KES 320.00***
TR costs	*Horizontal Cabling*	Fibre Plenum Round 50/125 microns, 4*50 m	800	KES 100.00	***KES 80,000.00***
	Splice	Mechanical Splice	32	KES 1,500.00	***KES 48,000.00***
	Enclosure	Splice Enclosure, Rack Mount	1	KES 14,000.00	***KES 14,000.00***
	Splice Tray	Splice Tray, for Rack Mount	1	KES 1,500.00	***KES 1,500.00***
Wiring closet costs/Main cross connect	*Equipment Cabinet*	For the main telecommunications room	1	KES 20,000.00	***KES 20,000.00***
	Vertical Cabling	8-fibre Riser Cable 50/125 microns - 30m	960	KES 100.00	***KES 96,000.00***
	Connector	LC Connector, Simplex MMF	32	KES 400.00	***KES 12,800.00***
	Adapter Panel Enclosure	Adapter Panel Enclosure, Fibre	4	KES 8,000.00	***KES 32,000.00***
	Adapter Panel (Pre-loaded)	Pre-Loaded Adapter Panel-LC Adapters	4	KES 5,500.00	***KES 22,000.00***
	Duplexing Clip	LC Duplexing Clip	16	KES 10.00	***KES 160.00***
	Workgroup Switch	Switch, Layer 3, 100Base-FX	1	KES 130,000.00	***KES 130,000.00***
	Core Switch	Core Switch	1	KES 450,000.00	***KES 450,000.00***
	Patch Cord	Patch Cord, 3m LC-MTRJ	40	KES 600.00	***KES 24,000.00***
Labour costs	*Calculation is 20% of costs of materials*		1	KES 129,514.00	***KES 129,514.00***
Other costs	*Uninterruptible Power Supply*	1KVA	1	KES 30,000.00	***KES 30,000.00***
	Fiber Termination Consumables	LC Consumable Kit	1	KES 11,000.00	***KES 11,000.00***
TOTAL COSTS (Ksh)					**KES 1,625,294.00**

FIBER-TO-THE-TELECOMMUNICATION ENCLOSURE

INPUTS	ITEM	DETAILS	ITEMS REQUIRED	COST PER UNIT	SUB-TOTAL
Work Area costs	NIC wireless	10/100Base-T	80	KES 1,500.00	KES 120,000.00
	Access point	WAP54G	8	KES 9,000.00	KES 72,000.00
	Patch cord	1m Fiber SC-LC	32	KES 300.00	KES 9,600.00
		1m CAT 6	32	KES 150.00	KES 4,800.00
	Faceplate	CAT6 double plus module	16	KES 450.00	KES 7,200.00
	Jack	CAT6	32	KES 50.00	KES 1,600.00
		LC	32	KES 200.00	KES 6,400.00
	Cable	2 CAT 6 (15m)	480	KES 50.00	KES 24,000.00
	Switch	Managed mini-switch 10/100TX 8 ports and 1000Base SX Uplink	4	KES 6,000.00	KES 24,000.00
	Patch panel	8 port CAT 6	4	KES 2,000.00	KES 8,000.00
		With 3 SFF, LC jacks or Plug Assy's	4	KES 10,000.00	KES 40,000.00
Wiring closet/Main cross connect costs	Cable	Fiber (from main equipment room to Telecom enclosure) 8*50m	1600	KES 100.00	KES 160,000.00
	Patch Panel	Fiber with SFF, LC jack or Plug Assy's	4	KES 10,000.00	KES 40,000.00
	Patch cord	3m LC to MTRJ	40	KES 600.00	KES 24,000.00
	Switch	Core switch	1	KES 450,000.00	KES 450,000.00
Labour costs	Calculation is 20% of costs of materials		1	KES 98,080.00	KES 98,080.00
Other costs	Uninterruptible Power Supply	1KVA	1	KES 30,000.00	KES 30,000.00
	Fiber Termination Consumables	LC Consumable Kit	1	KES 11,000.00	KES 11,000.00
TOTAL COSTS					KES 1,130,680.00